## 3. Faculty of Electrical Engineering

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The Faculty of Electrical Engineering was founded in 1946 as one of three Faculties of High School of Engineering. Up to now it is the only electrical and electronic engineering faculty in the whole region of Western Pomerania and one of the biggest faculties of the Szczecin University of Technology. The Faculty has the authority to award doctors degree in the field of electrotechnics.

There are the following institute and chairs:
- Institute of Control Engineering
- Institute of Electronics, Telecommunications and Information Technology
- Institute of Electrical Engineering
- Chair of Theoretical Foundations of Electrical Engineering and Computer Science
- Chair of Signal Processing and Multimedia Engineering

## ♦ Faculty of Electrical Engineering-courses

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| Course title: | **Basis of Teleinformatics** | | |
| Name of the lecturer: | *Ryszard Sikora, Michał Zeńczak* | | |
| ECTS points: | 5 | Language of instruction: | English |
| Semester: | summer | Hours per week: | lectures – 2 h laboratory – 2 h |
| Code: | | Teaching method: | lectures, experiments, computer class |

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| Entry requirements: | Mathematics, Theoretical Electrical Engineering, Information Technology, Electronics. |
| Objectives of the course: | Knowledge about radiobroadcast, cellular systems and other wireless systems. Application of teleinformatics in power systems.<br>Skills of designing of teleinfomatic systems. |
| Course contents: | Radio broadcast: radio waves propagation, interference, filtration, selectivity and sensitivity of radio receivers. Basis of cellular system: macro, micro and pico cells, cells section, interference, elimination, cellular systems capacity. Wireless systems: system structure, coding, service organisation, examples of teleinformatics network and installations. Transmission of information used in electric power systems: power line carrier, optical fibre usage in electric power systems. Teletechnic systems: UTJ, TIDEC, DETEC, SYNDIS, EX. Creating informatic systems. |

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| Assessment method: | Written examination |
| Recommended readings: | 1. Haykin S: Communication systems. John Wiley & Sons, Inc. 1994.<br>2. Kong J.A.: Electromagnetic Wave Theory. EMW Publishing Cambridge, Massachusetts, 2002.<br>3. Yacoub M.D.: Wireless Technology. CRC Press, 2002.<br>4. Usher M.J., Guy C.G.: Information and Communication for Engineers. MACMILLAN PRESS LTD, 1997. |

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| Course title: | **Biological Effects in Electromagnetic Fields** | | |
| Name of the lecturer: | *Michał Zeńczak* | | |
| ECTS points: | 4 | Language of instruction: | English (partially Polish) |
| Semester: | summer | Hours per week: | lectures – 2 h laboratory – 2 h |
| Code: | | Teaching method: | lectures, experiments, computer simulations |

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| Entry requirements: | Mathematics, Physics, Theoretical Electrical Engineering, Theory of Electromagnetic Fields. |
| Objectives of the course: | Knowledge about bioelectromagnetism, electromagnetic fields in natural environment and interaction of living systems with electromagnetic fields.<br>Skills of designing electric power engineering structures according to standards for electromagnetic fields in natural and occupational environment. |
| Course contents: | Basis of theory of electromagnetic fields in application for biology. Natural and technical sources of electromagnetic fields. Standards for electromagnetic fields. Electrical properties of living matter. Electromagnetic fields inside living systems. Mechanism of interaction of non-ionising electromagnetic fields with living systems. Infrared, visible and ultraviolet radiation. Influence of ionising radiation on living systems. Dosimetry of ionising radiation. |
| Assessment method: | Written examination |
| Recommended readings: | 1. Bronzino J.D. : The biomedical engineering. CRC Press, 1995.<br>2. Carstensen E.: Biological effects of transmission line fields. Elsevier, New York, Amsterdam, London 1987.<br>3. Malmivuo J. Plonsey R.: Bioelectromagnetism. Oxford University Press, 1995.<br>4. Polk C., Postow E.: CRC Handbook of biological effects of electromagnetic fields. CRC Press, Boca Raton, Florida 1986.<br>5. Wadas R.S.: Biomagnetism. PWN WARSAW 1978 |

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| Course title: | **Electromagnetic Field Theory** | | |
| Name of the lecturer: | *Stanisław Gratkowski* | | |
| ECTS points: | 4 | Language of instruction: | English (partially Polish) |
| Semester: | summer | Hours per week: | lectures – 3 h laboratory – 2 h |
| Code: | | Teaching method: | lectures, experiments, computer simulations |

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| Entry requirements: | Mathematics (a knowledge of vector calculus is helpful, but not necessary, since a short introduction to vectors is provided); physics |
| Objectives of the course: | This course is intended to present a unified approach to electromagnetic fields (advanced undergraduate level) |
| Course contents: | Electromagnetic field concept. Vector analysis. Electrostatics: Coulomb's law, Gauss's law and applications, electric potential, electric dipole, materials in an electric field, energy and forces, boundary conditions, capacitances and capacitors, Poisson's and Laplace's equations, method of images. Steady electric currents. current density, equation of continuity, relaxation time, power dissipation and Joule's law, boundary conditions. Static magnetic fields: vector magnetic potential, the Biot-Savart law and applications, magnetic dipole, magnetic materials, boundary conditions, inductances, magnetic energy, forces and torques. Time-varying electromagnetic fields and Maxwell's equations: Faraday's law, Maxwell's equations, potential functions, time-harmonic fields, Poynting's theorem, applications of electromagnetic fields. Plane wave propagation: plane waves in lossless media, plane waves in lossy media, polarization of wave. Antennas. Transmission lines. Computer aided analysis of electromagnetic fields: finite element method, integral equations. |
| Assessment method: | Written examination |
| Recommended readings: | 1. Cheng D. K.: *Fundamentals of Engineering Electromagnetics*. Addison-Wesley Publishing Company, Inc., New York 1993<br>2. Pollack G. L., Stump D. R.: *Electromagnetism*. Addison Wesley Publishing Company, Inc., New York 2002<br>3. Guru B. S., Hiziroglu H. R.: *Electromagnetic Field Theory Fundamentals*. Cambridge University Press, Cambridge, 2004<br>4. Stewart J. V.: *Intermediate Electromagnetic Theory*. World Scientific Publishing Co. Pte. Ltd., London 2001<br>5. Chari M. V. K., Salon S. J.: *Numerical Methods in Electromagnetism*. Academic Press, San Diego 2000 |

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| Course title: | **Model Predictive Control** |

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| Name of the lecturer: | *Stefan Domek* | | |
| ECTS points: | 4 | Language of instruction: | English (partially Polish) |
| Semester: | summer | Hours per week: | lectures – 3 h laboratory – 2 h |
| Code: | | Teaching method: | lectures, experiments, computer simulations |

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| Entry requirements: | Mathematics, signals and systems, control theory |
| Objectives of the course: | The primary objective of the course is to provide an introduction to the theory and application of model predictive control (MPC).<br>The second objective is to give students a possibility to apply model predictive control to a laboratory pilot plant. |
| Course contents: | General concepts of model predictive control (MPC); process models; objective functions; analytical solution for unconstrained SISO and MIMO plants; DMC and GPC algorithms; implementation issues and tuning; nominal stability; MPC with infinite horizons; MPC with terminal constraints (CRHPC); dual mode predictive control; MPC for constrained plants; quadratic programming solution; extensions to nonlinear MPC.<br>Students will complete two research/design MPC projects: for linear and nonlinear plants. They have to solve the problems theoretically and then to check the results by computer simulations and laboratory experiments. MATLAB and SIMULINK with the new MPC Toolbox distributed by The MathWorks, Inc. will be used for the simulation. |
| Assessment method: | Exam 50%<br>Detailed written project report 50% |
| Recommended readings: | 1. Camacho E. F., Bordons C.: *Model predictive control in the process industry. Advances in industrial control.* Springer Verlag 1995<br>2. Allgöwer F., Zheng A.: *An overview of nonlinear model predictive control applications*, Birkhäuser 2000<br>3. Maciejowski J. M.: *Predictive control with constraints.* Prentice Hall 2002<br>4. Tatjewski P.: *Advanced control of industrial processes. Structures and algorithms.* Akademicka Oficyna Wydawnicza Exit 2002 (In Polish)<br>5. Rossiter J. A.: *Model based predictive control. A practical approach.* CRC Press 2003<br>6. MATLAB MPC Toolbox User's Guide. The MathWorks Inc., 2004<br>7. Selected scientific articles |

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| Course title: | **Expert Systems** | | |
| Name of the lecturer: | *Bogdan Grzywacz* | | |
| ECTS points: | 4 | Language of instruction: | English (partially Polish) |
| Semester: | summer | Hours per week: | lectures – 2 h project – 1 h |
| Code: | | Teaching method: | lectures, computer simulations |

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| Entry requirements: | Basic knowledge about classical logic and fuzzy logic |
| Objectives of the course: | This course is intended to explain the rules of designing of Expert Systems |
| Course contents: | Artificial Intelligence - Fundamentals of Expert Systems - Knowledge Engineering. The structure of expert system. Expert Knowledge: Rules and Data. Methods of representation of knowledge: rules, predicate calculus, semantic nets, frames, calculation models Knowledge acquisition methods. Rule-Based Expert System. Schemes for forward and backward chaining. Redundancy and contradictories in rule base. Handling uncertainties in an expert system. Application of fuzzy logic, genetic algorithms and neural nets to expert systems – hybrid expert systems. Overview of tools for designing of expert system ( shells, specialized software – Prolog, Lisp). Examples of existing dedicated expert systems: Mycin, Prospector, Caduceus, Shearer. Expert systems in process control. |
| Assessment method: | Written examination |
| Recommended readings: | 1. Nikolopoulos C.: *Expert Systems.* Marcel Decker, New York 1997.<br>2. Siller W., Buckley J.: *Fuzzy Expert Systems and Fuzzy Reasoning.* Willey 2005.<br>3. Jovic F.: *Expert Systems in Process Control.* Chapman and Hall, 1992<br>4. S. Friederich, M. Gargano .: *Expert Systems Design and Development Using VP-Expert.* Willey ,1989<br>5. Niederliński A.: *Regułowe systemy eksperetowe.* Wyd. J .S. Gliwice 1998. |

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| Course title: | **Advanced Modeling and Simulation** | | |
| Name of the lecturer: | *Bogdan Grzywacz* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | winter | Hours per week: | lectures – 2 h laboratory – 2 h |
| Code: | | Teaching method: | lectures, experiments, computer simulations |

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| Entry requirements: | Representation of signals and systems in time domain and frequency domain, basic characteristics of stochastic processes |
| Objectives of the course: | This course supplies with knowledge necessary for creation of mathematic models of processes and systems. |
| Course contents: | Definitions of modeling and simulation. Systematic modeling methods: Network Methods, Variational Methods, Bond Graph Methods. Classification of models. Time continuous and discrete time linear models of dynamic systems. Estimation of parameters of linear models from input-output data – the least square method. On-line |

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| | estimation of model parameters – "tuning" of models. Sensitivity of models to parameters and initial conditions. Scaling of models . Choice of model structure . Model verification. Approximation of time continuous models by discrete time ones. "Recovery" of time continuous models on the base of discrete approximations. Static and dynamic nonlinear models. Regression models. Models of Wienner-Hammerstein type. Linearization and simplification of static and dynamic nonlinear models. Models of time-series (AR,MA, ARMA,ARIMA. ). Advanced models of time–series including periodic components and trends. "Fuzzy-logic" models. Modeling by means of neural nets. Tools for simulations. |
| Assessment method: | Written examination |
| Recommended readings: | 1. Welstead P.E.: *Introduction to physical system*<br>2. *modeling*. Academic Press, 1980<br>3. Stoica P., Soderstrom T. :*System Identification*. Prentice Hall International (1994)<br>4. Box G., Jenkins G. : *Time Series Analysis.* Holden-Day (1980)<br>5. MATLAB for Microsoft Windows. The Math Works, Inc MA<br>6. Morrison F: *Art of modeling of dynamic systems.*<br>7. Willey , 1996. |

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| Course title: | **Windows programming with .NET Framework** | | |
| Name of the lecturer: | *Tomasz Rogala* | | |
| ECTS points: | 3 | Language of instruction: | English |
| Semester: | summer | Hours per week: | lectures – 1 h laboratory – 1 h |
| Code: | | Teaching method: | lectures, laboratories |

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| Entry requirements: | Knowledge of procedural programming in C language. Knowledge of C++ and/or Java may be helpful but not necessary, since the object oriented programming concepts are introduced from the beginning. |
| Objectives of the course: | This course is intended to:<br>· introduce the .NET Framework technology<br>· explain the object oriented programming (OOP) concepts using C# language<br>· present the basics of web applications and client-server communication in .NET |
| Course contents: | Introduction to .NET technology: .NET Framework, C# language, compilation, MS Visual Studio environment. C# language fundamentals: types, variables and constants, expressions, whitespaces, statements, operators, namespaces. Classes and objects. Inheritance and polymorphism. Operator overloading. Exception handling. Interfaces. Delegates and events. .NET class library: arrays, strings and regular expressions, collections. Building Windows applications. Accessing databases. Web services and ASP. NET. Client-server communication using stream sockets and datagram sockets. |
| Assessment method: | Written examination. |
| Recommended readings: | 1. Liberty J. : *Programming C#.* O'Reilly 2002<br>2. Deitel H.M. : *C# How to program.* Prentice Hall 2001<br>3. *Microsft MSDN Library*. Available both online and on CD-ROM. |

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| Course title: | **ASICs and DSP** | | |
| Name of the lecturer: | *Krzysztof Penkala, Marek Jaskuła* | | |
| ECTS points: | 5 | Language of instruction: | English |
| Semester: | winter | Hours per week: | lectures – 2 h laboratory – 1 h project – 1 h |
| Code: | | Teaching method: | lectures, lab training, project |

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| Entry requirements: | Informatics, Digital Technique 1 and 2 |
| Objectives of the course: | To provide knowledge on advanced digital and analogue Application Specific Integrated Circuits and Digital Signal Processors |
| Course contents: | Lectures: ASICs, PLDs – classification, development of architecture and technology. Review and comparison of CPLDs and FPGAs of some manufacturers. ISP and ICR programming and testing, Boundary Scan Test, standard JTAG. Cost-of-Ownership for ISP modules. A systematic approach to digital system design, functional decomposition. CAE systems review. Introduction to VHDL. Examples of ASICs, particularly used in telecommunication, AV and biomedical equipment. Introduction to digital signal processors (DSPs), applications. Architecture of DSP, development. Sharc processor (Analog Devices) – Arithmetic-Logic Unit, Multiplier, Shifter, Program Sequencer, interrupts, memory. Programming tools. Sample algorithms.<br>Labs: CPLD/FPGA – designing and testing sample digital circuits and systems, implemented in CPLDs and FPGAs (Xilinx, Altera), with support of CAE systems. DSP – programming; program preparation, compiling, program running and testing. Arithmetic operations, operations of Multiplier unit, counters and loops, division. Demonstrations: filtering, sound effects. |
| Assessment method: | Written exam, accomplishment of practical labs and project |
| Recommended readings: | 1. Nelson V. P., Nagle H. T., Carroll B. D., Irwin I. D.: Digital Logic Circuit Analysis and Design. Prentice Hall, New Jersey, 1995.<br>2. Perry D. L.: VHDL. McGrawHill, 1997.<br>3. Oldfield J. V., Dorf R. C.: FPGAs. Reconfigurable Logic for Rapid Prototyping and Implementation of Digital Systems. John Wiley&Sons, Inc., N.Y., 1995.<br>4. Smith S. W.: The Scientist and Engineer's Guide to Digital Signal Processing, California Technical Publishing, 1997. |

5. Analog Devices DSP data sheets and programmer literature at www.analog.com.
6. Xilinx data sheets and programmer literature at www.xilinx.com.
7. Altera data sheets and application notes at www.altera.com.

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| Course title: | **Computer Graphics** | | |
| Name of the lecturer: | *Krzysztof Okarma* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | winter | Hours per week: | lectures – 2 h laboratory – 2h |
| Code: | | Teaching method: | lectures, experiments, computer simulations |

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| Entry requirements: | Fundamentals of computer engineering, mathematics (a short introduction to 3-D geometry is provided) |
| Objectives of the course: | This course is intended to present fundamental algorithms in computer graphics as well as some advanced techniques used in image synthesis. |
| Course contents: | Characteristics and parameters of computer images. Raster and vector graphics. Methods of line drawing in raster computer graphics. Bresenham's algorithm. Polygon triangulation methods. Techniques of area's filling in raster images. Geometric operations on raster images in two-dimensional and 3-D spaces. Visualisation of 3-D figures. Field of view. Virtual camera model used in computer graphics. Algorithms for surfaces' visibility detection. Depth buffer. Texturing methods. Modelling of smooth shapes and surfaces. Applications of fractals in computer graphics. Data structurea used in computer graphics. Methods of colours' representing (colour spaces). Graphic file formats. OpenGL standars – specification and properties. 3-D images synthesis methods. Light modelling and ahading methods. Ray-tracing and radiosity methods in computer visualisation. Computer graphics applications for medical images. |
| Assessment method: | Written examination |
| Recommended readings: | 1. Foley J.D. et al: *An Introduction to Computer Graphics*. Addison-Wesley, 2000 .<br>2. Jankowski M.: *Elementy grafiki komputerowej*. WNT, Warszawa 1990 (in Polish).<br>3. Nelson M.: *The Data Compression Book*. IDG Books Worldwide, Inc. 2000.<br>4. Pavlidis T.: *Algorithms for Graphics and Image Processing*, Computer Science Press, Rockville, 1982.<br>5. Russ J.C.: *The Image Processing Handbook*. CRC Press 1999.<br>6. Yun Q. Shi, Huifang Sun: *Image and Video Compression for Multimedia Engineering - Fundamentals, Algorithms and Standards*. CRC Press 2000.<br>7. Ling Guan, Sun-Yuan Kung, Larsen J.: *Multimedia Image and Video Processing*. CRC Press 2001. |

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| Course title: | **Computer Networks** | | |
| Name of the lecturer: | *Przemysław Włodarski* | | |
| ECTS points: | 5 | Language of instruction: | English (partially Polish) |
| Semester: | winter | Hours per week: | lectures – 2 h laboratory – 2h |
| Code: | | Teaching method: | lectures, experiments, computer simulations, programming |

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| Entry requirements: | Fundamentals of telecommunication networks |
| Objectives of the course: | This course is intended to present mechanisms and protocols in computer networks (advanced undergraduate level) |
| Course contents: | Introduction to the Internet architecture, addressing, encapsulation, client-server model. Ethernet and IEEE 802.2/9-2.3 standards, PPP and SLIP protocols, impact of MTU on network performance. Analysis of IP, ARP, RARP, ICMP, UDP and TCP protocols – headers, formats, applications and extensions – practical socket programming in Linux. Routing methods – static and dynamic (RIP, BGP, OSPF). Transmission Control Protocol (TCP) – interactive data flow, Nagle's algorithm, persist and keepalive clocks, MTU path discovery, sliding window, congestion control mechanisms: slow start, Random Early Detection (RED), Fast Retransmit and Fast Recovery (Reno), Explicit Congestion Notification (ECN). Performance evaluation and traffic shaping. Network management based on Simple Network Management Protocol (SNMP), structure of management information, object identifiers, ASN.1 and BER coding techniques. |
| Assessment method: | Written examination |
| Recommended readings: | 1. Tanenbaum A.S., *Computer Networks*. Prentice Hall, 4th edition, 2003.<br>2. Stevens W.R., *TCP/IP Illustrated, Volume 1: The Protocols*. Addison-Wesley, 1994.<br>3. Stevens W.R., *UNIX Network Programming, Vol. 1: Networking APIs*. Prentice Hall, 2nd edition, 1997.<br>4. Comer D.E., *Internetworking with TCP/IP, Vol. 1*. Prentice Hall, 4th edition, 2000.<br>5. Comer D.E., Droms R.E., *Computer Networks and Internets*. Prentice Hall, 4th edition, 2003. |

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| Course title: | **Computer Animation** | | |
| Name of the lecturer: | *Przemysław Mazurek* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | summer or winter | Hours per week: | lectures – 2 h laboratory – 2h |

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| Code: | | Teaching method: | lectures, experiments, computer simulations |

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| Entry requirements: | Computer Graphics (basic) |
| Objectives of the course: | This course is intended to present practical methods of computer modelling and animation |
| Course contents: | 3D objects modeling: surfaces, modifiers. Lighting. 3D Camera. Inverse kinematics, bones, skeleton, skinning. Textures. Using video as an animation reference. Keyframe animation. Animation controlers. Morphing. |
| Assessment method: | Animation project |
| Recommended readings: | 1. 3DS MAX/GMAX User Refrences and Tutorials<br>2. Blender User Refrences and Tutorials<br>3. Fleming B., Dobbs D.: *Animating Facial Features & Expressions*, Charles River Media, 1999 |

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| Course title: | **Power Electronics** | | |
| Name of the lecturer: | *Marcin Hołub* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | summer | Hours per week: | lectures – 2 h laboratory – 2h |
| Code: | | Teaching method: | lectures, experiments, computer simulations |

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| Entry requirements: | Electrical Engineering, Information and Electronics |
| Objectives of the course: | Gives an overview of modern power semiconductor devices, basies of power conversion from ac/dc, dc/dc, dc/ac and ac/ac. Many examples of recent applications are presented and discussed |
| Course contents: | 1. Power electronics: past and present, perspectives, connections with other technical branches.<br>2. Semiconductor power devices: thyristors (SCR, RTC, GTO,MTC,SITH), power transistors (BIT,MOSFET,IGBT,SIT). Power modules.<br>3. Control of semiconductor power devices, power transistor driving stages.<br>4. Static and dynamic losses of power semiconductors. Thermal characteristics, cooling methods. Over-voltage, over-current and short-circuit protection systems.<br>5. Rectifiers – one phase, three phase. Characteristics under resistive, RL and RLE load. A q-pulse rectifier.<br>6. Controlled rectifiers – thyristor rectifier with the 4T and 6T topology. Characteristics under resistive, RL and RLE load.<br>7. Commutation in power electronic circuits. Single- and three-phase inverters.<br>8. Hard switching DC/DC choppers, single and three-phase.<br>9. Resonant converters with soft switching (ZVS,ZCS).<br>10. Transistor inverters – single and three-phase topology. Methods of voltage and current shaping (MSI,PWM,SVM, harmonics elimination).<br>11. Matrix and special converters (PFC, E-class).<br>12. Electric drive converter systems, power electronic supply systems. |
| Assessment method: | Written examination |
| Recommended readings: | 1. N. Mohan, T. Undeland, W. Robbins. Power Electronics. J.Willy and Sons, New-York, Toronto, 1989.<br>2. Rashid M.H.: Power Electronics: Circuits, Devices and Applications. Second edition, 1993 |

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| Course title: | **Control of Electrical Drives** | | |
| Name of the lecturer: | *Marcin Hołub* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | summer | Hours per week: | lectures – 2 h laboratory – 2h |
| Code: | | Teaching method: | lectures, experiments, computer simulations |

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| Entry requirements: | Electrical Engineering, Information and Power Electronics |
| Objectives of the course: | learning and understanding basic principles of modern control system of d.c., a.c. and PM excited converter fed motor drives, being informed about their applications and methods of modeling and simulation. |
| Course contents: | 1. History and meaning of modern electric drive systems.<br>2. Separately excited DC machine – mathematical equation system, transfer function model.<br>3. Control systems of separately excited dc machines – torque, speed and position control. Closed loop topologies, cascade and single controller systems.<br>4. Symmetry and module optimal control parameters.<br>5. Simulation of a DC machine control systems using matlab-simulink.<br>6. AC induction machines – description, characteristics, means of scalar control.<br>7. Vector control – reference frame transformations, basic characteristics. Kron model. |

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| | 8. Vector control systems of AC induction machines. Indirect and direct control systems.<br>9. Permanent magnet machines – PMSM and BLDC.<br>10. Control of permanent magnet excited machinery.<br>11. Microcontrollers and DSPs in modern drive control systems. |
| Assessment method: | Written examination |
| Recommended readings: | 1. M. P. Kazmierkowski, H. Tunya. Automatic Control of Converter Fed Drives. PWN-Polish Scientific Publishers, Warszawa, 1994.<br>2. P.Vass. Sensorless Vector and Direct Torque Control. Oxford University Press, 1998.<br>3. P.Vass. Artificial Intelligence - Based Electrical Machines and Drives. Oxford University Press. 1999. |

| Course title: | **Digital Technique 1** | | |
|---|---|---|---|
| Name of the lecturer: | *Krzysztof Penkala* | | |
| ECTS points: | 3 | Language of instruction: | English |
| Semester: | summer | Hours per week: | lectures – 2 h laboratory – 1h |
| Code: | | Teaching method: | lectures, lab training |

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| Entry requirements: | Mathematics 1, Informatics 1 |
| Objectives of the course: | To provide basic knowledge on digital circuit theory and design |
| Course contents: | Lectures: Analogue versus digital technique. Number systems. Binary codes, BCD codes. Basics of binary arithmetic. Automata, logic circuit, digital circuit – basic definitions. Boolean Algebra, fundamental thorems. Switching (Boolean) functions, simplification, minimisation. Realising logic functions with gates, multiplexers and demultiplexers, ROMs, PLA modules. Digital logic circuit realisation techniques & technologies - overview, comparison, development. Flip-flops, logic description. Fundamentals of digital functional blocks - modules (combinatorial and sequential). Digital control system, logic description – algorithms. Basics of microprogramming technique. Introduction to ASICs, PLD modules – classification, development.<br>Labs: Switching functions minimisation. Realising logic functions with gates and different modules. Logic gates testing (switching functions, static and dynamic characteristics). Flip-flops testing. |
| Assessment method: | Accomplishment of practical labs |
| Recommended readings: | 1. Beards P. H.: Analog and Digital Electronics. A First Course, II ed. Prentice Hall, 1991.<br>2. Nelson V. P., Nagle H. T., Carroll B. D., Irwin I. D.: Digital Logic Circuit Analysis and Design. Prentice Hall, New Jersey, 1995.<br>3. Burger P.: Digital Design. A Practical Course. John Wiley & Sons, N.Y., 1998. |

| Course title: | **Digital Signal Processors** | | |
|---|---|---|---|
| Name of the lecturer: | *Przemysław Mazurek* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | summer or winter | Hours per week: | lectures – 2 h laboratory – 2h |
| Code: | | Teaching method: | lectures, experiments, programming (DSP563xx) |

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| Entry requirements: | Computer science. |
| Objectives of the course: | This course is intended to present practical programming techniques for Digital Signal Processors (DSP) |
| Course contents: | Intorduction to Digital Signal Processors. DSP hardware. Implementation of FIR and IIR filters. Signal synthesis algorithms. Signal detection algorithms. Audio processing. Real-time signal processing algorithms decompostion. Fixed and floatting Point arithmetics. Programming DSP using C language and mixed (C & assembly). SIMD (MMX, SSEx) techniques in IA32 architectures. |
| Assessment method: | Written examination |
| Recommended readings: | 1. Motorola DSP563xx Family Manual<br>2. Motorola DSP563xx Assembly Manual<br>3. Intel IA32 Architecture |

| Course title: | **High Intelligent Technique of Converter Fed Electrical Motor Drives** | | |
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| Name of the lecturer: | *Valery Khrisanov* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | summer or winter | Hours per week: | lectures – 2 h laboratory – 2h |
| Code: | | Teaching method: | lectures, experiments, computer simulations |

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|---|---|
| Entry requirements: | Electrical Engineering, Information and Power Electronics |
| Objectives of the course: | learning and understanding basic principles of modern control system of a.c. converter fed motor drives, being informed about their applications and methods of modeling and simulation. |
| Course contents: | 1. Introduction .<br>2. Fields of application, classification, specification and contemporary trends in modern Converter Fed A..C. Electrical Motor Drives (CFEMD).<br>3. Contactless conventional and unconventional A..C. Electrical Motors.<br>4. Scalar and Vector Control of A..C. Electrical Motors.<br>5. Power and Information Electronics as the muscles and brain of Electrical Energy Conversion (topology, switch commutation, modulation, protections, EMC, etc).<br>6. Block-scheme of CFEMD.<br>7. Analysis, modeling and computer simulation.<br>8. Sensorless and intelligent control.<br>9. Future trends of CFEMD. |
| Assessment method: | Written examination |
| Recommended readings: | 1. M. P. Kazmierkowski, H. Tunya. Automatic Control of Converter Fed Drives. PWN-Polish Scientific Publishers, Warszawa, 1994.<br>2. P.Vass. Sensorless Vector and Direct Torque Control. Oxford University Press, 1998.<br>3. P.Vass. Artificial Intelligence - Based Electrical Machines and Drives. Oxford University Press. 1999.<br>4. N. Mohan, T. Undeland, W. Robbins. Power Electronics. J.Willy and Sons,<br>5. New-York, Toronto, 1989. |

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| Course title: | **Image Processing** | | |
| Name of the lecturer: | *Krzysztof Okarma* | | |
| ECTS points: | 6 | Language of instruction: | English |
| Semester: | summer | Hours per week: | lectures – 2 h laboratory – 2h |
| Code: | | Teaching method: | lectures, experiments, computer simulations |

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| Entry requirements: | Fundamentals of signal processing and computer engineering |
| Objectives of the course: | This course is intended to present a unified approach to image processing techniques with short introduction to image analysis |
| Course contents: | Digital image – classes, representations and conversion methods. Colour models. Arithmetic and logic operations on digital images. Geometric operations, matrix notation. Digital image acquisition. Local processing and filtration using convolution methods (mask window, low-pass and high-pass two-dimensional filters, median and contour filters). Methods for reduction of the number of colours (dithering, popular colours and median algorithms, constant palette, simulation of colours using binary images). Deformations, bilinear projection and morphing. Frequency-based image processing methods (2-D Digital Fourier Transform and FFT, digital image's spectrum and filtration). Histogram and histogram-based operations. Binarization. Morphological operations (erosion, dilation, opening, closing, thinning, growing, skeleton methods, SKIZ), Golay's alphabet. Image segmentation. Indexing techniques in image processing. Measuring methods using image analysis. Lossy and lossless image compression standards. |
| Assessment method: | Written examination |
| Recommended readings: | 1. Foley J.D. et al: *An Introduction to Computer Graphics*. Addison-Wesley, 2000 .<br>2. Pavlidis T.: *Algorithms for Graphics and Image Processing*, Computer Science Press, Rockville, 1982.<br>3. Nelson M.: *The Data Compression Book*. IDG Books Worldwide, Inc. 2000.<br>4. Pratt W.K.: *Digital Image Processing (2nd Edition.)*. Wiley Interscience, New York 1991.<br>5. Ritter G.X., Wilson J.N.: *Handbook of Computer Vision - Algorithms in Image Algebra*. CRC Press 1996.<br>6. Russ J.C.: *The Image Processing Handbook*. CRC Press 1999.<br>7. Watkins Ch. i in.: *Nowoczesne metody przetwarzania obrazu*. WNT, Warszawa 1997 (in Polish).<br>8. Woźnicki J.: *Podstawowe techniki przetwarzania obrazu*. WKiŁ, Warszawa 1996 (in Polish). |

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|---|---|---|---|
| Course title: | **EM Fields Effects in Living Organisma** | | |
| Name of the lecturer: | *Michał Zeńczak* | | |
| ECTS points: | 4 | Language of instruction: | English (partially Polish) |
| Semester: | summer or winter | Hours per week: | lectures – 2 h laboratory – 1h |
| Code: | | Teaching method: | lectures, experiments, computer simulations |

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| Entry requirements: | Mathematics, Physics, Theoretical Electrical Engineering, Theory of Electromagnetic Fields. |
| Objectives of the course: | Knowledge about bioelectromagnetism, electromagnetic fields in natural environment and interaction of living systems with electromagnetic fields.<br>Skills of designing electric power engineering structures according to standards for electromagnetic fields in natural and occupational environment. |

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| Course contents: | Basis of theory of electromagnetic fields in application for biology. Natural and technical sources of electromagnetic fields. Standards for electromagnetic fields. Electrical properties of living matter. Electromagnetic fields inside living systems. Mechanism of interaction of non-ionising electromagnetic fields with living systems. Infrared, visible and ultraviolet radiation. Influence of ionising radiation on living systems. Dosimetry of ionising radiation |
| Assessment method: | Written examination |
| Recommended readings: | 1. Bronzino J.D. : The biomedical engineering. CRC Press, 1995.<br>2. Carstensen E.: Biological effects of transmission line fields. Elsevier, New York, Amsterdam, London 1987.<br>3. Malmivuo J. Plonsey R.: Bioelectromagnetism. Oxford University Press, 1995.<br>4. Polk C., Postow E.: CRC Handbook of biological effects of electromagnetic fields. CRC Press, Boca Raton, Florida 1986.<br>5. Wadas R.S.: Biomagnetism. PWN WARSAW 1978 |

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|---|---|---|---|
| Course title: | **Image Recognition I** | | |
| Name of the lecturer: | *Przemysław Mazurek* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | summer or winter | Hours per week: | lectures – 2 h laboratory – 2h |
| Code: | | Teaching method: | lectures, experiments, computer simulations (SNNS/Matlab) |

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|---|---|
| Entry requirements: | Computer science (basic). Digital Image Processing. |
| Objectives of the course: | This course is intended to present practical methods of image recognition using neural networks. |
| Course contents: | Classification, autoassociation, heteroassociation, regularity detection. Limations of image recognition. Differnet distance metrics for image recognition. Statistical image recognition methods. Hamming classifier. Image recognition using forward neurla networks. Types of neural networks. Neuron. Multialyer forward neural networks. Perceptron. Hamming neural networks. Selected neural networks learning algorithms for one and multi layer neural networks. Selections of neural network architectures. Learning and testing neural networks. Hierarchical neural networks. Pao networks. Fahlman cascade correlaction algorithm. RBF networks. Image compression using recognition. Neural networks architecture optimization. |
| Assessment method: | Image recognition project |
| Recommended readings: | 1. Masters T.: *Practical Neural Network Recipies in C++*<br>2. Matlab - *Neural Network Toolbox Manual* |

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|---|---|---|---|
| Course title: | **Introduction To Statistical Data Analysis** | | |
| Name of the lecturer: | *Andrzej Brykalski, Tomasz Rogala* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | summer | Hours per week: | lectures – 2 h laboratory – 1h |
| Code: | | Teaching method: | lectures, practical labs |

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|---|---|
| Entry requirements: | Mathematics |
| Objectives of the course: | To gain an understanding of the statistics and probability. |
| Course contents: | Introduction. Descriptive statistics and data visualization. Basic definitions (mean, median, mode). Probability. Conditional probability and independence events. Bayes theorem. Discrete and continuous random variable. Probability densivity function. Cumulative densivity function. Expected value. Normal probability distribution. Other chosen distributions. Central limit Theorem. Random sampling. Unbiased estimators. Confidence intervals. Student's t-distribution. Hypothesis testing. Multivariate normal distribution. Correlation. Covariance matrix. Linear regression. |
| Assessment method: | Exam |
| Recommended readings: | 1. David S. Moore, George P. McCabe. Introduction to the Practice of Statistics. Worth Publishers Inc. 2002<br>2. Statsoft Inc. Electronic statistics Textbook.<br>3. http://www.ststsoft.com/textbook/ststhome.html<br>4. Douglas C. Montgomery, George C. Runger. Applied Statistics and Probability for Engineers. John Wiley & Sons, 2003. |

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|---|---|
| Course title: | **Telecommunications Power Supplies** |

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|---|---|---|---|
| Name of the lecturer: | *Valery Khrisanov* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | summer or winter | Hours per week: | lectures – 2 h laboratory – 2h |
| Code: | | Teaching method: | lectures and practice lessons |

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|---|---|
| Entry requirements: | Electrical Engineering, Information and Power Electronics |
| Objectives of the course: | |
| Course contents: | 1. Introduction.<br>2. Classification, specification and contemporary trends in Telecommunications Power Supplies (TPS).<br>3. General block- schemes and the strategy of topologic solutions to meet high performances and specific demands of TPS. Multiple power conversion as a main feature of the modern high performance TPS.<br>4. Theory and technique of Passive and Active Rectification of a.c. voltage.<br>5. Active and Passive Smoothing Filters.<br>6. Input and output transformers and transformerless topologies in TPS.<br>7. Switch mode converters in TPS.<br>8. Stabilization of TPS output d.c. voltage.<br>9. Uninterruptible Power Supplies (UPS) in Telecommunications.<br>10. Electromagnetic compatibility and Power Factor correction.<br>11. Power Supplies in different areas of Telecommunications.<br>12. Conclusion: Future trends in TPS. |
| Assessment method: | testing and examination |
| Recommended readings: | 1. N. Mohan, T.M. Underland, W.P. Robbins. Power electronics, second edition, John Wiley &Sons Inc. 1995<br>2. K. Heumann. Basic Principles of Power Electronics, Springer – Verlag, Berlin, 1986<br>3. P. Wood. Switching Power Converters, Van Nostrand Reinhold Company, New York – London – Toronto, 1985 |

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|---|---|---|---|
| Course title: | **Operating Systems** | | |
| Name of the lecturer: | *Przemysław Mazurek* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | summer or winter | Hours per week: | lectures – 2 h laboratory – 2h |
| Code: | | Teaching method: | lectures, experiments, computer simulations |

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|---|---|
| Entry requirements: | Computer science (basic) |
| Objectives of the course: | This course is intended to present interprocess communication methods used in modern operating systems. |
| Course contents: | Operating systems classification. Real-Time Systems. Real-Time Operating Systems (hard & soft). General Purpose Operating Systems. Distributed operating systems. Schedulers. Proceses & theads. Processing environment. Signals, flags, queues, priority queues, message queues, pipes, files, shared memory, semaphores. Network interprocess communication - BSD sockets. MS Windows specific interprocess communication. Remote Procedure Calls (RPC). Deadlocks. |
| Assessment method: | Test examination |
| Recommended readings: | 1. Gray J. S.: *Interprocess Communications in Unix*<br>2. Silberschatz A., Gagne G., Galvin P. B.: *Operating Systems Concepts*<br>3. Stevens W. R.: *Unix Network Programming, Vol. 1*<br>4. Stevens W. R.: *Unix Network Programming, Vol. 2*<br>5. Bovet D. P., Cesati M..: *Linux kernel* |

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|---|---|---|---|
| Course title: | **Image Recognition II** | | |
| Name of the lecturer: | *Przemysław Mazurek* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | summer or winter | Hours per week: | lectures – 2 h laboratory – 2h |
| Code: | | Teaching method: | lectures, experiments, computer simulations (SNNS/Matlab) |

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|---|---|
| Entry requirements: | Computer science (basic). Digital Image Processing. |
| Objectives of the course: | This course is intended to present practical methods of image recognition using neural networks. |
| Course contents: | Recurent neural networks. Hopfield neural networks. BAM neural networks, Kohonen neural networks. ART neural networks. PCA (Principal Component Analysis), ICA (Independent Component Analysis). Bayesian method for |

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| | image recognition. |
| Assessment method: | Image recognition project |
| Recommended readings: | 1. Masters T.: *Practical Neural Network Recipies in C++*<br>2. Matlab - *Neural Network Toolbox Manual* |

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|---|---|---|---|
| Course title: | **Tomographic Techniques in Industry and Medicine** | | |
| Name of the lecturer: | *Wojciech Chlewicki* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | summer | Hours per week: | lectures – 3 h laboratory – 2h |
| Code: | | Teaching method: | lectures, experiments with simulated and real data |

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| Entry requirements: | Mathematics, physics, (basic knowledge about digital signal processing will be helpful); |
| Objectives of the course: | This course is intended to present foundations of X-ray and emission tomography (advanced undergraduate level) |
| Course contents: | Principles of tomography: The Radon transform, Fourier Slice Theorem. Direct Fourier methods. Analytical image reconstruction methods – Filtered Backprojection. Iterative image reconstruction methods: algebraic methods (ART, SART, SIRT, MART) and statistical methods (ML-EM, OS-EM, RAMLA). Iterative Bayesian image reconstruction. Image representation in iterative methods – local basis function approach. Possible realizations of projection/backprojection operators. Problems of limited angle and limited number of views. Fully 3D image reconstruction: multi row and cone beam CT, 3D PET mode. |
| Assessment method: | Written examination |
| Recommended readings: | 1. Kak C. and Slaney M.: *Principles of Computerized Tomographic Imaging*. Philadelphia, PA: SIAM 2001.<br>2. F. Natterer. *The Mathematics of Computerized Tomography*, volume 32 of Classics in Applied Mathematics. SIAM, 2001<br>3. Lewitt R.M. and Matej S.: Overview of methods for image reconstruction from projections in emission computed tomography. *Proceedings of the IEEE*, 91(10):1588–1611, 2003.<br>4. Fuchs T., Kachelriess M., Kalender W.: Fast volume scanning approaches by X-ray-computed tomography, *Proceedings of the IEEE*, 91 (10):1492–1502, 2003.<br>5. Gros X.E.: *NDT Data Fusion*, Elsevier, 1997. |

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|---|---|---|---|
| Course title: | **Principles of Digital Signal Processing** | | |
| Name of the lecturer: | *Janusz Kowalski* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | summer | Hours per week: | lectures – 2 h classes – 1 h<br>laboratory classes– 2 h |
| Code: | | Teaching method: | lectures, experiments, computer simulations |

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| Entry requirements: | Students should know foundations of the mathematical analysis and theory of probability. |
| Objectives of the course: | The goal of the subject of study is introduction to principles of digital signal processing. Moreover the theoretical foundations of the information theory, sampling and quantization will be explained. |
| Course contents: | Signal classifications. Distribution signals. Fourier transform (properties, examples of the transform's applications). Transmittance of the system. Filters. Correlations functions. Power spectral density (Wiener-Chinczyn theorem). Examples of the auto-correlation function and power spectral density function of the deterministic and random signals. Numerical methods of estimation of auto-correlation function and power spectral density function. Ergodic random processes. Sampling of signals (Shannon theorem, sampling of the signals existing in reality, sampling's errors). Quantization of signals. Short-time Fourier transform. Information and entropy. |
| Assessment method: | Written examination |
| Recommended readings: | 1. Bellanger M.: *Digital Processing of Signals, Theory and Practice*. John Wiley & Sons, UK 1984<br>2. Lyons R. G.: *Understanding Digital Signal Processing*. Addison-Wesley, USA 1999<br>3. Oppenheim A. V., Schafer R. W.: *Discrete Time Signal Processing*. Prentice-Hall, USA, 1989<br>4. Proakis J. G., Mandakis D. G.: *Digital Signal Processing – Principles, Algorithms and Applications*. Prentice-Hall, USA, 1992<br>5. Rabiner L. R.: *Theory and Applications of Digital Signal Processing*. Prentice-Hall, USA, 1975 |

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|---|---|---|---|
| Course title: | **Statistical Methods in Telecommunication** | | |
| Name of the lecturer: | *Przemysław Włodarski* | | |
| ECTS points: | 5 | Language of instruction: | English (partially Polish) |
| Semester: | summer | Hours per week: | lectures – 2 h laboratory – 2h |
| Code: | | Teaching method: | lectures, experiments, computer simulations |

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|---|---|
| Entry requirements: | Mathematics, fundamentals of telecommunication networks |
| Objectives of the course: | This course is intended to present statistical methods in telecommuncation from the point of view of performance evaluation (advanced undergraduate level) |
| Course contents: | Statistical data analysis, random variables, distributions, stochastic processes. Traditional models in Telecommunication Networks: Poisson, Markov Modulated Poisson Process (MMPP). Estimation of self-similarity in computer networks: R/S analysis, variance-time plot, Index of Dispertion for Counts (IDC), peridogram and wavelet analysis, Whittle and local estimators. Self-similar models of network traffic: superposition of heavy-tailed on/off sources, FARIMA processes, Pareto Modulated Poisson Process (PMPP), Markov Modulated Bernouli Process (MMBP), circulant embedded matrix method, Spatial Renewal Processes (SRP), methods based on power spectrum of fractional Gaussian noise. Queueing models in telecommunication networks: M/M/1/(K), M/D/1/(K), M/G/1/(K), G/M/1/(K), G/G/1/(K). Generation of self-similar traffic using traditional and self-similar models. Analysis of queueing performance based on network delay and buffer capacity. |
| Assessment method: | Written examination |
| Recommended readings: | 1. Medhi J., *Stochastic models in queueing theory*. Academic Press, 2nd edition, 2002.<br>2. Gross D., Harris C.M., Fundamentals ofqueueing theory. Wiley-Interscience, 3rd edition, 1998.<br>3. Park, K., Willinger, W., *Self-similar network traffic and performance evaluation*. John Wiley & Sons, 2000.<br>4. Tanenbaum A.S., *Computer Networks*. Prentice Hall, 4th edition, 2003. |

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|---|---|---|---|
| Course title: | **Signal Conversion** | | |
| Name of the lecturer: | *Przemysław Mazurek* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | summer or winter | Hours per week: | lectures – 2 h laboratory – 2h |
| Code: | | Teaching method: | lectures, experiments, computer simulations (Matlab) |

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| Entry requirements: | Computer science (basic), Signal Processing (basic) |
| Objectives of the course: | This course is intended to present different methods of signal acqusition and signal processing |
| Course contents: | Antialiasing (digital and analog). Resampling. Signal synthesis. Signal detection. Delta-sigma modulators. Undersampling. Companding. Transforms design. Wavelets and signal atoms analysis. Digital Wave Filters. Time optimal FIR and IIR filters. |
| Assessment method: | Test examination |
| Recommended readings: | 1. Mazurek P.: *Course Signal Conversion materials* |

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| Course title: | **Statistical Pattern Recognition** | | |
| Name of the lecturer: | *Andrzej Brykalski, Tomasz Rogala* | | |
| ECTS points: | 3 | Language of instruction: | English |
| Semester: | summer | Hours per week: | lectures – 1 h laboratory – 2h |
| Code: | | Teaching method: | lectures, practical labs |

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| Entry requirements: | Mathematics.<br>Introduction to statistical data analysis.<br>Knowledge of computer programming in any language. |
| Objectives of the course: | To gain an understanding of the basics of pattern recognition using both statistical methods and neural networks.<br>To gain an ability to implement chosen classification algorithms.<br>To solve sample pattern recognition problems using datasets from available pattern recognition databases |
| Course contents: | |

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| | Introduction. Basic definitions used in pattern recognition field. Design of classification system. Overview of statistical and neural network approach. Revision of basic statistical terms (conditional probability, random variable, probability density function, normal distribution). Bayes Decision Theory. Discriminant functions. Parameter estimation. Classification error and its minimization. Nonparametric methods (kNN). Feature extraction. Optimal features. Principal Components Analysis and Linear Discriminant Analysis (PCA and LDA transformations). Feature subset selection. Classification performance evaluation (learning and test set, generalization issue, cross-validation, bootstrap). |
| Assessment method: | accomplishment of practical labs |
| Recommended readings: | 1. R. Duda, P. Hart, D. Stork. Pattern Classification. John Wiley & Sons Inc.. 2001<br>2. C. M. Bishop. Neural Networks for Pattern Recognition. Oxford University Press 1995. |

| Course title: | **Object Oriented Programming** | | |
|---|---|---|---|
| Name of the lecturer: | *Andrzej Brykalski, Tomasz Rogala* | | |
| ECTS points: | 5 | Language of instruction: | English |
| Semester: | summer | Hours per week: | lectures – 1 h laboratory – 2h |
| Code: | | Teaching method: | lectures, practical labs |

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| Entry requirements: | Knowledge of procedural programming in C language. |
| Objectives of the course: | To gain an understanding of object oriented style of programming (OOP) using C++ language.<br>To gain practical experience with basic OOP techniques: encapsulation, inheritance and polymorphism<br>To learn to create C++ applications using Microsoft Visual Studio .NET 2003 |
| Course contents: | Structural programming vs. object-oriented programming (OOP) – differences, advantages and disadvantages. Main features of object-oriented approach: encapsulation, inheritance and polymorphism. Revision of the C basics (in/out operations, conditionals, loops, data types). Input/output operations in C++ using streams. Classes: definition, fields and member functions. Constructors and destructors. Tables of objects. Pointers to objects and objects members. Operator overloading. Inheritance. Virtual functions and polymorphism. Exception handling. |
| Assessment method: | Exam |
| Recommended readings: | 1. Bruce Eckel. Thinking in C++, Vol.1 (http://mindview.net/Books)<br>2. Bruce Eckel. Thinking in C++, Vol.2 (http://mindview.net/Books)<br>3. Davis Chapman. Teach Yourself Visual C++ in 21 days. SAMS Publishing. 1998.<br>4. Bjarne Stroustrup. The C++ programming language. AddisonWesley. 1997 |

Postgraduate one-semester study programme in English on

## ADVANCED TECHNIQUES OF SIGNAL PROCESSING, ANALYSIS AND TRANSMISSION IN BIOMEDICAL APPLICATIONS

## Course Supervisor: Dr. Krzysztof Penkala

A. Compulsory courses ............................................ 210 h (105 L + 105 P) – 17 pt (ECTS)

| Course code | Course name | Course leader | Course hours | Lecture hours | Hours of practicals | Credit points |
|---|---|---|---|---|---|---|
| A1 | Advanced biosignal processing and analysis | Dr. Marek Jaskuła | 45 | 15 | 30 | 3 |
| A2 | Biomedical imaging – equipment, image processing and analysis | Dr. Krzysztof Penkala, Dr. Wojciech Chlewicki | 45 | 30 | 15 | 4 |
| A3 | Telemedicine, IT&T in Health Care | Dr. Krzysztof Penkala | 45 | 30 | 15 | 4 |
| A4 | Medical informatics | Dr. Jerzy Pastusiak, Dr. Krzysztof Penkala | 30 | 15 | 15 | 3 |
| A5 | ASIC&DSP in biomedical applications | Dr. Witold Mickiewicz | 45 | 15 | 30 | 3 |

B. Optional courses (2 electives) ......................................... 90 h (60 L + 30 P) – 8 pt (ECTS)

| Course code | Course name | Course leader | Course hours | Lecture hours | Hours of practicals | Credit points |
|---|---|---|---|---|---|---|
| B1 | Elements of psychoacoustics and electroacoustics | Dr. Witold Mickiewicz | 45 | 30 | 15 | 4 |
| B2 | Advanced methods of medical image reconstruction | Dr. Wojciech Chlewicki | 45 | 30 | 15 | 4 |
| B3 | EM fields effects in living organisms | Dr.Sc. Michał Zeńczak | 45 | 30 | 15 | 4 |
| B4 | Modelling of EM fields in human body | Dr. Marek Ziółkowski | 45 | 30 | 15 | 4 |
| B5 | Sound system design | Dr. Witold Mickiewicz | 45 | 30 | 15 | 4 |
| B6 | Advanced methods of speech processing and transmission | Dr. Adam Podhorski, Dr. Jerzy Sawicki | 45 | 30 | 15 | 4 |

C. Research activities ........................................................... 60 h (60 P) – 5 pt (ECTS)

| Course code | Course name | Course leader | Course hours | Lecture hours | Hours of practicals | Credit points |
|---|---|---|---|---|---|---|
| C1 | Research lab | Dr. Krzysztof Penkala | 60 | - | 60 | 5 |

Total A + B + C ........................................................... 360 h (165 L + 195 P) – 30 pt (ECTS)

Notation: h - hours, L - lectures, P - practicals (lab, project, seminar), pt - credit points (ECTS)

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| Course title: | **Elements of Psychoacoustics and Electroacoustics (B1)** | | |
| Name of the lecturer: | *Witold Mickiewicz* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | winter or summer | Hours per week: | lectures – 2 h laboratory – 1h |
| Code: | B1 optional | Teaching method: | lectures, lab training |

**Entry requirements:** Physics

**Objectives of the course:** To provide knowledge on psychoacoustics basics and selected topics on electroacoustics (sound fields, transducers, sound reinforcement, sound processing).

**Course contents:** Lectures: Sound waves properties. Human auditory system. Musical sounds, notes and harmony. Elements of psychoacoustics – monaural and binaural hearing effects. Spatial hearing. Fundamentals of room acoustics and perceiving sound in different environments. Electroacoustical transducers and electroacoustical systems. Hearing aids. Digital sound processing. Audio compression. HRTF technology and 3-D audio systems.
Labs: Models of human auditory system. Experiments in hearing. Hearing aids, software support. MATLAB in processing, compression and enhancement of audio signal. 3-D audio enhancements of 2-channel sound. Hard disc recording systems. Recording technology. Electroacoustical systems measurements and design. Filtering, sound effects.

**Assessment method:** Written exam, accomplishment of practical labs

**Recommended readings:**

1. Howard D. H.: Acoustics and psychoacoustics. Focal press, 2001.
2. Blauert J.: Spatial Hearing - Revised Edition: The Psychophysics of Human Sound Localization. MIT Press, 1999.
3. Everest F. A.: Master handbook of acoustics. McGraw-Hill, 2001.

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|---|---|---|---|
| Course title: | **Advanced Biosignal Processing and Analysis (A1)** | | |
| Name of the lecturer: | *Marek Jaskuła* | | |
| ECTS points: | 3 | Language of instruction: | English |
| Semester: | winter or summer | Hours per week: | lectures –1 h laboratory – 2h |
| Code: | A1 compulsory | Teaching method: | lectures, computer simulations |

**Entry requirements:** Signal theory, Signal processing, Fundamentals of Biomedical Engineering

**Objectives of the course:** The course is intended to teach using advanced methods and techniques in processing and analysis of biosignals.

**Course contents:** Windowing technique (different window functions, criterion of optimization), parametric filter and filter design, spectral analysis: STFT, time-frequency analysis, wavelet, statistical signal processing. Introduction to Matlab and biosignal toolbox, biosignal analysis in time and frequency domain, filtering of brainstem auditory evoked potentials (BAEP) with parametric filter, windowing techniques, FFT, STFT, time-frequency analysis, using different kernel,

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| | kernel optimization, wavelet, ECG and EEG signal processing, ERG and VEP signal analysis. |
| Assessment method: | Written examination, accomplishment of labs |
| Recommended readings: | 1. Oppenheim, A.V. and Schafer W.: Discrete-time signal processing. Prentice Hall,1999.<br>2. Cohen L.: Time-frequency analysis. 1995.<br>3. Qian S., Chen D.: Joint time-frequency analysis. Methods and Applications. Prentice-Hall, 1996.<br>4. Vetterli M. and Kovacevic J.: Wavelets and subband coding. Prentice Hall, 1996. |

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|---|---|---|---|
| Course title: | **Advanced Methods of Medical Image Reconstruction (B2)** | | |
| Name of the lecturer: | *Wojciech Chlewicki* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | winter or summer | Hours per week: | lectures –2h laboratory – 1h |
| Code: | B2 optional | Teaching method: | lectures, lab training, computer simulations |

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| Entry requirements: | Mathematics, Informatics, Digital signal processing, Image processing, Fundamentals of Biomedical Engineering |
| Objectives of the course: | To provide up to date knowledge and to develop skills on various methods and techniques of biomedical image reconstruction. |
| Course contents: | Lectures: Principles of tomography: the Radon transform, Fourier Slice Theorem. Direct Fourier methods. Analytical methods – Filtered Backprojection. Iterative methods: algebraic methods (ART, SART, SIRT, MART) and statistical methods (ML-EM, OS-EM, ISRA). Iterative Bayesian image reconstruction. Image representation in iterative methods – local basis function approach. Possible realizations of projection/backprojection operators. Problems of limited angle and limited number of views. Fully 3D image reconstruction: multi row and cone beam CT, 3D PET mode. The exact 3D reconstruction issues: helical and saddle trajectories.<br>Labs: This will include writing (assembling) of image reconstruction procedures and their evaluation using software simulated and real phantom data. Additionally reconstructions will be performed using real clinical data. |
| Assessment method: | Written examination, accomplishment of practical laboratory tasks |
| Recommended readings: | 1. Robb R. A.: Three Dimensional Biomedical Imaging: Principles and Practice. Wiley-Liss, N.Y., 1998.<br>2. Kak C. and Slaney M.: Principles of Computerized Tomographic Imaging. Philadelphia, PA: SIAM, 2001.<br>3. Natterer F.: The Mathematics of Computerized Tomography. Volume 32 of Classics in Applied Mathematics. SIAM, 2001. |

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|---|---|---|---|
| Course title: | **ASIC&DSP in Biomedical Applications (A5)** | | |
| Name of the lecturer: | *Witold Mickiewicz* | | |
| ECTS points: | 3 | Language of instruction: | English |
| Semester: | winter or summer | Hours per week: | lectures –1h laboratory – 2h |
| Code: | | Teaching method: | lectures, lab training |

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| Entry requirements: | Signal theory, Digital technique, Microprocessor technique |
| Objectives of the course: | To provide knowledge and design skills in application of ASIC&DSP in biomedical engineering. |
| Course contents: | Lectures: Programmable logic devices. A systematic approach to logic design. Introduction to VHDL. Architecture and programming methods of digital signal processors (DSP). DSP and FPGA implementation of signal processing algorithms used in biomedical applications: filtering, frequency analysis and signal-to-noise enhancement. ASIC and DSP in medical diagnostics, therapy and rehabilitation equipment.<br>Labs: Course in DSP and FPGA programming using assembler, C and VHDL programming languages. Implementing filtering, FFT and other algorithms applied to biosignals on Analog Devices DSPs and Xilinx FPGAs. |
| Assessment method: | Written exam, accomplishment of practical labs |
| Recommended readings: | 1. Lee Sunggu: Design of computers and other complex digital devices. Prentice Hall, 2000.<br>2. Perry D. L.: VHDL. McGrawHill, 1997.<br>3. Smith S. W.: The Scientist and Engineer's Guide to Digital Signal Processing, California Technical Publishing, 1997.<br>4. Oldfield J. V., Dorf R. C.: FPGAs. Reconfigurable Logic for Rapid Prototyping and Implementation of Digital Systems. John Wiley&Sons, Inc., N.Y., 1995.<br>5. Analog Devices DSP data sheets and programmer literature at www.analog.com.<br>6. Xilinx data sheets and programmer literature at www.xilinx.com. |

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| Course title: | **Biomedical Imaging – equipment, image processing and analysis (A2)** | | |
| Name of the lecturer: | *Krzysztof Penkala, Wojciech Chlewicki* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | winter or summer | Hours per week: | lectures –2h laboratory – 1h |
| Code: | A2 compulsory | Teaching method: | lectures, lab training (also in hospitals), computer simulations |

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| Entry requirements: | Signal theory, Image processing, Fundamentals of Biomedical Engineering |
| Objectives of the course: | To provide up to date knowledge on various modalities of biomedical imaging technologies, systems and archiving/transmission standards. |
| Course contents: | Lectures: Human factors in biomedical imaging. Medical imaging systems – physical principles of image formation and equipment in Thermography (TG), Ultrasonography (USG), Nuclear Medicine (Gamma-camera, SPECT, PET), Digital Radiography (DR), Digital Subtraction Angiography (DSA), Computed Tomography (CT), Magnetic Resonance Imaging (MRI). Bio-optical imaging. Biomolecular imaging. Special techniques, e.g. ultra-fast data acquisition systems in MRI (EPI), Functional and Interventional MRI. Principles of image reconstruction (2-D, 3-D). Image processing, analysis and measurement; software tools. Image fusion. Virtual endoscopy. Image transmission and archiving – PACS, standard DICOM 3. DICOM validation tools.<br><br>Labs: Bioelectrical signals mapping: TBM, mfERG and mfVEP systems. Gamma AT and Gamma Vision systems. USG - Transcranial Doppler (TCD). Image browsing&analysis tools: systems OSIRIS/PAPYRUS and PC-Image. DICOM validation tools. MATLAB, IDL and LabView systems in image processing. Demonstration of medical imaging systems in hospitals and diagnostic centres. |
| Assessment method: | Written examination, accomplishment of labs |
| Recommended readings: | 1. Bronzino J. D. (ed.): Biomedical Engineering Handbook. CRC Press, IEEE Press, 1995.<br>2. Robb R. A.: Three Dimensional Biomedical Imaging: Principles and Practice. Wiley-Liss, N.Y., 1998.<br>3. Christensen D. A.: Ultrasonographic Bioinstrumentation. J. Wiley & Sons, N.Y., 1988.<br>4. Shellock F. G., Kanal E.: Magnetic Resonance. Bioeffects, Safety and Patient Management. Raven Press, N.Y., 1994.<br>5. Huang H. K.: PACS in Biomedical Imaging. VCH Publ. Inc., N.Y., 1996.<br>6. IT-EDUCTRA. FUNDESCO, Commission of the EC, 1998. |

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| Course title: | **EM Fields Effects in Living Organisms (B3)** | | |
| Name of the lecturer: | *Michał Zeńczak* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | winter or summer | Hours per week: | lectures –2h laboratory – 1h |
| Code: | B3 optional | Teaching method: | lectures, experiments, computer simulations |

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| Entry requirements: | Mathematics, Physics, Theoretical electrical engineering, Theory of EM fields. |
| Objectives of the course: | Knowledge about bioelectromagnetism, electromagnetic fields in natural environment and interaction of living systems with electromagnetic fields.<br>Skills of designing electric power engineering structures according to standards for electromagnetic fields in natural and occupational environment. |
| Course contents: | Basis of theory of electromagnetic fields in application for biology. Natural and technical sources of electromagnetic fields. Standards for electromagnetic fields. Electrical properties of living matter. Electromagnetic fields inside living systems. Mechanism of interaction of non-ionising electromagnetic fields with living systems. Infrared, visible and ultraviolet radiation. Influence of ionising radiation on living systems. Dosimetry of ionising radiation. |
| Assessment method: | Written examination, accomplishment of laboratory tasks |
| Recommended readings: | 1. Bronzino J.D.: Biomedical Engineering Handbook. CRC Press, IEEE Press, 1995.<br>2. Carstensen E.: Biological effects of transmission line fields. Elsevier, New York, Amsterdam, London 1987.<br>3. Malmivuo J., Plonsey R.: Bioelectromagnetism. Oxford University Press, 1995.<br>4. Polk C., Postow E.: CRC Handbook of biological effects of electromagnetic fields. CRC Press, Boca Raton, Florida 1986.<br>5. Wadas R.S.: Biomagnetism. PWN WARSAW 1978. |

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| Course title: | **Telemedicine, IT&T in Health Care (A3)** | | |
| Name of the lecturer: | *Krzysztof Penkala* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | winter or summer | Hours per week: | lectures – 2h laboratory – 1h |
| Code: | A3 compulsory | Teaching method: | lectures, lab training (also in hospitals), computer simulations |

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| Entry requirements: | Informatics, Computer systems, Telecommunications, Networking, Fundamentals of Biomedical Engineering |

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| Objectives of the course: | To provide up to date knowledge on advanced information technologies in biomedical applications and to develop design skills in this field. |
| Course contents: | Lectures: Telemedicine – history and development of telematics in Health Care. Classification of telemedicine services. Review of technologies. The Internet and GSM in e-Health. Specific fields: cardio-tele systems, teleradiology, medical teleconsultations. Telematics in rescue services. Telemonitoring and teleassistance in care of disabled and elderly people. Wireless and mobile medical systems (Wi-Fi and Bluetooth standards, Zigbee and other platforms). Wearable technologies, Biomedical Intelligent Clothing. Tele-service of medical equipment.<br>Labs: Operation of chosen cardio-tele systems. WWW and video-conference applications for telemedicine. Wireless transmission of biomedical signals. Integration of biosensors with Bluetooth and other RF modules. Wireless networks in hospital environment as well as in telemonitoring and teleassistance at home. Tele-service of medical equipment in hospitals. |
| Assessment method: | Written examination, accomplishment of practical labs |
| Recommended readings: | 1. Gordon C., Christensen J. P. (ed.): Health Telematics for Clinical Guidelines and Protocols. IOS Press, Ohmsha, 1995.<br>2. Mantas J. (ed.): Health Telematics Education. IOS Press, Ohmsha, 1997.<br>3. Coiera E.: Guide to Medical Informatics. The Internet and Telemedicine. Arnold, London, 1997.<br>4. Field M. J. (ed.): Telemedicine. A Guide to Assessing Telecommunications in Health Care. National Academy Press, Wash. D.C., 1996.<br>5. IT-EDUCTRA. FUNDESCO, Commission of the EC, 1998. |

| Course title: | **Medical informatics (A4)** | | |
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| Name of the lecturer: | *Jerzy Pastusiak, Krzysztof Penkala* | | |
| ECTS points: | 3 | Language of instruction: | English |
| Semester: | winter or summer | Hours per week: | lectures – 1h laboratory – 1h |
| Code: | A4 compulsory | Teaching method: | lectures, labs (also in hospitals), computer simulations |

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| Entry requirements: | Mathematics, Informatics, Computer systems, Fundamentals of Biomedical Engineering |
| Objectives of the course: | To provide knowledge on advanced information technologies in biomedical applications and to develop design skills in this field. |
| Course contents: | Lectures: Medical knowledge representation. Basics of data models and DB systems. Elements of SQL language. Medical data bases. Electronic patient record. Methods of computer aided medical diagnosis. AI in medicine (expert systems, ANN). VR and AR in medical applications. Systems and standards: HIS, PACS and HL 7, DICOM 3. Problems of systems integration and interoperability. Elements of bioinformatics.<br>Labs: Medical data bases. Computer systems for medical diagnosis support. Computer radiotherapy planning systems. HIS, RIS, PACS systems. |
| Assessment method: | Written examination, accomplishment of practical labs |
| Recommended readings: | 1. Bemmel, van J. H., Musen M. A.: Handbook of Medical Informatics. Bohn Stafleu Van Loghum, Springer, 1997.<br>2. Shortliffe E. H., Perreault L. E.: Medical Informatics. Computer Applications in Health Care. Addison-Wesley Publ. Comp., Readng, Mass., 1990.<br>3. Coiera E.: Guide to Medical Informatics. The Internet and Telemedicine. Arnold, London, 1997.<br>4. Huang H. K.: PACS in Biomedical Imaging. VCH Publ. Inc., N.Y., 1996.<br>5. IT-EDUCTRA. FUNDESCO, Commission of the EC, 1998. |

| Course title: | **Modelling of EM fields in human body (B4)** | | |
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| Name of the lecturer: | *Marek Ziółkowski* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | winter or summer | Hours per week: | lectures – 2h laboratory – 1h |
| Code: | B4 optional | Teaching method: | lectures, computer simulations |

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| Entry requirements: | Mathematics, EM fields theory |
| Objectives of the course: | The course is intended to teach advanced methods and techniques of speech processing, analysis and solving speech transmission. |
| Course contents: | Lectures: Anatomical and physiological basis of bioelectromagnetism. Bioelectric sources and conductors and their modelling – concepts of volume source and volume conductor – bioelectric source and its electric field – the concept of modelling – the human body as a volume conductor – source field models – equivalent volume source density – current dipoles, extended source models. Theoretical methods for analyzing volume sources and volume conductors – forward problems – Maxwell's equations for conducting media – Laplace and Poisson equations – basic solutions of potential fields in homogeneous, isotropic half-space and spherical, cylindrical volume conductors – solid angle theorem – Miller-Geselowitz model – lead field and reciprocity – inverse problems – boundary element method – finite element method – visualization. Biomagnetic instrumentation – SQUID sensor – magnetically and electrically shielded rooms – gradiometers – dewar/cryostat – commercial and non-commercial biomagnetic measurement systems. Simulation of cardiac electrophysiology – phantoms – physical source modelling.<br>Labs: Calculations of analytical solutions of simple problems related to biomagnetism. Modelling of human organs |

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| | using MRI data. Creation of BE meshes. Forward electric and magnetic problems – BEM. Inverse problems – localisation of single dipoles, reconstruction of extended sources. Statistical analysis of results and visualisation. |
| Assessment method: | Written examination, accomplishment of labs |
| Recommended readings: | 1. J. Malmivuo, R. Plonsey: Bioelectromagnetism. Oxford University Press, 1995, New York, Oxford, ISBN 0-19-505823-2.<br>2. L.I. Titomir, P. Kneppo: Bioelectric and Biomagnetic Fields: Theory and Applications in Electrocardiography, CRC Press, 1994, ISBN 0849387000.<br>3. W. Andrä, H. Nowak, eds.: Magnetism in Medicine. A Handbook, Wiley-VCH, 1998, Berlin, ISBN 3-527-40221-7.<br>4. IEEE Transactions on Biomedical Engineering. |

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| Course title: | **Research Lab (C1)** | | |
| Name of the lecturer: | *Krzysztof Penkala (course leader)* | | |
| ECTS points: | 5 | Language of instruction: | English |
| Semester: | winter or summer | Hours per week: | laboratory and project – 4 h |
| Code: | C1 compulsory | Teaching method: | lab and project |

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| Entry requirements: | Physics, Informatics, Signal processing, Telecommunications, Computer systems, Fundamentals of Biomedical Engineering |
| Objectives of the course: | To provide knowledge on research and design methods and to develop various skills useful in solving bioengineering problems. |
| Course contents: | Research work (individual or in 2-3 students teams) is run on topics corresponding to the area of all the courses. The topics are offered by the course leaders and chosen by the students or proposed by them (at the beginning of the semester and after some consultations). Projects are run using all facilities of the Department of Cybernetics and Electronics and co-operating Departments (including rooms, laboratory equipment, computers & software, Internet access, library, copying facilities etc.). Consultations with supervisors – the teachers involved in all the projects - are performed regularly during the semester, with presentation of the progress of research work in the mid of the semester, in a form of seminar open for all the students and teachers (4h). Final assessment of a particular project is made after evaluation of the written report by the supervisor and referee and on the basis of an oral presentation or a poster during the second, final seminar (6h). |
| Assessment method: | Evaluation of the written report and of oral or poster presentation of the project results during the final seminar. |
| Recommended readings: | Positions from all the courses. |

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| Course title: | **Sound System Design (B5)** | | |
| Name of the lecturer: | *Witold Mickiewicz* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | winter or summer | Hours per week: | lectures – 2 h laboratory – 1 h |
| Code: | B5 optional | Teaching method: | lectures, lab training |

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| Entry requirements: | Physics, Electronic circuits |
| Objectives of the course: | To provide knowledge and design skills in various sound systems engineering. |
| Course contents: | Lectures: Acoustic wave propagation. The decibel scale. Directivity and angular coverage of loudspeakers. Microphones. Outdoor sound reinforcement systems. Fundamentals of room acoustics. Behavior of sound systems indoors. Sound system architectures. Multichannel hi-fi and cinema sound systems. Public address and conference systems. Car audio.<br>Labs: Loudspeaker measurements and design. Room acoustics measurements and acoustical adaptation design. Microphones measurements and setup. Various sound system design. Using microphones, loudspeakers, amplifiers, mixing console and sound effects in sound reinforcement system design. Case studies. |
| Assessment method: | Written exam, accomplishment of practical labs |
| Recommended readings: | 1. Davis D. and C.: Sound System Engineering. Second edition, Howard F. Sams, Indianapolis, 1987.<br>2. Eargle J.: Electroacoustical Reference Data. Van Nostrand Reinhold, New York, 1994.<br>3. JBL Professional, Sound System Design Reference Manual, pdf document available at www.jblpro.com. |

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| Course title: | **Advanced Methods of Speech Processing and Analysis (B6)** | | |
| Name of the lecturer: | *Adam Podhorski, Jerzy Sawicki* | | |
| ECTS points: | 4 | Language of instruction: | English |
| Semester: | winter or summer | Hours per week: | lectures – 2 h laboratory – 1 h |

| Code: | B6 optional | Teaching method: | lectures, lab training, computer simulations |
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| Entry requirements: | Signal theory |
| Objectives of the course: | The course is intended to teach advanced techniques of speech processing and analysis as well as solving problems of speech transmission. |
| Course contents: | Lectures: Acoustic theory of speech production. Equivalent circuit of the vocal tract. Perception of speech: the ear and hearing. Speech signal representation. Techniques for speech analysis: FFT, LPC, cepstral processing. Spectral and formant analysis. Analysis of voice pitch. Speech synthesis. Text-to-speech systems. Speech coding: PCM, DPCM, DM, ADM, CELP. Systems for analysis-synthesis in telecommunications: vocoders. Speech and speaker recognition: HMM models.<br>Labs: The complete speech analysis systems for PC: Multispeech (Kay Elemetrics) and Sonolab (Young Digital Poland). Editing and analysis of the speech samples. Glottal pulse and formants analysis. Spectrograms. Vowels and consonants analysis. Speech coding: quality and intelligibility. |
| Assessment method: | Written examination, accomplishment of labs |
| Recommended readings: | 1. Jurafasky D., Martin J.H.: Speech and language processing. Prentice Hall, 2000.<br>2. Huang X., Acero A., Hon H.: Spoken language processing. Prentice Hall, 2001.<br>3. O'Shaughnessy D.: Speech communication: human and machine. Inst. of Electrical and Electronics Engineers, New York, 2000.<br>4. Owens F.J.: Signal processing of speech. Macmillan, London 1993. |