
The topics of the entrance exam of the Doctoral School of Informatics

Valid from 2023

Algorithms and data structures

Sorting algorithms (selection sort, insertion sort, heap sort, quick sort). Binary search trees. Problem-solving strategies (greedy algorithms, dynamic programming). Graph algorithms (breadth first and depth first search, topological sorting, strongly connected components, minimum spanning trees, shortest path).

Automata and formal languages

Regular languages and finite automata. Context-free languages and pushdown automata. Pumping lemmas, closure properties and decision questions for classes of languages. The Chomsky Hierarchy. Equivalence of general grammars and Turing machines.

Theory of computability and complexity of algorithms

Turing machines and their equivalence with other computational models. The Church-Turing thesis. Recursive, recursively enumerable and undecidable problems. Time and space complexity of algorithms on RAM machines and Turing machines. Nondeterminism. Time and space complexity classes, basic relationships among them. The classes P and NP, the Cobham-Edmonds thesis. Reducibility, completeness, NP-complete problems. The PSPACE, L, and NL classes.

Logic in Computer Science

Basic concepts of first-order logic. Skolem normal form. The compactness theorem. Resolution method in first-order logic: ground resolution and first-order resolution. Foundation of logic programming.

Operations research

Linear programming problem and its relationship with convex polyhedra. Different versions of the simplex algorithm. Duality. Integer programming. Assignment and transportation problems. Nonlinear programming.

Approximate calculations

Error types, the basic task of error calculation, number representation, rounding. Numerical stability, conditioning. Direct and iterative methods of systems of linear equations. Convergence of the latter. The conjugate gradient method. Computer procedures for determining eigenvalues, LR method, power method. Function approximations, interpolation, spline. Newton method. Quadrature formulas, numerical integration, finite differences. Accuracy order of quadrature formulas. Numerical derivative, automatic differentiation, interval arithmetic.

Computer graphics

Graphical primitives, their display, clipping. Filling and clipping of area primitives. Curves and surfaces, splines. 3-D rendering, masking, shading, ray tracing.

Image processing

Fundamentals of image processing: image function, image matrix, sampling, quantization. Transformation, filtering, restoration of images. Coding and description of images. Edge detection, corner points and point matching, segmentation, registration.

Artificial Intelligence

Problem solving, state space, uninformed and informed search (A^*). Game trees, search methods, minimax algorithm, alpha-beta pruning. Heuristic optimization: evolutionary methods, simulated annealing.

Machine learning

The basic problem and variants of inductive learning: supervised learning, unsupervised learning, reinforcement learning. Decision trees. Statistical learning, naive-Bayes, Bayes nets. Linear models (SVM, logistic regression). Learning as optimization: loss function, stochastic gradient method. Dimension reduction, clustering, mining of complex networks. Artificial neural networks, deep neural network architectures (convolution, transformer).

Programming languages, program design

Programming paradigms and their most important properties. Assembly programming. Imperative programming languages, subprograms, control structures, types. Structured programs, subprograms, modules. Principles of object-oriented programming (C++, JAVA). Logic programming (Prolog). Functional programming. Parallel programming. UML-based program design.

Compilers

Phases of compilers. Lexical, syntactic and static semantic analysis. Theoretical models (regular, context-free, attribute grammars). Code generation. Code optimization.

Computer networks

Network architectures. The basic element of communication systems, the protocol. Life cycle of protocols. Internet protocols. SDL is a description language. Network applications.

Databases, Information Systems

Data modeling, relational data model. Operations in the relational model. Normalization, normal forms. SQL database language. Object-oriented database management. Distributed database management. Elements of the SSADM methodology.

Operating systems

Processes. Scheduling of processes, interprocess communication. Input and output (I/O) subsystem. Memory management. File systems.

Signals and systems

The signal as information carrier. Orthogonal transformation of one-dimensional signals. The spectrum of the signal, the effect of sampling on the spectrum of the signal. Analysis of time series using FFT. Signal energy and power. Description of LTI systems in time, frequency and operator domains. Characteristics of typical components (P, D, I, PT1, PT2). Frequency transfer characteristics of real filters, the Bode diagram. The Tustin transformation. Discrete-time systems, IIR and FIR basics.

Control technology

Impact analysis of the regulatory framework. Quality requirements of regulations. Concept and analysis of stability, stability criteria. The ideal and the real PID controller, the discrete-time implementation of the real PID controller. Hardware structure and operation of PLCs.

System theory

Availability, controllability, observability and reconstructability. Kalman resolution, canonical forms. Pole shifting with state feedback. Minimal state monitor. Stability of nonlinear systems, Lyapunov methods, La Salle theorem. Sliding control.

Intelligent systems

Structure of fuzzy control systems. Mamdani's fuzzy control. Takagi-Sugeno fuzzy control. The place and role of neural networks in intelligent systems. The neural network as a universal approximator, the backpropagation algorithm. The operation and role of the genetic algorithm in the development of intelligent systems.

Embedded systems

Construction of embedded systems. Analog and digital components, sensors, actuators, signal conditioning, data converters, processors, peripherals. Principles and tools of embedded software development. Real-time systems, processes, operating systems.

Measurement technology and signal processing

Fundamentals of measurement theory, structure and properties of instruments. Digitization, sampling measurement of analog signals. Digital signal processing, spectral analysis of sampled signals, time-dependent spectral analysis, convolution and deconvolution. Digital filters. Digital signal synthesis. Lock-in measurement technique, modulation and demodulation. Data acquisition systems, software-defined instruments.