Master’s degree Exam Requirements
Applied Informatics

Theoretical Informatics and Mathematical Methods (TEIMAT)

Academic year 2025

1. **Formal languages, grammars and automata** (Basic terms of the theory of formal languages, definition of grammar and Chomsky's hierarchy of grammars. Regular languages, finite automata, utilization of regular languages. Context-free grammars, stack automata, mutual relation of context-free languages and stack automata).

2. **Theory of computability** (Turing machine and its variants, universal Turing machine. Decidability vs. language recognizability, the Church-Turing theorem, the halting problem and other algorithmically undecidable problems).

3. **Complexity theory** (Time complexity, analysis of the algorithm, asymptotic complexity of the algorithm. Definition of classes P and NP, polynomial reducibility of problems, notion of NP-completeness, examples of NP-complete problems, practical consequences).

4. **Algorithms and their complexities.** Finding the minimal skeleton of a graph, articulations, bridges, blocks in a graph, algorithm for finding articulations and blocks in a graph. Bipartite graphs, graph matching, assignment problem. The role of the Chinese postman.

5. **Oriented graphs.** Strong connectivity and strongly connected components in a graph, acyclic graphs, topological ordering of a graph, extremal paths in an acyclic graph. Methods of network analysis (CPM, PERT), flows and maximum flow in networks.

6. **NP complete problems in the area of discrete mathematics,** graph coloring problem, 4 color problem, problem of existence and finding a clique and independent set in a graph, problem of finding Hamiltonian circles in a graph, traveling salesman problem.

7. **Principles of numerical methods and solutions of nonlinear equations**. Sources of error in numerical calculations, floating-point number system and representation of real numbers in computers, errors in numerical calculations (absolute error, relative error, properties of numerical algorithms and asymptotic accuracy). Nonlinear function, its zero point and nonlinear equation, separation of roots of a nonlinear equation, basic methods of finding roots, accuracy estimates and convergence conditions.

8. **Issues of numerical methods, approximation of functions and numerical calculation of the derivative and the integral of functions** (Errors in numerical calculations, conditionality in numerical problems. Interpolation polynomial, interpolation splines, least square method. Numerical derivation, basic formulas, calculation error. Numerical integration, basic and compound formulas, calculation error).

9. **Numerical solution of systems of linear algebraic equations - direct and indirect methods**. Linear algebraic equations and their systems, matrix of the system, Gaussian elimination method, selection of the principal element, effect of rounding errors, conditionality of the problem, LU decomposition of the matrix, calculation of the inverse matrix, calculation of the determinant. Iterative methods and their convergence criteria.

10. **Data description, visualization, and inference.** Descriptive characteristics of the data sample: Central location (mean, median, mode), variation (variance, standard deviation), relative, and cumulative relative frequency (explanation, properties and applications). Visualization (bar charts, box and whisker plots, histograms, pie charts).

11. **The principles of inference from sample to population.** Confidence interval for mean or proportion, and test of hypotheses about means or proportions (specify hypotheses, significance level, decision rule).

12. **Relationship between two or more variables.** Coefficient of correlation (the main properties, scatter plots representing different levels of association). One-way association, simple and multivariate linear regression analysis. Linear re-gression, assumptions of the model and the principles of the Least Square estimate equa-tion. The test of the significance of parameters in the model. Indicators of the model quality: Expected properties of residuals, test Durbin-Watson, and common risks of the linear regression modelling.

13. **Principles of machine learning** (traditional programming and machine learning paradigm, supervised and unsupervised learning, data preparation, implementation in Python, evaluation of models).

14. **Neural networks** (basic concepts (neuron, weight, threshold, activation function, bias, synapse), perceptron, multilayer feedforward neural network, deep neural networks, applications).

15. **Principles of game theory** (basic concepts (player, rules, strategy, payoff), classification of games, representation of game, zero and non-zero sum games, elimination of dominated strategies, Nash equilibrium, games with risk and uncertainty, games with incomplete information).

Literature

Raschka, S., Mirjalili, V. (2017) Python Machine Learning. Packt.
Garreta R. et al. (2017) Scikit-learn: Machine Learning Simplified Learning Path. Packt.
Kelleher, J.D. et al. (2015) Fundamentals of Machine Learning for Predictive Data Analytics: Algorithms. Worked Examples, and Case Studies. MIT Press.
Goodfellow, I., Bengio, J., Courville, A. (2016) Deep Learning. MIT Press.
Buduma, N. (2017) Fundamentals of Deep Learning: Designing Next-Generation Machine Learning Algorithms. OReilly.
Muller, A.C., Guido, S. (2016) Introduction to Machine Learning with Python: A Guide for Data Scientists. OReilly.
Sipser, M., Introduction to the Theory of Computation Course Technology, 3rd Ed., Thomson, Boston, MA, 2012.
MacCormick, J., What Can Be Computed? A Practical Guide to the Theory of Computation. Princeton University Press, 2018.
Osborne, M.J. (2000) An Introduction to Game Theory.
Leyton-Brown, K., Shoham, Y. (2008) Essentials of Game Theory: A Concise, Multicisciplinary Introduction.
Bonanno, G. (2015) Game Theory: An open access textbook with 165 solved exercises.
Groebner D.F., et al: Business Statistics, A Decision – Making Approach. Prentice Hall, 2008 (2005, 2001).