Óbudai Egyetem
John von Neumann Faculty of Informatics

CURRICULUM OF

COMPUTER SCIENCE ENGINEERING MSC

Budapest, 01 September 2017

CURRICULUM OF COMPUTER SCIENCE ENGINEERING MSC

1. Aim of the course:

The aim of the course is to qualify engineers who, having acquired the necessary high-level scientific and specific IT-related technological skills, to be competent to design new IT systems and tools, to develop and integrate IT systems, to conduct and coordinate IT-purpose research and development tasks, as well as to be capable of pursuing their knowledge in the frame of PhD studies.

The computer science engineering curriculum is interdisciplinary. The base of this interdisciplinarity, is informatics. Three dynamically expanding specialization is offered in the program, which combine the practical orientation required by the industrial sphere with the theoretical background required in research and development. These three specializations are:

- robotics specialization;
- biomedical engineering specialization, focusing on two areas:
  - medical image processing;
  - evidence based medicine (EBM).
- mobile application and game development (AMK specialization)

These specializations are introduced with well-founded mathematical and informatics courses, which are followed by more practical courses taught by the research centres and industrial partners of the university.

Thus, the master program deepens the bachelor program, throughout which the master program's courses integrate the knowledge provided by the bachelor program (and its specializations). The master program also homogenizes the bachelor program's specializations, providing equal opportunity to start the MSc program for every student.

Robotics is a rapidly developing interdisciplinary field, with computer science engineering serving as one of its important foundations. Cloud based robotics (intelligent swarm robots, cognitive robots), medical robotics (health care providing robots, therapeutic robots, rehabilitation and surgical robots), service robots (robots caring for the elderly, home robots, support robots) form the topics of the MSc program, in which control engineering, robotics, image processing, artificial intelligence provide the major fields that are educated. The Antal Bejczy Center for Intelligent Robotics provides research projects, industrial and international partners for the practical side of the program.

Medical image processing and medical informatics is one of the most complex research and development areas of modern health care, and is primarily based on fields of information technology such as Big Data, business intelligence, cloud computing, IT security, embedded systems and sensor technology. Its essence is to support medical imaging techniques (CT, PET, MRI, ultrasound), instruments (mass spectrometers, EEG, ECG), telemedicine, tissue engineering, 3D image and model creation and clinical decision support from computer engineering perspective. Besides software engineering, medical image diagnostics, data mining and artificial intelligence as also among the covered fields.

Evidence based medicine (EBM) is also among one of the most complex research directions in modern medicine. Also, this area is not educated at such level in Hungary. The aim of EBM is to base clinical decision making – both in diagnosis and therapy – on the best available so-called evidences (results of well-designed, large sample, optimally experimental clinical studies). This includes the synthesising of the results (and their biostatistical analysis), the quantification of possible risks and benefits based on these (using modelling), which provides way to the best clinical decision. This requires knowledge in biostatistics, modelling, control engineering and artificial intelligence; these are covered in the curriculum. Practical projects are provided by the Physiological Controls Group, and the collaborating medical and health care institutions and their databases.

The computer game industry and in the last few year mobile applications are the key sectors in the IT. Desktop applications are migrating to mobile and wearable devices. The graphical solutions used in game development, the VR devices and software solutions, the devices and

elements of the extended reality, the AI elements and tools are parts of industrial solutions concerning the Industry 4.0 concept. These are used more and more extensively during the industrial design and development, and in data visualization. So this specialization can provide useful knowledge to every software developer not only in the field of computer games, but also in the scientific research, in the education and in the industry.
These interdisciplinary fields are unimaginable without informatical support nowadays. Both designing and carrying out such investigations requires engineering, computer engineering knowledge. This curriculum makes it possible to acquire these, providing internationally competitive skills to the students.

2. **Duration:**

   Full-time (regular) course: 4 semesters, 1125 contact classes

3. **Number of credits to obtain:** 120 credits

4. **Educational level and qualification indicated in the degree:**

   Name of master course: Computer Science Engineering
   Educational level: master (magister, Master of Science, abbreviated: MSc)
   Qualification: Computer Science Engineer

5. **Main areas of the course:**

	Credits
Mathematics and natural sciences	21
Economics and human sciences	10
Professional core curriculum	28
Specialization	25
Optional subjects	6
Thesis	30
Altogether:	**120**

6. **Internship**
   Professional practice of at least 6 weeks (containing 240 work hours).

7. **Foreign language literacy requirements:**

   a) Conditions to issue the final certificate: –

   b) Conditions to issue the degree:
   To receive the master's degree it is required to possess a state-approved, complex, English language certificate of at least intermediate (B2) level; or a state-approved, complex language certificate of at least intermediate (B2) level of any other living language in which the discipline has scientific literature plus a state-approved, complex, English language certificate of basic (B1) level. The student should have a command of the professional language too.

8. **Types of training:**

   full-time (regular)

9. **Places and addresses of the course:**
   John von Neumann Faculty of Informatics, Óbuda University, Bécsi Street 96/b, 1034 Budapest, Hungary
   Alba Regia Technical Faculty, Óbuda University, Budai Street 45, 8000 Székesfehérvár

10. **Program leader:**
    Imre Rudas DSc, professor

11. **Means of evaluation:**

    a) practical mark
    b) examination
    c) final examination

12. **Conditions to take the final exam:**

    a) final certificate
    b) thesis approved by a reviewer

    Admission to the final examination is subject to the obtainment of a final certificate. The final certificate is issued to students having fulfilled all educational requirements specified in the curriculum – except for writing the thesis – and obtained the necessary amount of credits.

13. **Components of the final exam:**

    The final exam comprises the defence of the thesis and oral exams specified in the curriculum (with preparation times at least 30 minutes per subject), which have to be taken the same day.

14. **Result of the final examination:**

    The overall result of the final examination is the average of grades obtained for the thesis and the subjects of the oral part of the final exam:

    $$F = (Th + S1+S2+\ldots+Sm)/(1+m)$$

15. **Conditions to issue the degree:**

    a) successful final exams
    b) fulfilment of foreign language requirements

16. **Available specializations:**
    - robotics
    - biomedical engineering
    - mobile application and game development (AMK specialization)

17. **Date of effect:** 01 September 2017

András Molnár, Ph.D. habil.
associate professor, dean

FOUNDATIONS OF MATHEMATICS AND NATURAL SCIENCES

<table>
<tr><td colspan="2">Name:
Applied mathematics</td><td>NEPTUN-code:
NAMAM1EANE</td><td>Number of periods/week:
full-time: 3 lec + 1 sem + 0 lab</td></tr>
<tr><td colspan="2">Credit: 5
Requirement: exam</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Márta TAKÁCS, Ph.D.</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4">Way of assessment:
– 2 mid-term test and a written exam</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">The aim of the subject is to acquire mathematical knowledge that is needed for engineers of MSc level, particularly for computer engineers. The topics covered by the subject include the following: revision of basic differential calculus, fundamental concepts of number theory, prime tests, RSA cryptography, finite fields, systems of linear equations, matrices and their decompositions, vector spaces, eigenvalues and eigenvectors, diagonalizability, orthogonality, Gram-Schmidt orthogonalization process, singular value decomposition, symmetric bilinear forms and their definiteness, extreme values of functions with two variables and the definiteness of the Hessian matrix.</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
Information- and coding theory</td><td>NEPTUN-code:
NAMIK1EANE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 0 lab</td></tr>
<tr><td colspan="2">Credit: 3
Requirement: mid-term mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Aurél GALÁNTAI, Ph.D.</td><td>Position:
professor, habil.</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4">Way of assessment:
– written exam</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">Basics of information theory, entropy, variable length source coding, Huffman code. The communication channel: conditional entropy, mutual information, channels and their capacities, decoding, ideal observer. Basics of error-correcting codes: Galois fields, vector spaces. Linear codes: Hamming code, orthogonal and first order Reed-Müller code. Cyclic codes. Data compression. Theoretical limits of compression. Arithmetic coding. Important compression techniques: Lempel-Ziv algorithms, the Burrows-Wheeler method. Elements of cryptology. Classical encryptions. Model of algorithmic attacks and cryptanalysis of classical encryptions. DES and AES. Public key encoding: basics and the RSA algorithm.</td></tr>
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<table>
<tr><td colspan="2">Name:
System- and control theory</td><td>NEPTUN-code:
NBIRI1EANE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 6
Requirement: exam</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Levente KOVÁCS, Ph.D.</td><td>Position:
professor, habil.</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Biomatics</td></tr>
<tr><td colspan="4">Way of assessment:
– regular homeworks
– written exam</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">After a short rehearsal of the fundamentals of system theory and classical control engineering, the students will get acquainted with several methodologies from modern control theory. First, the fundamentals of state-space control are discussed (controllability, pole placement), which is followed by state-space controller design techniques extended with constant set point tracking, state part-timemation and compensation of disturbance in the input signal (load part-timemation). Then the optimal versions of the state-space controller design methodologies are discussed (LQ regulators, minimax control, Kalman-filters). In the second part of the semester, the students will learn the theory of robust control and become familiar with the methodology of H∞ synthesis. The course will end with the discussion of the discrete-time implementation of the controllers learned in the semester. After the course, the students will be able to use the tools of modern control theory in practice, and control systems that are critical or require high precision.</td></tr>
</table>

Name: **Algorithm theory**		***NEPTUN-code:*** NAMAL1EANE	***Number of periods/week:*** full-time: 3 lec + 0 sem + 0 lab
Credit: 5 ***Requirement:*** exam		***Prerequisite:*** -	
Responsible: Aurél GALÁNTAI, Ph.D.	***Position:*** professor, habil.	***Faculty and Institute name:*** John von Neumann Faculty of Informatics Institute of Applied Mathematics	

Way of assessment:

- mid-term exam
- written exam

Course description:

Introduction. Mathematical basics. Formal languages and automatopn: generative grammatics, finite deterministic and nondeterministic automata, stack automata. Computation models: Turing machine, Boole function and networks. Universal Turing machines. Algorithmic decidibality and computability. Undecidable problems. Recursive functions. Analysis of algorithms. Master theorem. Searching, sorting and selection functions. Matrix algorithms: Strassen and Winograd algorithms. Parallel algorithms: computational models, efficiency indicators, case studies, parallel complexity classes. Non-deterministic Turing machines and the NP class. NP-completeness.

ECONOMICS AND HUMAN SCIENCES

<table>
<tr><td colspan="2">Name:
Engineering management</td><td>NEPTUN-code:
GVMMM1EANE</td><td>Number of periods/week:
full-time: 2 lec + 2 sem + 0 lab</td></tr>
<tr><td colspan="2">Credit: 5
Requirement: mid-term mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Ágnes SZEGHEGYI, Ph.D.</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
Keleti Faculty of Business and Management
Institute of Enterprise Management</td></tr>
<tr><td colspan="4">Way of assessment:
– 2 midterm test and evaluation of laboratory activity</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">Upon completion of this course students should understand and be prepared to handle the most important parts of management regarding the engineering works. Knowledge of widely accepted principles and methodology used by the developed and industrialised countries are provided. They are presented adapted to domestic conditions too so that students can apply them in practice including the rapid and flexible adaptation to environmental conditions and the ability to manage the changes. In order to meet this challenges the course contributes to the development of strategic thinking and problem solving therefore it discusses the relevant and related information on maths, informatics and decision theory.</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
Business economics</td><td>NEPTUN-code:
GSVUG1EANE</td><td>Number of periods/week:
full-time: 2 lec + 2 sem + 0 lab</td></tr>
<tr><td colspan="2">Credit: 5
Requirement: mid-term mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Imre Zoltán NAGY, Ph.D.</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
Keleti Faculty of Business and Management
Institute of Enterprise Management</td></tr>
<tr><td colspan="4">Way of assessment:
– mid-term work and theorethical mid-term exam</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">The aim of the subject is to give a short outlook on the main economic principles of business management, with a decision oriented approach. It is highlighted the macro (economic, social, knowledge) and micro environment, the main types of business entities, organizational structures. It is discussed the market mechanism, market competition from the point of view value chain concept, the principles of economic decisions (Gross Margin), cost and price calculations (cost function), the questions of resource management and primary and supporting activities (material planning, logistic, stock pile mechanism) and their relations with strategy, and business plan. The final mark is calculated by the result of the individual work (short calculations, discussion fs case studies, essay, presented during the last two weeks and the written exam).</td></tr>
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PROFESSIONAL CORE CURRICULUM

<table>
<tr><td colspan="2">Name:
Safety technology of information systems</td><td>NEPTUN-code:
NBIIB1EANE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 4
Requirement: exam</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Valéria PÓSER, Ph.D.</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Biomatics</td></tr>
<tr><td colspan="4">Way of assessment:
– requirement of signature: mid-term exam
– Oral exam. Final mark is calculated as the average of the mid-term and the exam.</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">Students will learn about the vulnaribilites of the elements of information systems, their security issues, protection methods, tools and their practical application.
Major topics that are covered: The elements of informatics systems, its sensibility. Fundamental concepts of encryption. Symmetric and asymmetric encryption methods. Hash functions. Block cipher modes of operation. Authentication of message. Internet security protocols, SSL, TLS, IPsec. Security services of operation systems. Encryption, authentication, practical realization of digital signatures. Safe correspondence and data storage (PGP), key management, the authentication of keys, encryption of letters, digital signature, disassembling. Certification problems, password-based partner authentication. Users' identification, authentication, authorization, access control. User management. Secure remote operations. Public key infrastructure, its elements and function. Firewalls, penetration detecting, protection against viruses, data loss prevention, rescue and archiving.</td></tr>
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<table>
<tr><td colspan="2">Name:
Image processing and computer graphics</td><td>NEPTUN-code:
NAISK1EANE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 4
Requirement: mid-term mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Zoltán VÁMOSSY, Ph.D.</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Informatics</td></tr>
<tr><td colspan="4">Way of assessment:
– successful home project + min. 50% in the tests written during the semester</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">Homogeneous coordinates and 3D transformations. Modeling objects. Camera models, orthographic and perspective projection. Objects in 3D projections. The imaging basics. Gray scale and color images features: resolution, histogram, etc. Typical image noises, distortions. Image enhancements, image filtering. Histogram and modification in compensation. Methods of edge detection, edge enhancement, smoothing. Line and curve detection, Hough transform. Morphological operations. Texture analysis. Frequency domain methods, FFT, DFT, filtering, deconvolution. Image segmentation. Edge and region-based methods. Detecting corner points (Harris, KLT), analyzing image regions. Invariant features, edges, texture, color, topology. PCA transformation. Camera calibration. Motion detection, object tracking. Optical flow models and calculations. SSD algorithms. Stereo methods, epipolar geometry. Model-based image processing: active contour methods, splines, ASM, AAM. Content-based image retrieval methods. Outlook for parallelization opportunities, multithreading and GPGPU implementations.</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
Database- and Big Data technologies</td><td>NEPTUN-code:
NAIAD1EANE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 4
Requirement: mid-term mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Rita Dominika FLEINER, Ph.D.</td><td>Position:
senior lecturer</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Informatics</td></tr>
<tr><td colspan="4">Way of assessment:
– mid-term exam and successful submission of homework assignment</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">During the course students learn about concepts, procedures and tools related to advanced topics of database management and big data technologies.

Topics: refreshing and deepening SQL knowledge, Oracle database architecture, Oracle instance, memory structures. Data modeling, database design, relational data model, normal forms. SQL processing. Database tuning, access paths, execution plan, index structures, join methods, CBO statistics, selectivity, costs, materialization, pipelining, query optimization. Transactions, concurrency control and recovery. Database security. NoSQL databases and types. Document stores, key-value stores, graph databases, column stores: basics, architecture, queries. CAP theorem. Hadoop framework, file system, resource management. MapReduce paradigm. Basic concepts of data analysis, forecasting, data science. Open source packages and query tools overview. Datamining techniques.</td></tr>
</table>

Name: **Parallel programing**		***NEPTUN-code:*** NAISP1EANE	***Number of periods/week:*** full-time: 2 lec + 0 sem + 2 lab
Credit: 5 ***Requirement:*** exam		***Prerequisite:*** -	
Responsible: Zoltán VÁMOSSY, Ph.D.	***Position:*** associate professor	***Faculty and Institute name:*** John von Neumann Faculty of Informatics Institute of Applied Informatics	

Way of assessment:

- precondition of signature: successful home project
- written exam

Course description:

Introduction to parallel computing and parallel computer architectures. Shared and distributed software architectures. PRAM model. Performance characteristics, Amdahl's Law and Gustafson' law. Design patterns for parallel programming (efficiency, simplicity, portability and scalability aspects). Decomposition methods by data and function, agglomeration, mappings. Parallel programming algorithms. Parallel sum and parallel prefix scan. Dense matrix algorithm. MapReduce as algorithmic framework. Sorting and search algorithms. Numerical methods. Discrete Optimization and Dynamic Programming with parallelization. Parallel programming fundamentals in practice, processes, thread management. Threading libraries: implicit (OpenMP) and explicit thread management (Windows and .NET framework threads), synchronization methods (lock, mutex, semaphore) and signaling (barriers). Debugging, tracing in parallel environment. Parallel image processing techniques. Dataparallel computing on GPGPU architectures.
Lab: solving practical tasks.

<table>
<tr><td colspan="2">Name:
Advanced software engineering</td><td>NEPTUN-code:
NAIHA0EANE</td><td>Number of periods/week:
full-time: 3 lec + 0 sem + 0 lab</td></tr>
<tr><td colspan="2">Credit: 3
Requirement: mid-term mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
József TICK, Ph.D.</td><td>Position:
associate professor, habil.</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Informatics</td></tr>
<tr><td colspan="4">Way of assessment:
- two mid-term exams</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">Formalism of the description of information technology- and software-systems, modeling, designing and developing complex information systems, desing, decomposition and integration strategies based on formal methods. Application of development tools based on information technology in the process of development. Model-based development methods of software systems, meta-model architectures, their practical application. Solutionof reverse and round-trip engineering, quality-based approach of software development, questions of quality, data security, secure code. Verification, validation and testing of software systems. Aspect-oriented software development. Process models of software development, effective application of agile approach (Scrum, Lean and Kanban).</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
High Availability Embedded Systems</td><td>NEPTUN-code:
NAIMI1EANE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 1 lab</td></tr>
<tr><td colspan="2">Credit: 4
Requirement: mid-term mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
András MOLNÁR, Ph.D.</td><td>Position:
associate professor, habil.</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Informatics</td></tr>
<tr><td colspan="4">Way of assessment:
- mid-term exam
- oral exam</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">During the course, the students will get knowledge about the theoretical and practical problems of highly reliable embedded systems and the possible solutions of these problems. Through the evolution of microcontrollers, the known architectures, controller peripheries, communication possibilities and other typical properties will be explained on the theoretical course. The hardware and software redundancy is a highlighted field on this course.</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
Cloud computing systems</td><td>NEPTUN-code:
NAICC1EANE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 4
Requirement: exam</td><td colspan="2">Prerequisite:
NAISP1EANE Parallel programming</td></tr>
<tr><td>Responsible:
Róbert LOVAS, Ph.D.</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Informatics</td></tr>
<tr><td colspan="4">Way of assessment:
- midterm exams
- successful submission of a homework assignment and its presentation</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">The advanced level course concentrates on the system level theory, the design challenges, and the most significant practical realisations of computational clouds, as a middleware, particularly based on open-source practices (OpenStack) and focusing on the Infrastructure-as-a-Service solutions. The course provides a short overview on theoretical and practical knowledge concerning public, private, and hybrid clouds from the aspects of users, system engineers, and operators. The students get acquainted with the types of services (IaaS/PaaS/Saas) offered by clouds, and the main characteristics of their implementations, as well as their typical solutions. Some selected components of cloud, as a middleware, are discussed in details; starting from the block and object stores (e.g. Cinder/Swift), through the components responsible for the authentication (e.g. Keystone), ending with the telemetry and orchestration tools (e.g. Ceilometer/Heat). In the field of platform services, the students get a short overview on the cloud based deployments and use cases of Big Data tools.</td></tr>
</table>

SPECIALIZATION

BIOMEDICAL ENGINEERING

<table>
<tr><td colspan="2">Name:
Application of biostatistical methods</td><td>NEPTUN-code:
NBIBS1EONE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 5
Requirement: exam</td><td colspan="2">Prerequisite:
Algorithm theory</td></tr>
<tr><td>Responsible:
Levente KOVÁCS, Ph.D.</td><td>Position:
professor, habil</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Biomatics</td></tr>
<tr><td colspan="4">Way of assessment:
– regular homeworks
– written exam</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">Introduction to biostatitics. Steps of modeling in physiology, pathophysiology. Computer program sin biostatistics. Descriptive statistics, analytical and graphical tools. Inferential statistics, estimation and hypothesis testing. Regression modeling and multivariate statistics. Advanced regression modeling (generalized linear models). Time series analysis and spatial methods.</td></tr>
</table>

Tárgyneve: **Sensory modalities**		*NEPTUN-code:* NBISZ1EONE	*Number of periods/week:* full-time: 2 lec + 0 sem+1 lab
Credit: 4 ***Requirement:*** mid-term mark		***Prerequisite:***	
Responsible: Miklós KOZLOVSZKY, Ph.D.	***Position:*** associate professor	***Kar ésintézetneve:*** John von Neumann Faculty of Informatics Institute of Biomatics	
Way of assessment: –			
Course description:			
The several different types of remote monitoring sensors that are used in healthcare and their measurement characteristics will be discussed in the course. The aim is to improve the students 'problem solving and modeling ability in remote health monitoring by giving appropriate engineering viewpoint and the guidelines for the correct application of information technology tools.			

<table>
<tr><td colspan="2">Name:
Diagnostic medical imaging</td><td>NEPTUN-code:
NBICO1EONE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 4
Requirement: exam</td><td colspan="2">Prerequisite:
Image processing and computer graphics</td></tr>
<tr><td>Responsible:
Miklós KOZLOVSZKY, Ph.D.</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Biomatics</td></tr>
<tr><td colspan="4">Way of assessment:
– mid-term exam (with one retake possibility)
– Written exam. Final mark is calculated as the average of the mid-term and the exam.</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">The course focuses on the properties of the diagnostic medical imaging systems (X-ray, computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), ultrasound (US), optical coherence tomography (OCT), digital subtraction angiography (DSA), infrared thermography, high-resolution digital microscopy). It gives an overall picture about the modalities, the possibilities of reducing the errors, and the fusion of different modalities. It also discusses the infrastructure and methods to process the large datastructures created by such imaging methods.</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
IT security of health care systems</td><td>NEPTUN-code:
NBIEI1EONE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 1 lab</td></tr>
<tr><td colspan="2">Credit: 3
Requirement: mid-term mark</td><td colspan="2">Prerequisite:
Safety technology of information systems</td></tr>
<tr><td>Responsible:
Valéria PÓSER, Ph.D.</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Biomatics</td></tr>
<tr><td colspan="4">Way of assessment:
– mid-term exams</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">The information technology tasks of the health care, special data. Information systems in healthcare. The special defensive requirements in the health care, regulations, standards, recommendations. The qualification of the information systems and services. Data management, data rescue and data storage, Data Loss Prevention. The safety of health care databases, data storage. System management, the uniform version control of the software. Access control, data transfer, data integration. Mobility, remote access, gateway between the information systems of family doctor and hospital. The techniques of network security in the public health. National Health Information System.</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
Basics of evidence based-medicine</td><td>NEPTUN-code:
NBIEB1EONE</td><td>Number of periods/week:
full-time: 1 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 4
Requirement: exam</td><td colspan="2">Prerequisite:
NBIRI1EANE System- and control theory</td></tr>
<tr><td>Responsible:
Tamás FERENCI, Ph.D.</td><td>Position:
senior lecturer</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Biomatics</td></tr>
<tr><td colspan="4">Way of assessment:
– written exam</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">Evidence based medicine (EBM) is a highly influential concept of modern medicine and healthcare. The core idea of EBM is to base clinical decision making – both in diagnostics and therapy – to the best available so-called evidences (in best case, on the results of several carefully designed, large-sample randomized clinical trials). This involves the questions of aggregating such results (with mathematical tools), calculation of costs and benefits based on this, which will enable the guidence – or at least support of – the clinical decision making. The aim of the course is to provide insight into evidence based medicine, and those fields that are necessary in the practice of EBM. In particular, the course will have special emphasis on epidemiology.</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
Cloud based IoT and Big Data platforms</td><td>NEPTUN-code:
NAIFB1EONE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 5
Requirement: exam</td><td colspan="2">Prerequisite:
NBISZ1EONE Sensory Modalities</td></tr>
<tr><td>Responsible:
Róbert LOVAS, Ph.D.</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Informatics</td></tr>
<tr><td colspan="4">Way of assessment:
– midterm exam (with one retake possibility) and successful submission of a homework assignement
– Written exam. Final mark is calculated as the average of the midterm and the exam.</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">The course introduces the services, the architecture, the technologies, the operational mechanisms and the use of distributed and parallel IT platforms based on cloud computing, and focusing on their Big Data and IoT (Internet of Things) application areas. The course discusses the evolution and characteristics of Platform-as-a-Services (PaaS) widely adopted in the typical research and industrial environments. The course covers the theoretical and practical backgrounds of cloud based IoT and Big Data application areas for medical purposes (e.g. workflow and orchestration approaches). The knowledge is to improve the students' problem solving and model creation skills concerning parallel and distributed computing by applying engineering approach, and the most advanced IT platforms and methods in the appropriate way for addressing medical application areas.</td></tr>
</table>

ROBOTICS

Name: **Machine intelligence**		***NEPTUN-code:*** NAMGI1ERNE	***Number of periods/week:*** full-time: 3 lec + 0 sem + 0 lab
Credit: 4 ***Requirement:*** exam		***Prerequisite:*** -	
Responsible: Márta TAKÁCS, Ph.D.	***Position:*** associate professor	***Faculty and Institute name:*** John von Neumann Faculty of Informatics Institute of Applied Mathematics	
Way of assessment: – written exam			
Course description:			
Fuzzy sets, fuzzy quantitites, fuzzy numbers. Triangular norms. Triangular conorms. Operations of fuzzy sets. Linguistic variables. Fuzzy implication operators. Zadeh extension principle. Possibility and necessity. Averaging operators. Compositional rule of implication. Simplied fuzzy inference. Neural networks. Perceptron learning rule. Delta learning rule with linear transfer function. Delta learning rule with semilinear transfer function. Generalized delta rule. Kohonen's rule. Approximation capability of multilayer neural networks. Fuzzy neural networks. Approximating functions with fuzzy neural networks. Fine tuning shape parameters of fuzzy sets with neural networks. ANFIS architecture for the Takagi-Sugeno scheme. Sensitivity analysis of fuzzy neural networks.			

<table>
<tr><td colspan="2">Name:
Programming of robot systems</td><td>NEPTUN-code:
NBIRP1ERNE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 4
Requirement: exam</td><td colspan="2">Prerequisite:
Szoftverfejlesztés párhuzamos architektúrákra</td></tr>
<tr><td>Responsible:
Péter GALAMBOS, Ph.D.</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Biomatics</td></tr>
<tr><td colspan="4">Way of assessment:
- signature: successful submission of assignments
- oral exam</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">Goal of the course is to give an insight to the programming paradigms of industrial and service robot systems along modern approaches. Besides the conventional robot programming languages (e.g., FANUC TP, RAPID), theory and practice of distributed, component-based software frameworks (RT-Middleware, ROS) are espacially focused during the classes thrugh practical exampples. The course introduces the basics of offline
robot programming and touches the 3D VR-based testing and system integration environments. Through the laboratory activities, special emhasise is laid on the real work with industrial and service robotic systems e.g., FANUC industrial robots, NAO humanoid robots, DaVinci surgical robot system, KUKA youbot.</td></tr>
</table>

Name: **Kinematics and dynamics of industrial robots**		*NEPTUN-code:* NBIIK1ERNE	*Number of periods/week:* full-time: 2 lec + 0 sem + 2 lab
Credit: 4 *Requirement:* exam		*Prerequisite:* NAIMI1EANE High Availability Embedded Systems	
Responsible: József TAR, Ph.D.	*Position:* professor, habil.	*Faculty and Institute name:* John von Neumann Faculty of Informatics Institute of Applied Mathematics	

Way of assessment:

- either oral exam or solving a numerical task

Course description:

The goal is to provide the Students with the mathematical foundations that are needed for the efficient description of open kinematic chains and tackling forward and inverse kinematic problems.

Kinematics: The Special Euclidean group: translations and rotations, the fundamental operations that can be done with rigid bodies. Definition of the open kinematic chain. Denavit – Hartenberg conventions, rotation around a given axis, roration around rotating axles. Definition of the invesrse kinematic task. Special structures having closed-form analytical solution. Differential inverse kinematics: singularities and redundancies; Moore-Penrose Pseudo-inverse, SVD, SVD-based pseudo-inverse, Gram-Schmidt Algorithm; Application of Fixed Point transformations in solving inverse kinematic tasks;

Dynamics: Expression of the kinetic energy by the use of the homogeneous matrices. Variational Principle, Euler-Lagrange equations of motion; Generalized forces and their measuring possibilities, physical possibilities for motion control; the robot-environment dynamic interaction, contact forces, friction models (static and dynamic ones) and their effects.

<table>
<tr><td colspan="2">Name:
Service robots. Medical robotics</td><td>NEPTUN-code:
NBICI1ERNE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 0 lab</td></tr>
<tr><td>Credit: 3
Requirement: exam</td><td colspan="3">Prerequisite:
NBIIK1ERNE Kinematics and dynamics of industrial robots</td></tr>
<tr><td>Responsible:
Tamás HAIDEGGER, Ph.D.</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Biomatics</td></tr>
<tr><td colspan="4">Way of assessment:
– mid-term exam
– written and oral exam</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">Robotics, and service robotics within are the most rapidly developing technological areas, and according to the predictions, there will be a service robot in every household by 2020. Moreover, most of the Y generation will have a robotic surgery during their lifetime. The structure, kinematics, control methods and application challeneges of service robots are completely different that of the industrial ones, therefore special attention should be paid to these.
Topics of the course: Human-centerd robotics: introduction to service applications. Special application requirements, control theory and safety issues. Standardization of medical robots, their use in hospital and home care. Automating the basic tasks around a human patient. Design and impementation of safe medicalrobots. The patient as operator, human-machine interfaces. Safe manipulation techniques in the close proximity of the human, the role of navigation. Employment of accurate patient data, medical images and diagnostics for medical robots. Safety-driven design and validation of systems.</td></tr>
</table>

Name: **Control theory in robotics**		***NEPTUN-code:*** NBIRI2ERNE	***Number of periods/week:*** full-time: 1 lec + 0 sem+ 1 lab
Credit: 3 ***Requirement:*** mid-term mark		***Prerequisite:*** NBIRI1EANE System- and control theory	
Responsible: József TAR, Ph.D.	***Position:*** professor, habil.	***Faculty and Institute name:*** John von Neumann Faculty of Informatics Institute of Applied Mathematics	

Way of assessment:

- either oral exam or solving a numerical task

Course description:

The goal is to provide the Students with the dynamic robot control methods of fundamenal significance for the robots of open kinematic chain.

Control method based on the possession of the exact dynamic model: Computed Torque Control. Robust control: the Variable Structure/Sliding Mode Controller. Adaptive control methods usin inaccurate initial dynamic models: Lyapunovs stability definitions. Lyapunov's „2nd or Direct" method and classical examples: Adaptive Inverse Dynamics Controller, Adaptive Slotine-Li Controller. Alternatives of the use of Lyapunov functions in adaptive control: Banach's Fixed Point Theorem, The „Robust Fixed Point Transformaton-based Adaptive Controller", Novel Fixed Point Transformations and their convergence properties; Modification and combination of the Classical Adaptive Controllers with the Fixed Point Transformation-based control; The Model Reference Adaptive Control using Fixed Point Transformations.

<table>
<tr><td colspan="2">Name:
Intelligent development tools</td><td>NEPTUN-code:
NAMIF1ERNE</td><td>Number of periods/week:
full-time: 0 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 3
Requirement: mid-term mark</td><td colspan="2">Prerequisite:
NAMIK1EANE Information- and coding theory</td></tr>
<tr><td>Responsible:
József TAR, Ph.D.</td><td>Position:
professor, habil.</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4">Way of assessment:
– solving a chosen task (submission of program, documentation, presentation and presenting the results)</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">The aim is to provide the Students with modern and efficient development tools that can help them in solving various mathematical and technical problems, and in the presentation of their results.
Besides mentioning the Computer Algebra Systems (CAS), numerical methods, statistical computations and their automation and visualization of the results are discussed and exemplified.
Softwares to be used: LaTeX, bash, awk, gnuplot, Wolfram Alpha, Maxima, Octave, FreeMath, R, Scilab, Atom – Julia.</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
Modeling and design</td><td>NEPTUN-code:
NBIBS1ERNE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 4
Requirement: mid-term mark</td><td colspan="2">Prerequisite:
NAMGI1ERNE Machine intelligence</td></tr>
<tr><td>Responsible:
László HORVÁTH, Ph.D.</td><td>Position:
professor, habil.</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4">Way of assessment:
– informatical design of an engineering model in a demanding industrial modeling system and its presentation</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">Course introduces and explains modeling, simulation, knowledge technology, and systemic principles and methods from leading industrial practice. Main emphases are on active generic models based on knowledge representation and context chains and representation of product structures as multidisciplinary systems. Topics are: Virtual world for engineers. Representation of shape in product model. Connections between model entities. Representation of geometry. Definition and analysis of product behavior. Human and computer. Cross-disciplinary definition. Connection between real and virtual world objects. Representation of engineering knowledge. Modeling product as system, RFLP Structure. Modeling of robot systems. Functional modeling of shape. Life cycle management of models.</td></tr>
</table>

MOBILE APPLICATION AND GAME DEVELOPMENT

<table>
<tr><td colspan="2">Name:
Mobile applications I.</td><td>NEPTUN-code:</td><td>Number of periods/week:
full-time 1 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 4
Requirement: mid-term mark</td><td colspan="2">Prerequisite:</td></tr>
<tr><td>Responsible:
Éva Hajnal Ph.D.</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
Alba Regia Technical Faculty</td></tr>
<tr><td colspan="4">Way of assessment:
– regular homeworks
– written tests</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">An introduction to Linux microoperating systems. An introduction to the design and analysis of mobile applications that covers the architecture of mobile devices, APIs for graphical user interfaces on mobile devices, location-aware computing and social networking. The course also covers the theory and practice of space and time optimization for these relatively small and slow devices.</td></tr>
</table>

Name: **Software tools of game development**		***NEPTUN-code:***	***Number of periods/week:*** full-time: 2 lec + 0 sem + 3 lab
Credit: 5 ***Requirement:*** exam		***Prerequisite:***	
Responsible: Éva Hajnal Ph.D	***Position:*** associate professor	***Faculty and Institute name:*** Alba Regia Technical Faculty	
Way of assessment: – regular homeworks – written tests			
Course description:			
Usage and software solutions for modern peripherals (Kinect sensor, leap motion etc.). Virtual reality and extended reality. Immersion systems and the role of the immersion. Reality. Rendering in VR. Graphics and visualization. Audio- and haptic representation. Homogeneous transformations. Interactions with virtual world. Manipulation, Navigation. Collaborations. Physical modeling. Collision detection. Deformations. Calculations of forces. Connection between virtual and real physics. Extended reality systems. Information layer. Pasting virtual elements into the reality and real elements into the virtual reality. Image based modelling, 3D reconstruction. VR standards. Network, internet solutions. Human factor. Health problems. VR sickness. Good practices.			

<table>
<tr><td colspan="2">Name:
Devices of mobile and computer games</td><td>NEPTUN-code:</td><td>Number of periods/week:
full-time: 1lec + 0 sem + 0 lab</td></tr>
<tr><td colspan="2">Credit: 2
Requirement: exam</td><td colspan="2">Prerequisite:</td></tr>
<tr><td>Responsible:
György Györök Ph.D habil</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
Alba Regia Technical Faculty</td></tr>
<tr><td colspan="4">Way of assessment:
– written or oral exam</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">In this subject the students study about the structure and operation of sensors of mobile devices and the devices are used in the modern computer game industry (Kinect sensor, leap motion detector, VR devices). Input devices – input gloves. Output devices. 3D visualization tools. 3D flat panel displays. Glasses. Holography. Audio devices. IoT devices used in games and in mobile applications.</td></tr>
</table>

Name: **Multiplatform graphical applications**	***NEPTUN-code:***	***Number of periods/week:*** full-time: 1 lec + 0 sem + 2 lab
Credit: 3 ***Requirement:*** mid-term-mark	***Prerequisite:***	
Responsible: Éva Hajnal Ph.D	***Position:*** associate professor	***Faculty and Institute name:*** Alba Regia Technical Faculty
Way of assessment: – regular homeworks – written tests		

Course description:

The students get acquainted with Unity (XNA) and other multiplatform development framework, its software basics and they get practice in it.
Surface properties, physical attributes. Connection between the physical simulation and visualization.
The elements of the graphics pipeline and its operation. Resources, memory handling.
Graphics card controlling with DirectX. Shaders.
Animations. Water surface and terrain. Particle systems and nets. HDRI, software simulation of depth of field.
Graphics card controlling from the console.
Object oriented structure of game motors. PhysX. Case study: game development.

Name: **Mobile applications II.**		***NEPTUN-code:***	***Number of periods/week:*** full-time: 0 lec + 0 sem + 2 lab
Credit: 2 ***Requirement:*** mid-term-mark		***Prerequisite:*** **Mobile applications I.**	
Responsible: Éva Hajnal Ph.D.	***Position:*** associate professor	***Faculty and Institute name:*** Alba Regia Technical Faculty Institute of Engineering	
Way of assessment: – regular homeworks – written tests			
Course description:			
The main purpose of this subject is to show the main policy and formation of engineering approach in this field. The subject was based on typical market projects showing their good practices and pitfalls. From specification to test and code development all step are examined including the field of communication protocols. The students will learn about multiplatform mobile software development technics. At the end of the lecture the students will be able to develop professional mobile applications.			

OPTIONAL SUBJECTS

<table>
<tr><td colspan="2">Name:
Simulation methods</td><td>NEPTUN-code:
NAMSM1EVNE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 0 lab</td></tr>
<tr><td colspan="2">Credit: 2
Requirement: exam</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
József TAR, Ph.D.</td><td>Position:
professor, habil.</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4">Way of assessment:
– either oral exam or solving a numerical task</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">The mathematical problems that typically arise in nonlinear control theory normally do not have closed-form analytical solutions. The use of numerical techniques is inevitable in this subject area. The main aim of the course is to provide the Students with the information on using legally free software packages for this purpose that are independent of any licenses owned by the University as e.g. MATLAB-Simulink licence. The use of these packages is illustrated by solving nonlinear control tasks.</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
Information Systems Audit</td><td>NEPTUN-code:
NAIIA1EVNE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 0 lab</td></tr>
<tr><td colspan="2">Credit: 2
Requirement: exam</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Valéria PÓSER, Ph.D.</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Biomatics</td></tr>
<tr><td colspan="4">Way of assessment:
– written and/or oral exam</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">IT is regularly audited both in the government and in the business sector. It is especially important, if the IT of such critical infrastructures, as e.g. the financial sector, and the energy sector is compliant to the laws, government decrees and European Union directives. From the viewpoint of the owners / mother companies an emphasized viewpoint is the quality of the support of the institutional strategy, too.
Every member of the IT staff, even the developers of either data processing applications or those of the embedded systems have to be prepared to participate in such audit interviews, that explore if their results effectively support governance, together with such information quality criteria, as those of the ISACA (Information Systems Audit and Control Association), and those of the ISO (International Standard Organization). The goal of subject Information System Audit is to support them in complying the audit requirements.</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
Product Development of Medical Equipment</td><td>NEPTUN-code:
NBIOKGEVNE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 2
Requirement: mid-term mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Levente KOVÁCS, Ph.D.</td><td>Position:
professor, habil.</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Biomatics</td></tr>
<tr><td colspan="4">Way of assessment:
– two mid-term exams</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">Development of medical devices is a difficult task with several quality requirements. The lecture dedicates on this aspect presenting the basic system and sowtware development issues not accesible in the Eastern European region. Topics of of the lecture contain the normative rules of the EU, manufacturers' quality system, risk assessment, the PEMS lifecycle model, the PEMS embedded system development, device verification, validation and usability settings, the MediSPICE system.</td></tr>
</table>