**KAZAKH NATIONAL UNIVERSITY NAMED AFTER AL-FARABI**
**FACULTY OF INFORMATION TECHNOLOGY**

Approved at the meeting
Scientific and Methodological Council
KazNU named after al-Farabi
protocol No. _____
from "_____" _____2020

# PROGRAM
# ENTRANCE EXAM
# FOR APPLICANTS ON PHD BY SPECIALTY
# "8D06114–ARTIFICIAL INTELLIGENT IN MEDICINE"
# (for 3 year studies)

ALMATY 2020

The program is compiled in accordance with the state compulsory standard of postgraduate education. The program was compiled by Ph.D., associate professor M. Mansurova, senior teacher M. Sakypbekova.

The program was considered at a meeting of the Department of Artificial Intelligence and Big Data

Minutes No. 28 April 14, 2020

Head Department _____ M.E. Mansurova

Approved at a meeting of the Methodological Bureau of the Faculty of Information Technology

Minutes No. 8 of April 21, 2020

Chairman of the method bureau _____ F.R. Gusmanova

Approved at the meeting of the Scientific Council
Minutes No. 10 of April 24, 2020

Chairman of the Scientific Council
Dean of the faculty _____ B.A. Urmashev

Scientific Secretary _____ A.K. Sambetbaeva

## PROGRAM CONTENT

### 1. Goals and objectives of the entrance exam in the specialty

#### 1.1. The purpose of the entrance exam in the specialty

The purpose of the entrance exam is to identify the level of theoretical training entering the doctoral program and the formation of a personal recommendation for admission on the basis of competitive participation.

The program of the entrance exam includes the following disciplines: “Advanced data structures, algorithms and analysis”, “Software development technology”, “Theory of distributed systems”.

#### 1.2. Tasks of the entrance exam in the specialty

**During the exam revealed:**

– Knowledge of the fundamental foundations of theoretical computer science; main achievements and development trends of modern information technologies; technologies of professional and scientific activity; knowledge of the main provisions of professional and scientific ethics and their use in work; knowledge of at least one foreign language at the level of fluency in the language of the specialty; knowledge of the basics of pedagogy and psychology; knowledge of the basics of management and the motivation of the scientific activities of the team.

– The ability to find, analyze and process scientific, technical, natural science and general scientific information, leading it to a problem-task form; publicly present their own new scientific results; to design and carry out their professional, scientific and scientific-pedagogical activities, as well as the activities of the team; be able to conduct joint scientific activities; to design your further professional development.

– Skills of independent research work and research work, as well as activities within the group; scientific project activities, the solution of standard scientific and professional tasks, the correct and logical design of their thoughts in oral and written form, the teaching of computer science in secondary specialized and higher educational institutions.

### 2. Requirements for the level of training of people entering PhD doctoral studies

Requirements for the level of training entering the doctoral program.

Previous level of education: academic master's degree in specialties:

6M060200 - Informatics
6M070200 - Automation and control
6M070400 - Computer Engineering and Software
6M070300- Information Systems
6M100200 - Information Security Systems
6M070500 - Mathematical and computer modeling
6M070100 - Mathematics
6M060300 - Mechanics
6M071800 - Electrical power engineering
6M060400 - Physics
6M071700 - Heat power engineering
6M072300 - Technical Physics
6M060500 –Nuclear Physics
6M074600 - Space technology and technology
6M071900 - Radio engineering, electronics and telecommunications

Applicant must have a state document of the appropriate level of education.

The entrance exam program for applicants for doctoral studies in the educational program "8D06114 - Artificial Intelligence in Medicine" was developed at the Department of Artificial Intelligence and Big Data.

**3. Prerequisites of the educational program**

- Advanced data structures, algorithms and analysis.
- Software development technology.

**4. The list of exam topics**

**The discipline "Advanced data structures, algorithms and analysis"**

1. The intuitive concept of an algorithm and its properties. Measures of algorithm efficiency.Classes of Algorithms.Polynomial and exponential algorithms.Principles of development of algorithms.Implementation and empirical analysis.

2. Analysis of algorithms. Modern programming methods.Technology development programs and their implementation.Algorithmic model of a Turing machine.Calculation of functions on a Turing machine.Superposition of cars.Machine connection.Branching machines. Loop implementation.

3. Random access machines (MTD) and computable functions. Algorithmic model of MTD.Calculation of functions on MTD.Church thesis.

4. The principles of constructing discrete models. Choice of an algorithm for solving problems.Von Neumann stability analysis.Basic functions. Church thesis for partially recursive functions. Computability on MTD of partially recursive functions. Computability of recursion.Computability of minimization.

5. Features of modeling convective and diffusion transfers. The implementation of explicit and implicit algorithms.

6. Algorithmically complex problems. Building an algorithm for joint solution of a system of equations.Features of programming.

7. Characteristics of computational complexity. Algorithms for solving a system of equations.Functions of time and capacitive complexity.

8. Lower bounds for the time complexity of computing on Turing machines. Classes of complexity and NP and their relationship.Subsets of sets.Generating a subset of sets.

9. NP-complete problems. Cook's theorem.Basic NP complete tasks.Strong NP fullness.

10. Class co-NP. The structure of the classes NP and co-NP.Application of the theory of NP-completeness to the development of approximate algorithms. Chart of difficulty classes.

11. The complexity of algorithms using recursion. Modeling and implementation of the algorithm for solving two-dimensional problems

12. Recursive matrix inversion algorithm

13. Features of the construction of algorithms for applied problems of oil filtration.

14. Features of the construction of algorithms for problems with an unknown upper bound. Implementation of algorithms using an uneven difference grid.

15. The optimality of computing. Ways to optimize computing.

## References

### Main literature:


1. Cormen Thomas. Algorithms: construction and analysis. M .: William, 2005.

2. Computer Science for advanced level. Ray Bradley Stansley T. publishers Ltd, 1999.

3. M.T. Goodrich, R. Tamassia. Data structures and Algorithms in Java., Prentice Hall. 2005 .-- 695 p.

4. R. Sagevik. Fundamental algorithms in S-SPb: DiaSoftUp LLC, 2003.- 1136 p.

5. Abramov S.A. Lectures on the complexity of algorithms, - M .: MCNMO, 2009.

6. Kuzyurin N.N., Fomin S.A. Efficient algorithms and computational complexity, - M .: MIPT, 2007.

7. Shurygin V.A. The complexity method of the theory of algorithms. - M .: LIBROCOM, 2009.

8. Belov V.V., Chistyakova V.I. Algorithms and data structures: M .: course, SIC INFRA-M, 2019. url: http://znanium.com/catalog/product/978314

9. Cruise Robert L. Finogenova K. G. Data structures and program design. Tutorial. 2017.

10. Learning Algorithms Through Programming and Puzzle Solving Alexander S. Kulikov and PavelPevzner Active Learning Technologies. 2018.

11. Stephen S. Skien. Algorithm Development Guide, 2nd Edition. 2011 year


### Additional literature:


1. B.Ya. Sovetov, S.A. Yakovlev Modeling systems. M. Higher School, 2007.

2. Samarsky A.A. Numerical methods.M., World, 1991.

3. Maltsev A.I. Algorithms and recursive functions. - M.: Science, 1986.


## Discipline "Software Development Technologies"

1. The software development process. Overview of modern software development technologies.Organization of the software development process.

2. Project management. Identification and reduction of risks.Development and support tools.

3. Requirements and software architecture. Requirements analysis.Description of requirements.Adding detailed requirements.Software architecture.Types of architectures and their models.

4. Designing software systems. Fundamentals of designing software systems.

5. Features of the synthesis process of software systems. Features of the design phase. Classical design methods.

6. Software testing. Principles of software testing.

7. Structural software testing. Functional software testing.

8. Organization of the software testing process. Methods of testing software systems.System testing.

9. Object-oriented software systems.

10. User interface development for various software systems and interface design requirements.

11. Fundamentals of object-oriented representation of software systems. The basis of the language of visual modeling.

12. Static models of object-oriented software systems.

13. Dynamic models of object-oriented software systems.

14. Models for implementing object-oriented software systems. Metrics of object-oriented software systems.

15. The unified process of developing object-oriented software systems.

## References

### Main literature:

1. Orlov S.A. Software Development Technologies. St. Petersburg: Peter, 2002.446 s.

2. Kokareva E.V. Gagarina L.G., Visnadul B.D., Software development technologies. INFRA-M, Publishing House Forum, 2008

3. Braude E. Software development technology. St. Petersburg: Peter, 2004.

4. Rudakov, A. V. Technology of software development. Workshop Textbook / A.V. Rudakov, G.N. Fedorova. - M.: Academy, 2014.

5. Sokolova, VV Computer Engineering and Information Technology. mobile application development. textbook for applied undergraduate / V.V. Sokolova. - M .: Yurayt, 2016.

6. Sergushicheva A.P. Software development technology: Methodological guidelines for the implementation of laboratory work No. 4 “Application of CASE-tools for software development”. - Vologda: VSTU, 2007.

7. Kotlyarov V.P. Fundamentals of software testing / V.P. Kotlyarov, T.V. Kolikova. - M.: Internet University of Information Technology, Binom. Knowledge Laboratory, 2011.

### Additional literature:

1. Vasiliev, AE Microcontrollers. Embedded Application Development (+ CD-ROM) / A.E. Vasiliev. - M.: BHV-Petersburg, 2012.

2. Gusyatnikov, V. N. Standardization and development of software systems / V.N. Gusyatnikov, A.I. Bezrukov. - M .: Finance and statistics, Infra-M, 2012.

3. Richard F. Schmidt. Software Engineering.Architecture-Driven Software Development.USA, 2013.

## Discipline "Theory of pattern recognition"

1. Introduction to the problem of pattern recognition and cluster analysis. Feature of modern recognition systems; Studying the object of recognition; Classification of recognizable objects; Building a dictionary of signs; Limitations of the feature dictionary; Class description; Recognition algorithm development; System management methods; Recognition performance indicators. The task of cluster analysis

2. Basic concepts and definitions. Learning and self-learning recognition systems. Classification of recognition systems and cluster analysis.Some concepts of constructing recognition and classification systems.

3. Pre-processing of images and selection of features. The principle of clustering; Methods for implementing the principles (heuristic, mathematical, linguistic); Physical, structural and mathematical features; Similarity matrix; Similarity measures.Building a simple mathematical model for pattern recognition.Algebraic theory of pattern recognition. Distance functions. Kinds of distance function

4. Methods for determining the information content of signs; Selection of features through approximation by functions; Choice of signs based on maximizing divergence; A generalization of the principles of classification by minimum distance. Image pretreatment and feature selection. The principle of clustering; Methods for implementing the principles (heuristic,

mathematical, linguistic); Physical, structural and mathematical features; Similarity matrix; Similarity measures.Building a simple mathematical model for pattern recognition.Algebraic theory of pattern recognition. Distance functions. Kinds of distance function.

5. Feature space. Informational content of signs. Algorithms for determining the information content of signs. Comparative analysis.Variance estimation; Information about the object closest and remotest from the standard.

6. Recognition and classification algorithms used by various distance functions. Some classification algorithms based on the Euclidean metric. Matrix of group decisions of the committee of taxonomy algorithms; The construction of compact subsets based on the allocation of nuclei; Graph algorithms for structural correction. Basic concepts.Formulation of the problem.

7. Evaluation of the results of the clustering process. Some principles of creating extreme algorithms.Functionality of quality. Algorithm of K-intragroup means. Maximin distance algorithm. Graph-based clustering; Separating structural bonds; Corrective matching algorithms; Algorithm of sequential correction in the task of committee synthesis; Analysis of the stability of solving classification problems.

8. Algorithms for Calculating Grades (ABO). Stages of building algorithms for calculating estimates.Algorithm for reducing standards in classification problems. Algorithm for representing classifications in EN (unit cube of size N); Stability analysis of the classification algorithm A on the set M = {S1, ...,Sm}; Classification Space Metric properties of the classification space; Operations on basic algorithms.

9. Parametrization and a system of models for calculating estimates. Functions of algorithm efficiency.Interactive self-organizing data analysis method - ISOMAD. From biological networks to ANN; The most important properties of biological neural networks; Ways to implement neural networks

10. Extreme algorithms in pattern recognition problems. The construction of extreme algorithms for computing estimates. Clustering Algorithms. FOREL-1 Algorithm

11. Attribute space, Extreme informational weight of attributes. Cluster analysis algorithms using quality criteria based on the shortest open path. Algorithm for the simplest arrangement of cluster centers.

12. Methods of group (committee) synthesis in recognition and classification problems. Statement of the problem and basic concepts. Synthesis of algorithms based on the allocation of central (reference) objects. Algorithm for training one neuron.

13. Metric in the space of classifications. Algorithms for solving the main recognition problem in the classification space.Construction of optimal partitions in the class of recognition algorithms.Artificial neural networks in recognition and classification. Neurobiological sources of neural networks. Biological neural networks.

14. Classification of neural networks. Neural network architecture.Neural network training. A general approach to finding linear decision functions. Ho-Kashyap Algorithm.

15. Neural network training. Neural network architecture.The practical application of neural networks for classification (clustering) tasks.Associative memory networks.Hopfield Algorithm and Network.Hamming Algorithm and Network.

## References

### Main literature:

1. Amirgaliev E. N. Theory of pattern recognition and cluster analysis // Almaty: KazNTU, 2002. –364 p.

2. Vasiliev V. N. Recognizing systems: Handbook, Kiev: NaukovaDumka, 1983. 424 p.

3. Zhuravlev Yu. I. On the algebraic approach to solving recognition and classification problems. | | Problems of cybernetics.M .: Science. Vol. 33. 1978.P. 93 - 103.

4. Theory and pattern recognition algorithms. Tutorial. M. MIIGAiK, 2004.- 70p.

5. Automated processing of aerospace information for mapping spatial data. Tutorial. M. MIIGAiK, 2013 -96c.

**Additional literature:**

1. Duran N, Odel P. Cluster analysis. M .: Statistics, 1977.128 s.

2. ZhuravlevYu.I. Correct algebras over sets of incorrect (heuristic) algorithms I □□ Cybernetics 1977.No. 4. P. 14-21

3. Bonner R.E. Some classification methods □□ Translation Collection “Automatic Analysis of Complex Images”. M.: Mir, 1969.S. 205-234.

4. Fu K. Sequential methods in pattern recognition and machine learning.M .: Nauka, 1971.

**Response Evaluation Criteria**

The answer is evaluated at **“90+”** when it gives a complete and accurate answer to the question, demonstrates fluency in terms and concepts, contains a consistent and logical presentation, as well as completed conclusions and generalizations on the topic.

The answer is evaluated at **“75-89”,** when it gives a complete and accurate answer to the question, demonstrates knowledge of the basic terms and concepts, contains completed conclusions and generalizations on the topic.

The answer is evaluated at **“60-75”,** when it gives a complete and accurate answer to the question, demonstrates knowledge of basic terms and concepts, contains sufficient conclusions and some generalizations on the topic.

The answer is evaluated at **“50-60”,** when it gives a complete and accurate answer to the question, demonstrates satisfactory knowledge of the basic terms and concepts, satisfactory knowledge and knowledge of methods and means of solving problems, contains insufficiently consistent presentation of the material, as well as individual conclusions and generalizations on the topic .

The answer is rated at **"0-50"** when the lack of a complete and accurate answer to the question.