Development of teaching programs of artificial intelligence methods in aerospace education

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Abstract. As a part of the National Strategy on Artificial Intelligence development in the Russian Federation, the basic concepts and definitions related to artificial intelligence (AI) and the necessity for the preparation of training programs were analyzed. The analysis of Federal state educational standards (FSES) and professional standards for enlarged groups of specialties and directions (EGSD) 24.00.00 AEROSPACE ENGINEERING was conducted and the perspective programs on the foundations of artificial intelligence and intelligent data analysis were proposed.

1 Introduction

The relevance of the considered task is determined by the Presidential Decree No. 490 of October 10, 2019 "On the Development of Artificial Intelligence in the Russian Federation".

The educational technologies should also rely on the Federal Law of 29.12.2012 No. 273-FZ "On Education in the Russian Federation", the Federal standards of higher education concerning the professional standards of the consolidated group of training areas and majors EGSD (enlarged groups of specialties and directions) 24.00.00 Aviation and Rocket-Space Engineering.

The application of artificial intelligence (AI) methods in education include two main trends:

- use of AI methods in the organization of the educational process;
- teaching of AI methods.

The first trends is universal. Technologies such as adaptive learning, personalized learning, automatic assessment, interval learning, evaluation of the faculty by students, smart campuses, control of the examination process are currently under development. Appropriate information platforms are also being developed for organizing the educational process using new technologies.

An enlarged classification of the AI technology application includes the following aspects:

- computer vision technologies in education (for monitoring students during online proctoring);
- technologies of natural language processing, speech recognition, and synthesis;
- technologies of intellectual support for decision-making.

The second trends of implementing AI methods in the curriculum relies on both the latest achievements in AI and the specifics of educational activities.

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In articles [1, 2] general approaches to the formation of educational programs are considered. The problems of digital transformation at a new stage are considered in [3, 4]. In [5–10], descriptions of methods of using intelligent technologies are given. Foreign experience is analyzed in the article [11].

2 Key concepts and definitions in the AI field used in the curriculum development

The key term, "artificial intelligence", is defined as "a set of technological solutions that allow the simulation of human cognitive functions, obtaining results comparable, at least, to the results of human intellectual activity".

An expanded definition of AI is as follows: AI is the science and technology of creating intelligent machines, especially intelligent computer programs. AI is related to the similar task of using computers to understand human intelligence but is not necessarily limited to biologically plausible methods. The goal of AI is to create technical systems capable of solving non-computational tasks and performing actions that require the processing of meaningful information and are considered the prerogative of the human brain.

The main attributes and distinctions of intelligent systems (IS):

1. Developed communicative abilities—processing arbitrary requests in a dialogue in a language closest to natural language (the system of natural language interface—SNLII).
2. Focus on solving weakly structured, poorly formalized problems (implementation of soft models).
3. Ability to work with undefined and dynamic data.
4. Ability to develop a framework and extract knowledge from the accumulated experience of specific situations.
5. The ability to obtain and use information that is not explicitly stored, but is derived from the database.
6. The system has not only a model of the subject area but also a model of itself, which allows it to define the scope of its competence.
7. Ability to draw conclusions by analogy.
8. Ability to explain its actions, user failures, to warn the user about some situations that lead to the violation of data integrity.

In contrast to conventional analytical and statistical models, IS allows obtaining a solution to poorly structured problems that are difficult to formalize.

The main types of intelligent systems are:

1. Systems with intelligent feedback and intelligent interfaces.
2. Computer-aided pattern recognition systems.
3. Computer-aided decision support systems.
4. Expert systems.
5. Neural networks.
6. Cognitive modeling.
7. Genetic algorithms and evolutionary modeling.
8. Knowledge extraction from experience (empirical facts) and Data Mining.

According to the above list, data mining is included in the list of intelligent systems. An alternative concept is the interpretation of Data Mining, which includes AI methods and is defined as a decision support process based on the search for hidden patterns in data.

The purpose of pattern finding is to present data as a representation of the searched processes. Building prediction models is also the goal of pattern search. Data Mining tools, unlike statistical tools, do not require a strictly defined amount of retrospective data. At the same time, it is necessary to control the statistical significance of the detected knowledge.

3 Analysis of FSES and professional standards for EGSD 24.00.00, and preparation of prospective courses on AI methods

Analysis of the FSES (Federal state educational standards) and professional standards combined with the AI methods and data mining was conducted to determine the focus of the individual modules and general courses development.

Seven FSES of 3++ generation were studied, and the majors for which it is feasible to include both individual modules and comprehensive training on AI methods were determined. Integrated training is recommended for the training programs 24.05.03 (Aircraft testing); 24.05.04 (Navigation and flight support of space vehicles); 24.05.05 (Integrated aircraft systems); 24.05.06 (Aircraft control systems).

In addition, 60 professional standards in the field of Rocket and Aerospace Industry were analyzed. AI General Course was recommended to be included in the training system for 22 of considered professional standards.

Analysis of 16 professional standards in the Aviation field showed the advisability of studying the general course of AI methods for at least four standards.

4 Development of the basic program on the Artificial Intelligence methods, recommended in the EGSD 24.00.00 educational programs

The main document to be developed is the educational program: a set of basic properties of education (volume, content, expected outcomes) and organizational and methodological conditions. This set is presented as a curriculum, a calendar of the curriculum, working programs of subjects, courses, disciplines (modules), other components, assessment and methodological materials, and in cases prescribed by Federal Law No. 273-FZ of 29.12.2012 “On Education in the Russian Federation”, as a working program.

The following program is offered to form a general basic course on AI methods. The course consists of modules that may be considered both as a whole and as separate components.

The specifics of the course are fulfilled through the consideration of end-to-end examples in lectures and practical classes.

The objectives of the discipline include the formation of a system baseline representation and primary knowledge, skills, and competencies in the AI basics and methods, along with insights into the implementation of artificial intelligence methods in technical applications. This course prepares teachers and students to apply the concepts of intelligent systems in scientific and practical areas.

The main tasks of the discipline are to acquire skills in the research and development of artificial intelligence systems in engineering practice.

The specific problems of implementing artificial intelligence technologies depend on the focus of a particular educational program. Therefore, a significant element here is an educational module—a set of educational elements sufficient to organize and pass the training on a particular topic (class) of the discipline (course).

Table 1. Modules and contents of the general course on AI methods

Module	Topic
General issues of Artificial Intelligence	Lecture 1. General issues of Artificial Intelligence. Basic concepts and definitions of Artificial Intelligence. Place and role of the Artificial Intelligence Systems in Control Theory Applications
	Lecture 2. Models of cognitive psychology. Models of information perception in intelligent systems. Logic in Artificial Intelligence. Heuristic methods. Decision-making in an intelligent environment. Reasoning models. Dispute models. Prolog-logic programming language
Knowledge Engineering. Expert systems	Lecture 3. Representational languages and knowledge manipulation languages. Knowledge engineering. Intellectual knowledge bases. Knowledge representation models. Object-oriented databases. Evolutionary modeling
	Lecture 4. Expert systems. The concept of expert systems in control tasks for objects and processes in various activities
Mathematical basics of Artificial Intelligence methods	Lectures 5–7. Mathematical basics of Artificial Intelligence Methods. DATA Science, Statistics and Machine Learning. Clustering. Classification. Regression. Linear methods of classification and regression, nonlinear methods of classification and regression. Basics of Genetic Algorithms. Methods for model reconstruction from experimental data
Software implementation of Intelligent Systems	Lectures 8–9. Software implementation of Intelligent Systems. Basic algorithms of Machine Learning. AI languages and programs. Python basics. Lists, tuples, dictionaries, functions, lambda-functions, exceptions, plugins, classes
Neural Networks and Fuzzy Logic	Lectures 10–11. Neural networks (NN). Neural networks in control tasks. The basic architecture of artificial neural networks, the principle of training. Backpropagation method. The general scheme of training. Implementation of a simple neural network in Python. The architecture of networks: the choice of activation function, auxiliary layers, weights initialization. Parameters update, optimization methods. Methods for training neural networks and intelligent agents. Convolutional NN. Problems solved by convolutional NN. Introduction to modern architectures of NN: VGG, GoogleNet, LeNet. Reinforcement learning. Functions for describing agent's behavior. Deep Q Learning algorithm. Open AI Gym library. Basic features of the Neural Toolbox package of Matlab

Table 1. (Continue)

Module	Topic
Neural Networks and Fuzzy Logic	Lecture 12. Fuzzy logic methods. The basic concept of fuzzy sets. Methods for defining membership functions, their analytical and graphical representation. Methods of defuzzification. Fuzzy inference systems
	Lecture 13. Pattern recognition. Image analysis. Application of traditional technologies and Artificial Intelligence technologies in solving recognition, classification, and ranking tasks of analysis objects
Intelligent Control Systems	Lecture 14. Intelligent Control Systems. Structural diagrams using neural controllers. Structural schemes of a regulator with fuzzy logic. Complexation of neuro-fuzzy robust control methods. Problem statement for the complexation of readings of heterogeneous sensory systems
	Lecture 15. Intelligent robotic systems
Application of AI methods in aerospace engineering	Lectures 16–17. Applied problems of implementation of AI methods for a specific training program: aerospace engineering

Table 2. DATA Mining course syllabus

Module	Lecture	Seminar
Developing models and generating data for research	Data. Data operations. Dirty data processing methods	Two types of models: Big Data and limited data. Simulink models and system of ordinary differential equations models for end-to-end examples (on the example of the aircraft). Technologies of parallel computing in MATLAB
Dirty data processing methods	Tasks, methods, and stages of DATA Analysis—DATA Mining (DA-DM)	Work with missing data. Handling inconsistent data. Data filtering. Data smoothing with convolution. Removing the Data Trend from the Experimental Data Processing for Cross-Cutting Examples (using aircraft as an example)
Statistical methods in DATA Mining	Statistical methods in DA-DM. Distribution Forms	Key Indicators. Descriptive Statistics. Calculating and plotting descriptive statistics. Example 1—Calculation of Maximum, Mean, and Standard Deviation. Example 2—subtracting the mean using MATLAB data statistics for end-to-end examples. Distribution Shapes. One-Dimensional Histograms. Two-dimensional Histograms Multivariate Histograms for describing the quality indicators of the cross-cutting examples

Table 2. (Continue)

Module	Lecture	Seminar
Regression analysis	Data transformation and Dimensionality reduction (linear and nonlinear methods)	Linear Correlation. Linear Regression. Simple Linear Regression. Residuals and quality of the approximation. Example: Calculating R2 with Polynomial Approximations. Calculation of Adjusted R2 for Polynomial Regressions. Basic Fitting UI. Preparing for basic fitting. Opening Basic Fitting UI. Interpolating and extrapolating values. Creating a code file to display the result. MATLAB functions for polynomial models
Data Conversion and Dimensionality reduction	Time Series Analysis	Data Conversion. Dimensionality reduction-Linear methods. Introduction. Principal Component Analysis PCA
Time Series Analysis	Clustering	Creating and modifying time series objects. Viewing Objects in a Time Series. Changing Time Series Objects and Interpolation Method. Event detection. Creation of objects in a collection of time series. Removal and interpolation of missing data. Display time vector values as a string of data. Creation of Plots of Time Series Collection Members. Time series generator
Clustering	Classification and Regression Smoothing	Hierarchical Methods. Optimization methods. K-means method for evaluating the impact of system structure and parameters on the quality performance of the end-to-end example
Classification and regression	Graphical methods and cluster visualization. Multivariate visualization. Data tours. Interactive data exploration	Classification rule construction methods. Decision Tree methods. Methods for constructing mathematical functions. Regularization networks. Discretization and sparse grids for end-to-end examples. Prediction of time series
Multivariate visualization	Factor analysis	Multivariate visualization Factor analysis Glyph charts. Scatterplots charts. Scatterplot Matrices. Hexagonal scatterplots charts. Dynamic Graphics. Data identification. Linking. Coplots. Dot Diagrams. Andrews Curves

The educational module outcome is the development of certain knowledge, abilities, skills, or competencies by the student.

Description of the modules of the general course on AI methods is presented in table 1. According to the analysis of FSES 3++ for EGSD 24.00.00 and relevant professional standards in the fields of Rocket and Aerospace Industry and Aviation, we recommend including the "Intelligent Analysis of Data—DATA Mining" course for all training programs.

DATA Mining skills will become the basis in solving the most important problems for all engineers designing new equipment, specialists involved in the equipment operation, research engineers, and scientists. The received knowledge and skills will be irreplaceable for design decision-making support, prognosis, choosing the development directions, Big Data processing, and problem-solving in the limited information conditions.

An analysis of the problems in the aerospace industry resulted in the following course on data mining, presented in table 2.

5 Conclusions

1. The analysis of FSES 3++ on EGSD 24.00.00 "Aviation and Rocket-Space Engineering" and professional standards in the field of Rocket and Space Industry and Aircraft Engineering was performed in terms of the necessity to include the study of AI methods in professional training.

2. The courses and individual modules on the basics of AI and data mining methods were developed for implementation in the curriculum of the EGSD 24.00.00.

3. Recommendations on the implementation of both general courses and individual modules of AI methods into the training system of specialists have been prepared.

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