COMPUTER SCIENCE, MASTER STUDY PROGRAMME,
SECOND BOLOGNA CYCLE

COURSE DESCRIPTIONS

BASIC COURSES
(Read the short descriptions of all basic courses of the study programme. In the table Basic courses you will find the list of the elective courses which were offered in the last two years.)

Course name: SELECTED TOPICS IN THEORETICAL COMPUTER SCIENCE
Number of ECTS credits: 6

Content:
Models of computing. Finite automata, stack machines and their properties; corresponding formal languages with their properties. Computability and undecidability. Nondeterminism and NP completeness. Samples of NP complete problems. Lower space and time bounds. Time and space complexity classes and relations among them. Student also prepares a seminar in a form of survey paper or smaller practical project.

Course name: THEORY OF PROGRAMMING LANGUAGES
Number of ECTS credits: 6

Content:

Course name: SELECTED TOPICS IN THEORY OF ALGORITHMS
Number of ECTS credits: 6

Content:
Models of computation, NP completeness. Word-size parallelism and transdichotomous model of computation. Linear programming. Approximative and probabilistic algorithms. Competitive algorithms and online algorithms. Parallel algorithms and algorithms for distributed systems – algorithms for computer networks (P2P etc.). Student also prepares a seminar in a form of survey paper or smaller practical project.
Course name: **SYSTEM DYNAMICS**  
Number of ECTS credits: 6

**Content:**  
A chronological and structural overview of system theories and its variants. System dynamics: basic definitions, variables, interactions, basic patterns of complex systems. Modeling complex systems, problem articulation, hypothesis, model definitions, testing, evaluation. Causal loop diagrams – from qualitative to quantitative modeling, understanding specific nature of certain variables, knowledge of adapted modeling approaches, knowledge of mathematical instrumentarium. Typical patterns of complex systems and their models. Simulations and study of practical, real-world examples. Seminal work – a small project or short a research paper.

Course name: **INTELLIGENT SYSTEMS**  
Number of ECTS credits: 6

**Content:**  
Topics covered (including subtopics):  
- Fundamental Issues [core*]  
- Basic Search Strategies [core]  
- Knowledge Based Reasoning [core]  
- Advanced Search [elective*]  
- Advanced Reasoning [elective]  
- Agents [elective]  
- Natural Language Processing [elective]  
- Machine Learning [elective]  
- Planning Systems [elective]  
- Robotics [elective]  
- Perception [elective]

*There are 3 core topics that form the basis and 8 elective topics of which 3 will be covered in this course. These 3 elective topics will be selected each year following the current research directions.

Course name: **APPLIED STATISTICS**  
Number of ECTS credits: 6

**Content:**  

Course name: **SELECTED TOPICS IN INFORMATION SYSTEMS**  
Number of ECTS credits: 6

**Content:**  
Course name: **SELECTED TOPICS IN SOFTWARE ENGINEERING**  
Number of ECTS credits: **6**

**Content:**
- Software process and software process frameworks  
- Software product development technologies: computer aided software engineering (CASE), software product line engineering, development of software products based on testing.  
- Software product planning:  
  - Division strategies of software system to software components.  
  - Architectural patterns  
  - Design patterns  
  - Software component interfaces and software integration.  
- Software maintenance and evolution, re-engineering and reverse engineering.  
- An example of complex software system development.

**ELECTIVE COURSES**  
*(Read the short descriptions of all elective courses of the study programme. In the table Elective courses you will find the list of the elective courses which were offered in the last two years.)*

Course name: **GRAPH ALGORITHMS**  
Number of ECTS credits: **6**

**Content:**  

Course name: **ALGORITHM ENGINEERING IN COMPUTER COMMUNICATIONS**  
Number of ECTS credits: **6**

**Content:**  
Equipment in computer communications and embedded systems. Algorithms used in computer networks. Protocols in Internet. Processing of individual packets: classification, quality of service (QoS), firewalls. Modelling and monitoring of a traffic in Internet. Student also prepares a seminar in a form of survey paper or smaller practical project.

Course name: **APPLICATIONS OF ARTIFICIAL INTELLIGENCE**  
Number of ECTS credits: **6**

**Content:**  
Intelligent systems. Description of typical intelligent system structure and examples of intelligent systems in computer science. Machine learning techniques. Description of basic and advance

Course name: **BIOMETRIC TECHNOLOGIES**  
Number of ECTS credits: **6**

**Content:**
Introduction to Biometrics:
- Basic pattern recognition and machine learning principles and methods.
- Feature extraction and machine learning methods in biometric systems.
- Basic principles in biometric recognition: verification and identification.

Overview of biometric systems:
- fingerprint recognition,
- hand geometry and palm recognition,
- face recognition,
- signature verification,
- voice biometrics: speaker identification and verification,
- multi-modal biometric approaches.

Case study: Development of a speaker verification system by using speech technologies

Course name: **SPOKEN LANGUAGE TECHNOLOGIES**  
Number of ECTS credits: **6**

**Content:**
Overview of pattern recognition techniques and signal processing methods in spoken language technologies.

Speech recognition:
- speech signal feature extraction: hidden Markov models, HMMs,  
development of speech recognition system based on HMMs  
Overview of speech recognition development tools: Sphinx3,4, HTK  
Development of a simple speech recognizer for digit recognition

Language modeling for speech recognition:  
- rule-based language models,  
- statistical language models: n-grams,  
- Overview of language modeling tools.

Speech synthesis:  
- basic concepts of speech synthesis  
different speech synthesis systems: TD/FD PSOLA, HMM-based, corpus-based  
Overview of speech synthesis development tools: Festival speech synthesis system, HTS

Speaker recognition
- overview of speaker identification and verification systems,  
UBM-MAP-SVM based speaker recognition system: GMM, adaptation techniques MAP, support
Course name: VECTOR MACHINES, SVM,
- score normalization methods: z-norm, t-norm
- development of a speaker-verification system

Course name: IMPLEMENTATION OF DATABASE MANAGEMENT SYSTEMS
Number of ECTS credits: 6

Content:
- Disks and files.
- Indexes.
- Caches.
- Sorting.
- Relational storage manager.
- Triple-stores.
- Graf database management systems.
- Evaluation of operations in database systems.
- Query optimization.
- Concurrency control.
- Crash recovery.
- Web of data.

Course name: SELECTED TOPICS IN CRYPTOGRAPHY
Number of ECTS credits: 6

Content:

Course name: SELECTED TOPICS IN IMAGE PROCESSING
Number of ECTS credits: 6

Content:

Course name: SELECTED TOPICS IN DATA STRUCTURES
Number of ECTS credits: 6

Content:
Course name: **SELECTED TOPICS IN DISTRIBUTED COMPUTING**  
Number of ECTS credits: **6**

**Content:**  
Models for distributed computing. Algorithms for distributed environments – algorithms useful in computer networks (P2P etc.). Technologies for distributed computing: distributed memory, object oriented distributed system design, distributed dictionary, un-interruptability and time synchronization, distributed scheduling and process migration, remote function calls and method invocation, robustness, security. Distributed services and tools. Student also prepares a seminar in a form of survey paper or smaller practical project.

Course name: **SELECTED TOPICS IN PARALLEL PROGRAMMING**  
Number of ECTS credits: **6**

**Content:**
- Introduction to parallel programming.  
  - Renewal of basic concepts of parallel and distributed programming.  
- Introduction to modern parallel systems.  
  - General-purpose computing on graphics processing units (GPGPU) computer systems, which enable parallel computing.  
- Review of different approaches.  
  - Compute Unified Device Architecture (CUDA), Open Computing Language (OpenCL) …  
- A more detailed understanding of OpenCL.  
  - OpenCL framework for writing programs that can be executed on different heterogeneous platforms.  
- Optimization of programs.  
  - To take full advantage of GPGPU computer system.  
- Application.  
  - Implementation of simple programs on a GPGPU computer system.  
- Examples of real-world problems.  
  - Studying and implementation of real-world problems.

Course name: **LINEAR PROGRAMMING WITH APPLICATIONS**  
Number of ECTS credits: **6**

**Content:**  

Course name: **METAHEURISTIC OPTIMIZATION ALGORITHMS**  
Number of ECTS credits: **6**

**Content:**  
general combinatorial and numerical optimization problem. Travelling salesman problem, graph partitioning, multi-parametric numerical functions, and various industrial applications. Evaluation of results. A statistical approach, performance measures, and presentation of results. Metaheuristics in multi-objective optimization. Application aspects. Hybridization and parallelization of algorithms. During the course the student prepares a course work, which is in a form of an overview paper and small project.

Course name: **INTRODUCTION TO BIOINFORMATICS**  
Number of ECTS credits: **6**

**Content:**  

Course name: **DATA MODELS AND LANGUAGES**  
Number of ECTS credits: **6**

**Content:**  

Course name: **DATA MINING ON THE WORLD WIDE WEB**  
Number of ECTS credits: **6**

**Content:**  

Course name: **PROCESSOR ARCHITECTURE**  
Number of ECTS credits: **6**

**Content:**  
Processors with reduced instruction set. Computing model: static, dynamic. Processors with complex instruction set. Superscalar processors. VLIW in EPIC processors. Processors to use fine-grain parallelism. Processors to use coarse-grain parallelism. Reconfigurable and asynchronous processors. A student has to prepare course work, which may be in the form of a review paper or a small project.
Course name: COMPUTER SECURITY
Number of ECTS credits: 6

Content:

Course name: COMPUTER VISION
Number of ECTS credits: 6

Content:
Introduction with overview of computer vision applications areas and basic terminology. Image acquisition; scene, illumination, cameras, image sensors, optics, lens distortions. Color spaces and color recognition. Image preprocessing. Basic algorithms for image processing and analysis; edge detection, corner detection, shape detection, morphology. Image features for pattern recognition. Geometric transformations. Specifics of computer vision in medicine; 3D and 4D images. Examples of computer vision applications.

Course name: STATISTICAL MODELLING
Number of ECTS credits: 6

Content:

Course name: TELECOMMUNICATION NETWORKS
Number of ECTS credits: 6

Content:
- Overview of TCP/IP technology
- Basis of classical telephony
- Future telecommunication networks
- Detail overview of VoIP technology and quality of voice
- Detail overview of protocols in future telecommunication networks
- Multimedia
Course name: **CODING THEORY**  
Number of ECTS credits: **6**

**Content:**  
The course covers the most important topics in coding theory, that includes (among others) the topics below:

- mathematical basics (groups, rings, ideals, vector spaces, finite fields)
- basic concepts in coding theory
- algebraic methods for construction of error-correcting codes
- Hamming codes
- Linear codes
- Binary Golay codes
- Cyclic codes
- BCH codes
- Reed-Solomon codes
- Bounds (Hamming, Singleton, Johnsson bound, ...)

Course name: **APPLIED BIOINFORMATICS**  
Number of ECTS credits: **6**

**Content:**  

Course name: **SELECTED TOPICS IN HUMAN-COMPUTER INTERACTION**  
Number of ECTS credits: **6**

**Content:**  
Classical and modern research topics in the field of human-computer interaction. Possible topics include:

- Basics of human-computer interaction
- Mental models
- User modeling
- User error in critical systems.
- Navigation (multiple displays, infinite canvas, information space).
- Tasks analysis and contextual design.
- User based evaluation of the system or product.
- 3D GUI
- Direct manipulation.
- Prticipatory practices.
- Prototyping.
- Design of menues.
- Virtual envoironments.
- Information visualisation.
- Augmented reality.
Course name: RESEARCH AND INNOVATION IN PRACTICE
Number of ECTS credits: 6

Content:
- Research Methods: Quantitative methods, Qualitative methods and Experimental Computer Science
- Understanding Innovation
- Modern methodologies
- The Power of the Lean Method
- Lean Software Development Principles
- Agile Methodology and Agile engineering
- The Benefits of Agile Software Development
- Examples of using modern methodologies in practice.

Course name: SELECTED TOPICS IN INTELLIGENT SYSTEMS APPLICATIONS
Number of ECTS credits: 6

Content:
Intelligent Systems:
- as Intelligent Tutoring Systems
- for Computer Networks and Web Technologies
- for Data Mining, Big Data and Information Retrieval
- in medicine and bioinformatics
- as Intelligent Transportation Systems
- and robots for hazardous environments
- and robots for rehabilitation.

Course name: SELECTED TOPICS IN INFORMATION VISUALISATION
Number of ECTS credits: 6

Content:
Classical and modern research topics in the field of information visualisation. Possible topics include:
- appropriate allocation of visual attributes to data variables,
- designing with color and luminance contrast,
- the psychology of human vision and perception,
- visual analytics,
- interaction,
- storytelling,
- text visual analytics,
- big data visualization,
- uncertainty visualization,
- network visualization,
- cartographic visualization,
- animation and time series visualization.

Course name: SELECTED TOPICS IN FROM DATABASE SYSTEMS
Number of ECTS credits: 6

Content:
1. Distributed database systems.
Relational model; architectures of distributed database systems; shared-nothing architecture; range/hash/block partitioning; partition assignment; degree of declustering; collocation; replication; query processing; coordination task; intra- and inter-operation parallelism; parallel joins; semi-joins; partitioned and pipelined parallelism; query optimization; partition pruning; data shipping; scheduling.

2. Columnar database systems.
Column-oriented data model; MonetDB; C-Store; Vertica; storage layouts; column-oriented compression; delta storage; data updates; columnar algebra; vectorized processing; late materialization.

3. MapReduce systems.
MapReduce model; Hadoop; distributed file systems; HDFS; Google file system; MapReduce programs: joins, sorting; high-level systems: Pig, Hive, Hbase.

4. Graph database systems.
Graph data model; RDF, RDF-Schema, SPARQL; graph storage-systems; SPO-indexes; RDF-3X indexes, Virtuoso indexes; vertical/horizontal storage layout; graph partitioning algorithms; central/distributed storage systems; cache usage; main-memory storage systems; graph algebra; query processing; data and ontology level inference; query optimization.

5. Dataflow systems.
Data-intensive analytics; extended MapReduce model; dataflow system stack; Google stack: GFS, Bigtable, Pregel, Dremel, Tenzing; storage system: distributed FS, wide or nested-columnar, in-memory storage; computational model: computational vertices and communicational edges; computation structures: trees, DAGs, directed graphs; query interface: domain-specific, functional or declarative; query optimization: static, dynamic, heuristic.