SHS Web of Conferences **137**, 01005 (2022) https://doi.org/10.1051/shsconf/202213701005
AESHE 2021

Implementation of artificial intelligence development strategy in the Russian Federation in the educational programs of aerospace engineering training of Bauman Moscow State Technical University

Vladimir Kalugin[1], *Alexander* Lutsenko[1], *Irina* Romanova[1,*], and *Yongjian* Xu[2]

[1]Bauman Moscow State Technical University, 5/1, 2nd Baumanskaya st., Moscow, 105005, Russia
[2]Shanghai Jiao Tong University, 800 Dongchuan RD. Minhang District, Shanghai, China

Abstract. As a part of the National Strategy on Artificial Intelligence development in the Russian Federation, the specific features of training in USSN 24.00.00 Aviation and Rocket-Space Engineering at "Mechanical Engineering" (SM) Department of Bauman Moscow State Technical University were considered. The analysis of self-established educational standards and the classification of artificial intelligence course modules, implemented at the SM Department, is carried out. Individual courses that already use methods of artificial intelligence or are promising for the introduction of such methods are presented.

1 Introduction

Artificial Intelligence (AI) is a set of technological solutions that allows simulating human cognitive functions (including self-learning and searching for solutions without a predetermined algorithm) and obtaining results comparable at least to the results of human intellectual activity when performing specific tasks.

Although the first information systems for assisting people in making decisions date back to the mid-1950s, recent years have seen rapid growth in methods, algorithms, and practical applications of AI in various fields of activity.

Presidential Decree No. 490 of October 10, 2019 "On the Development of Artificial Intelligence in the Russian Federation" and the adopted accordingly National Strategy for the Development of Artificial Intelligence to the year 2030 (`https://www.garant.ru/products/ipo/prime/doc/72738946/`) determines both general tasks of the accelerated development of artificial intelligence in the Russian Federation and the major directions for enhancement of training system in this field. That includes conducting scientific research in the field of artificial intelligence and increasing the availability of information and computing resources for users.

At the Artificial Intelligence Journey (AI Journey 2020) conference on "Artificial Intelligence—Main Technology for the 21st Century" (`http://www.kremlin.ru/events/president/news/64545`), the goal for education was specified in a Presidential address: (quote) "I believe that training courses, modules on artificial intelligence and big data analysis should be included in educational programs, and for all areas of professional activity".

*e-mail: irina.romanova@bmstu.ru

Following the conference on Artificial Intelligence, the President approved the list of instructions, particularly according to Pr-2242, paragraph 1 e) —2: to complement the educational programs of higher education in all fields of specialization and areas of training with sections on the study of artificial intelligence for training in the application of such technologies in various fields of activity.

According to clause 45 of the National Strategy, the main directions of increasing the amount of qualified personnel for the Russian market of artificial intelligence technologies and the level of public awareness about the possible areas of use of such technologies are, inter alia:

Paragraph a)—development and implementation of educational modules as part of educational programs at all levels of education, advanced training, and professional retraining programs to provide citizens with knowledge, competencies, and skills in mathematics, programming, data analysis, machine learning, contributing to the development of artificial intelligence.

Herewith, the convergent knowledge provided through integration of mathematical, natural science, and social and humanities education is a priority for the development of promising methods of artificial intelligence.

Paragraph c)—improving the quality of mathematical and natural science education of students (within both primary and complementary educational programs), its integration with social and humanities education, creating conditions for attracting students to advanced training in these areas.

This article considers both the current state of training specialists for USSN (consolidated group of training areas and majors) 24.00.00 Aviation and Rocket-Space Engineering at the "Mechanical Engineering" (SM) Department of Bauman Moscow State Technical University, and the vectors of implementation of artificial intelligence development strategy in the curriculum for this program.

The promising methods of artificial intelligence focused on the creation of fundamentally new scientific and technical products, have been analyzed in advance. They include:

- autonomous task solving;
- automatic design of physical objects;
- automatic machine learning;
- information processing based on new types of computing systems;
- interpretive data processing;
- big data processing;
- intelligent data analysis;
- intelligent decision support.

The experience of training specialists in the field of aerospace technology is discussed in articles [1, 3]. The works [4, 10] are devoted to the problems and methods of AI, and the peculiarities of intelligent systems, as well as their application in the aerospace sphere.

The problem of including one or another AI technology in the educational process depends on the training program. The basis in the development of core professional educational programs (CPEP) for this major at Bauman Moscow State Technical University is the independently established educational standards (IEES).

2 The analysis of IEES implemented at "Mechanical Engineering" Department for the USSN 24.00.00 specialists where the methods, technologies, and examples of the application of artificial intelligence should be studied

At present, the specialists are trained in 7 sub-departments: SM-1 "Spacecraft and launch vehicles", SM-2 "Aerospace Systems", SM-8 "Launch Vehicle Systems", SM-12 "Technology of Rocket and Space Engineering" (24.05.01 program, Design, Production and Exploitation of Aerospace Systems); SM-3 "Orbital Mechanics and Flight Control" (24.05.04 program, Navigation and Ballistic Support of Space Applications); SM-5 "Autonomous Information and Control Systems"; SM-13 "Aerospace Composite Structures" (undergraduate and graduate training programs 24.03.01, 24.04.01, Rocket Systems and Cosmonautics).

Primarily, it is necessary to analyze the IEEE in terms of the areas of professional activity that they contain:

- 25 Rocket and Aerospace Industry (fields: engineering and technology related to design, testing, operation and effectiveness assessment of aerospace and rocket hardware, barrel and jet artillery, study of ballistic, aerodynamic and kinematic properties and features of professional objects, navigation and ballistic support of their application, dynamics and control of motion (flight), space flight control, ballistic design);
- 32 Aviation (fields: aerodynamic design of promising models of aviation and aerospace technology, ground and flight aerodynamic testing of models, mock-ups and full-scale structures of manned and unmanned aircraft).

All promising methods of artificial intelligence should be included in the department's training programs.

An analysis of competencies embedded in the IEES implemented in the SM department was also carried out. In particular, the study of AI methods will contribute to the achievement of the following competencies:

- Fundamental Universal Competences (UCF): UCF-1 "Is capable of search, critical analysis and synthesis of information, its semantic optimization and visual presentation, apply a systematic approach to solve the tasks; use the basics of philosophical knowledge and analyze the patterns of the historical development of society to form worldview and civic position";
- Fundamental General Professional Competencies (GPCF): GPCF-1 "Is capable of applying natural science and general engineering knowledge, methods of mathematical analysis and modeling, theoretical and experimental research skills to solve various professional tasks"; GPCF-2 "Is capable of understanding the principles of modern information technologies and use them for analyzing and solving professional tasks"; GPCF-6 "Can develop physical and mathematical models of space and rocket-to-satellite objects"; GPCF-9 "Is capable to use scientific and creative skills to search and find non-trivial solutions of scientific and technical problems and create innovations in the rocket and space equipment design field";
- Fundamental Professional Competencies (PCF): PCF-1 "Is capable of forming the logic of spacecraft control system functioning in case of on-board equipment failures"; PCF-4 "Is capable of conducting research work, coordinating and managing the processes of developing the design and technological documentation at all stages of the aerospace product life cycle"; PCF-6 "Is capable of conducting scientific analysis and forecasting the requirements development for the GNSS means and tools and their functional additions".

3 Analysis of the implemented curricula and course programs of the SM Department for specialists in USSN 24.00.00 where methods, technologies, and examples of the application of AI are covered

The course programs of sub-departments at the Mechanical Engineering Department were analyzed. All students of the Mechanical Engineering Department in USSN 24.00.00 study in some form individual methods, modules, or full courses of Artificial Intelligence.

Table 1. Disciplines topics of the SM Departments at USSN 24.00.00 in which AI methods are to be studied and/or implemented

Sub-Department	Courses with AI implementation
SM-2	Automated layout of manned and unmanned spacecraft (SC) and systems. Fundamentals of parallel computing methods.
SM-3	Methods of control in spacecraft flight control. Methods of information analysis for spacecraft flight control. Analysis of processing and displaying information from the spacecraft. Objective and types of telemetry information processing. Method of two-level control. Method of intelligent analysis. Types of spacecraft states. Variants of a "fuzzy" situation development. Classification of an emergency situation (ES). Safety protocol in case of ES. The analysis of the modern world development of processing and displaying information from spacecraft. Features of information transfer. Main restrictions on control. Features of decision making when controlling the spacecraft. Formation of executive-level flight plans (priorities, compatibility, quality criteria). Basic algorithms of executive-level planning. Optimization of scientific experiments planning. Analysis of applicability of mathematical methods to solve the flight planning problem. Consideration of applicability of artificial intelligence methods in planning tasks. Random events, values, and processes in ballistics and airborne boost-glide systems. Incompatible and independent events. Formulas for total and inverse probability. Probability functions and densities, initial and central moments, cumulants, correlations, characteristic functions. Gaussian random variables, vectors, and processes. Markov processes. Tracking systems for randomly maneuvering targets. Stationary mode of tracking. Spectral density. Calculation of the tracking error variance. Analysis of the influence of transmissibility parameters on the accuracy of target coordinate estimates. Optimal filters. Ground-based automated spacecraft control system.
SM-5	Adaptive control in aerospace systems devices. Adaptation as a method of counteracting uncertainty in control and information processing systems. Methods of realization of the stochastic adaptive control. Identification-type adaptive systems. Discrete adaptive systems with an implicit reference model. Discrete adaptive systems with a configurable model of the control object. Statistical methods of identification. Regression analysis. Identification of a nonlinear system. Hammerstein's model. Measurement errors. Measurement function errors. Model errors. Accuracy assessment.

Table 1. (Continue)

Sub-Department	Courses with AI implementation
SM-5	Feasibility and repeatability of measurements. Optimal composition of measurements. The order of drawing up the program and methods of conducting tests of experimental and mock-up launchers during research and development work. Synthesis of optimum control systems based on dynamic programming method. The reduction of the optimal control problem to the mathematical programming problem by the method of projective matrix operators.
SM-8	Features and models of equipment operation in technical and launch systems based on random processes. Models equipment operation in technical and launch systems based on the mass service systems. Fundamentals of systematics. System analysis of ground equipment of aerospace systems. Fundamentals of the reliability theory. Calculation of basic fault tolerance, durability, and reliability indicators. Calculation of reliability indicators for various distribution laws of failure probability. Reliability of complex systems. Finite deterministic automata. Mile and Moore automata, combinatorial automata. Formal description of automata, automata tables, and graphs. Hardware and software implementation of automata.
SM-12	Acquiring the skills of practical and independent research of the effective operation of industrial processes based on the use of modern methods of quality control and analysis. “Statistica” program. Extracting knowledge from experimental data to obtain useful information and make decisions during the creation of numerical models of technological processes. Application of decision-making theory and expert judgment to select (and justify) a research direction. Methods for Finding Optimal Decisions in Selecting Test Options for Aerospace Equipment Products Based on Data Analysis (Properties and Operating Conditions of Rocket and Space Products). Optimization of technological parameters using analytical and numerical simulation of material processing processes based on the analysis of initial data. Decision-making methods for optimizing the variants of design technology. Development of expert and information retrieval systems to support the standard decision-making on the design technologies. Development of tests for students in the MS Forms environment with scoring in an automated mode based on the completed survey forms. Implementation of AI in the educational process).

Table 1. (Continue)

Sub-Department	Courses with AI implementation
SM-13	Methods for planning experimental studies and analysis of the reliability of the data obtained. Processing of experimental data to obtain composite materials properties. Using genetic algorithms for solving inverse problems. Analysis of random and methodical errors of temperature measurements during the bench tests of materials and structural elements. Application of machine learning algorithms for constructing multidimensional dependencies between operating parameters and calculated parameters of the thermal stress state of aircraft elements. Implementation of optimal solution search algorithms in Python environment. Automation of the design process in the Ansys environment using the Fortran/APDL programming language. The application of multilayer perceptron from the Python Sklearn library for constructing dependencies between input and output parameters of technical objects. Fundamentals of implementation of parallel computations in gas dynamics, heat transfer, and strength problems. The structure of modern computer-aided design systems. Statistical processing of experimental data. Testing statistical hypotheses, the choice of data distribution law. Application of planning algorithms for multifactor experiments (Python DOE library). Application of the high-level Pandas Python library for big data analysis. Series and Dataframe data structures.

The detailed analysis of Artificial Intelligence methods leads to the following classification of artificial intelligence course modules, already implemented in the SM department:

- "Artificial Intelligence Methods (General Course)" (7 courses);
- "Fundamentals of Data Analysis" (12 courses);
- "Data Analysis and Machine Learning" (10 courses);
- "Neural Networks" (5 courses);
- "Big Data Processing Systems" (3 courses);
- "Knowledge Engineering" (6 courses).

In each sub-department, among the studied programs, we found courses that can serve as a basis for the organization of intra- and interuniversity interaction for the preparation of new and modification of existing artificial intelligence curriculum.

Table 1 shows the most interesting topics of individual disciplines that already use methods of artificial intelligence or are promising for the introduction of such methods.

4 Conclusions

1. Sub-departments are divided into two groups:
   - ready-made courses in AI methods;
   - aspects of the application of AI methods in courses.

2. All departments are united by the availability of applied use of AI methods in specific majors and fields of training.
3. The direction of the curriculum improvement according to the National Strategy:
   - scientific and methodological elaboration of applied use of AI methods in the specific training field;
   - development of individual models, adjusted to the specifics of aerospace and defense engineering training;
   - experience exchange on the creation of educational and methodical sets, which consider separate aspects, general problems of Artificial Intelligence for non-profiled departments;
   - updating special courses on methods of artificial intelligence for majors that directly use these methods in their project activities;
   - retraining of faculty members in methods of teaching individual modules and courses in general in the field of artificial intelligence;
   - promoting scientific research of applied aspects of a particular focus;
   - integration of professional training and the economic cycle of disciplines with compulsory innovation components;
   - development of training, educational and methodological manuals on methods of artificial intelligence for aerospace and defense technology.

References

[1] V.T. Kalugin, *Faculty of Special Engineering MSTU named after N.E. Bauman—80 years*, Defence Equipment, **8–9**, 3 (2018)

[2] G. Shcheglov, V. Mayorova, V. Zelentsov, *Integration of Small Satellites Design Process into The Specialist's Degree Educational Program*, in Proceedings of the 69th International Astronautical Congress (IAC 2018), 1–5 October 2018, Bremen, Germany (2018)

[3] V.I. Mayorova, D.A. Grishko, V.V. Leonov, *Vivid mathematics as a general vector of multidisciplinary STEM education for future aerospace engineers*, Acta Astronautica, **178**, 72 (2021), DOI: 10.1016/j.actaastro.2020.09.003

[4] N.V. Lebedeva, S.V. Solov'yev, *Use of intelligent systems in operational control of spacecraft flight*, Aerospace MAI Journal, **25(2)**, 152 (2018)

[5] I.K. Romanova, *Study of the influence of deformations and asymmetry on aircraft movement parameters*, AIP Conf. Proc., **2171**, 130001 (2019)

[6] I.K. Romanova, *Application of data mining technologies in the tasks of detecting damage to unmanned aerial vehicles*, in Proceedings of the VII All-Russian Scientific and Practical Conference "Technologies for Development And Debugging of Complex Technical Systems", 1–2 April 2020, Moscow, Russia, 393 (2020)

[7] S.V. Solov'yev, *Justification of choice of clustering method and criterion for mining during spacecraft flight control*, Spacecrafts and Technologies, **4(33)**, 151 (2020)

[8] S.V. Solov'yev, *Principles for constructing an intelligent ground-based space flight control system*, Modern Science: actual problems of theory and practice. Natural and technical sciences, **3**, 144 (2021)

[9] I.K. Romanova, *Modern approaches to detecting changes in shape and other damage to flight vehicle during movement*, AIP Conf. Proc., **2318**, 110001 (2021), DOI: 10.1063/5.0036045

[10] N.A. Serdyukova, V.I. Serdyukov, *Smart System Sustainability and Smart System Management*, Intelligent Systems Reference Library book series, **191** (2020), DOI: 10.1007/978-3-030-54470-6_9