Federal State Autonomous Educational Institution of Higher Education
Peoples' Friendship University of Russia named after Patrice Lumumba

Academy of Engineering
(name of the main educational unit (MEU) that developed the educational program of higher education)

WORKING PROGRAM OF THE DISCIPLINE

VIRTUAL REALITY AND COMPUTER VISION
(name of discipline/module)

Recommended for the field of study/specialty:

27.04.04 CONTROL IN TECHNICAL SYSTEMS
(code and name of the field of study/specialty)

The discipline is mastered within the framework of the implementation of the main professional educational program of higher education (EP HE):

Artificial Intelligence, Machine Learning, and Space Science
(name (profile/specialization) of the educational institution of higher education)

2026

1. THE GOAL OF MASTERING THE DISCIPLINE

The course "Virtual Reality and Computer Vision" is part of the Master's program "Artificial Intelligence, Machine Learning, and Space Sciences" in the 27.04.04 "Control in Technical Systems" program and is studied in the first semester of the first year. The course is offered by the Department of Mechanics and Control Processes. It consists of eight sections and 20 topics and focuses on modern image processing and analysis technologies, the potential uses and applications of computer vision systems, and approaches to creating virtual reality-enabled systems.

The goal of mastering the discipline is to master the basic concepts of image processing and analysis, the principles of creating computer vision and virtual reality systems.

2. REQUIREMENTS FOR THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the course "Virtual Reality and Computer Vision" aimed at developing the following competencies (parts of competencies) in students:

Table 2.1. List of competencies developed in students while mastering the discipline (results of mastering the discipline)

Cipher	Competence	Indicators of Competency Achievement (within this discipline)
GPC-1	Able to analyze and identify the natural scientific essence of control problems in technical systems based on provisions, laws and methods in the field of natural sciences and mathematics	GPC-1.1 Knows the basic laws, provisions and methods in the field of natural sciences and mathematics; GPC-1.2 Able to identify the natural scientific essence of control problems in technical systems guided by the laws and methods of natural sciences and mathematics; GPC-1.3 Proficient in tools for analyzing control problems in technical systems.
GPC-2	Able to formulate control problems in technical systems and justify methods for solving them	GPC-2.1 Knows the basic methods of solving control problems in technical systems; GPC-2.2 Able to justify methods for solving control problems in technical systems; GPC-2.3 Proficient in methods of setting control problems in technical systems.
GPC-3	Capable of independently solving control problems in technical systems based on the latest advances in science and technology	GPC-3.1 Knows the basic approaches to solving control problems in technical systems; GPC-3.2 Able to apply basic approaches based on the latest achievements of science and technology to solving control problems in technical systems; GPC-3.3 Proficient in methods of solving control problems in technical systems based on the latest achievements of science and technology.
GPC-9	Capable of developing methods and performing experiments at existing facilities with processing of results based on information technology and technical means	GPC-9.1 Possesses modern information technologies and technical means for conducting experiments at operating facilities; GPC-9.2 Has skills in developing methods and performing experiments at operating facilities; GPC-9.3 Has the skills to develop methods and perform experiments at existing facilities with processing of results using information technology.
PC-2	Able to apply modern theoretical and experimental methods for developing mathematical models of objects and processes under study in the field of aerospace systems management	PC-2.1 Knows modern theoretical and experimental methods used to develop mathematical models of studied objects and processes of professional activity; PC-2.2 Able to determine the effectiveness of the methods used to develop mathematical models of the objects and processes under study; PC-2.3 Has mastered modern theoretical and experimental methods for developing mathematical models of objects and processes of professional activity in the field of study.
PC-3	Capable of carrying out work and	PC-3.1 Able to analyze the results of theoretical and experimental

Cipher	Competence	Indicators of Competency Achievement (within this discipline)
	research on the processing and analysis of scientific and technical information obtained using geographic information systems and technologies	research; PC-3.2 Able to formulate recommendations for improving devices and systems, prepare scientific research results for publication and prepare documents for filing an invention application; PC-3.3 Participates in the analysis of research results, has the skills to formulate recommendations for improving devices and systems, as well as write articles and submit documents for registration of inventions.;

3. PLACE OF THE DISCIPLINE IN THE STRUCTURE OF THE EDUCATIONAL EDUCATIONAL INSTITUTION

Course "Virtual Reality and Computer Vision" refers to the mandatory part of block 1 “Disciplines (modules)” of the educational program of higher education.

As part of the higher education program, students also master other disciplines and/or practices that contribute to the achievement of the planned results of mastering the discipline "Virtual Reality and Computer Vision".

Table 3.1. List of components of the educational program of higher education that contribute to the achievement of the planned results of mastering the discipline

Cipher	Name of competence	Previous courses/modules, practical training*	Subsequent disciplines/modules, practices*
GPC-1	Able to analyze and identify the natural scientific essence of control problems in technical systems based on provisions, laws and methods in the field of natural sciences and mathematics		Advanced Methods of Space Flight Mechanics; Advanced Methods of Earth Remote Sensing; Geoinformation Systems and Applications; Undergraduate Training;
GPC-2	Able to formulate control problems in technical systems and justify methods for solving them		Undergraduate Training; Dynamics and Control of Space Systems;
GPC-3	Capable of independently solving control problems in technical systems based on the latest advances in science and technology		Dynamics and Control of Space Systems; Advanced Methods of Space Flight Mechanics; Research work / Scientific research work; Undergraduate Training;
GPC-9	Capable of developing methods and performing experiments at existing facilities with processing of results based on information technology and technical means		Undergraduate Training; Dynamics and Control of Space Systems; Geoinformation Systems and Applications;
PC-2	Able to apply modern theoretical and experimental methods for developing mathematical models of objects and processes under study in the field of aerospace systems management		Research work / Scientific research work; Undergraduate Training; *Artificial Neural Networks (Deep Learning)***; *Artificial Neural Networks (Deep Learning)***;

Cipher	Name of competence	Previous courses/modules, practical training*	Subsequent disciplines/modules, practices*
			Advanced Methods of Space Flight Mechanics; *Artificial Neural Networks (Reinforcement Learning)***; Geoinformation Systems and Applications; Dynamics and Control of Space Systems;
PC-3	Capable of carrying out work and research on the processing and analysis of scientific and technical information obtained using geographic information systems and technologies		Advanced Methods of Earth Remote Sensing; Research work / Scientific research work; Undergraduate Training;

* - filled in accordance with the competency matrix and the SUP EP HE

** - elective courses/practices

4. SCOPE OF THE DISCIPLINE AND TYPES OF EDUCATIONAL WORK

The total workload of the course “Virtual Reality and Computer Vision” is 5 credits.

Table 4.1. Types of educational work by periods of mastering the educational program of higher education for full-time education.

Type of academic work	**TOTAL,**academic hours		**Semester(s)**
			1
Contact work, academic hours	*34*		*34*
Lectures (LC)	17		17
Laboratory work (LW)	17		17
Practical/seminar classes (SC)	0		0
Independent work of students, academic hours	*119*		*119*
Control (exam/test with assessment), academic hours	*27*		*27*
Total complexity of the discipline	**academic hours**	***180***	*180*
	credit	***5***	*5*

5. CONTENT OF THE DISCIPLINE

Table 5.1. Content of the discipline (module) by types of academic work

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
Section 1	Formation and presentation of images	1.1	Imaging devices. Image types.	Digital cameras, video cameras, 3D scanners, thermal imagers, depth sensors (Kinect, LiDAR). Raster and vector images. Grayscale, color, multispectral, and hyperspectral images. Depth imaging.	LC
		1.2	Types of images.	Black and white, grayscale, color (RGB, CMYK), multispectral, thermal, X-ray, ultrasound, depth map, normal map, displacement map.	LC, LW
		1.3	Digital image formats	Raster formats: BMP, JPEG, PNG, GIF, TIFF. Lossy and lossless compression. RAW formats. VR formats: equirectagonal projection (ERP), cube maps.	LC, LW
Section 2	Basic concepts of pattern recognition	2.1	Pattern recognition tasks. Features used to describe objects.	Tasks: classification, clustering, detection, segmentation, identification, verification. Features: color histograms, textural features (GLCM, LBP), geometric features (area, perimeter, compactness), descriptors (SIFT, SURF, ORB, HOG).	LC
		2.2	Representation of objects as feature vectors.	Feature space. Feature vector. Feature normalization and standardization. Euclidean distance, Manhattan distance, Mahalanobis distance.	LC, LW
		2.3	Recognition methods	K-Nearest Neighbors (k-NN). Bayesian classifier. Neural networks. Support Vector Machine (SVM). Decision trees and random forests. Quality assessment: confusion matrix, precision, recall, F-score.	LC, LW
Section 3	Filtering and enhancing images	3.1	Histogram equalization. Noise removal. Image smoothing.	Histogram equalization for enhanced contrast. Adaptive histogram. Noise removal: median filtering, Gaussian filtering, bilateral filtering. Smoothing: averaging filters, Gaussian filter.	LC, LW
		3.2	Image filtering. Edge detection.	Spatial and frequency filtering. Sobel filter, Prewitt filter. Canny operator. Laplace operator. Marr-Hildreth logic filter.	LC, LW
		3.3	Convolution Function: Spatial Frequency Analysis Using Harmonic Functions	Discrete convolution. Convolution kernel. Fast Fourier transform (FFT). Amplitude and phase spectrum. Frequency domain filtering. Harmonic functions.	LC, LW
Section 4	Content-based image search	4.1	Image databases. Image database queries. Indexing in image search engines.	Relational and object image databases. Metadata. Query by example. Query by description. Indexing: inverted indexes, k-d trees, R-trees. Hashing (LSH). CBIR systems.	LC, LW

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
Section 5	Movement in two-dimensional images	5.1	Image subtraction. Calculating displacement vectors.	Frame difference. Background model. Optical flow. Lucas-Kanade and Horn-Schunck methods. Object displacement vectors.	LC, LW
		5.2	Calculating trajectories of moving points.	Feature point tracking. KLT (Kanade-Lucas-Tomasi) algorithms. Kalman filter. RANSAC for trajectory smoothing. Object trajectories.	LC, LW
Section 6	Image segmentation	6.1	Region detection. Edge detection.	Threshold segmentation (Otsu). Region growing. Watershed segmentation. Segmentation using clustering (k-means, mean shift). Canny edge detector. Contour representation.	LC, LW
		6.2	High-level structure detection. Segmentation based on coordinated motion.	Geometric primitive detection (Hough transform). Shape recognition. Moving object segmentation. Background subtraction. Gaussian mixture model (GMM).	LC, LW
Section 7	Comparison in two-dimensional space	7.1	Affine geometric transformations. Recognizing two-dimensional objects using affine transformations.	Affine transformations: translation, scaling, rotation, shear, reflection. Matrix representation. Invariants of affine transformations. Object recognition independent of position, scale, and rotation.	LC, LW
		7.2	2D Object Recognition Using Relational Models: Nonlinear Image Warping Methods	Relational models: relationship graphs, structural descriptions. Graph matching. Elastic deformation methods. Thin-plate splines (TPS). Active Shape Models (ASM), Active Appearance Models (AAM).	LC, LW
Section 8	Perception of three-dimensional scenes from two-dimensional images	8.1	Three-dimensional features in two-dimensional images.	Depth, hidden lines, shading, texture, shadows, ambient occlusion. Shape from shading. Shape from texture.	LC, LW
		8.2	Determining the shape of objects based on one feature	Shape from X Method. Photometric Stereo. Shape Reconstruction from Silhouette.	LC, LW
		8.3	Vanishing Points. Movement-Related Features	Vanishing points as perspective indicators. Depth reconstruction based on camera movement (structure from motion). Triangulation.	LC, LW
		8.4	Contours and virtual lines. Depth estimation using a stereoscopic system.	Contour lines. Epipolar geometry. Stereo matching. Disparity map. Triangulation. 3D scene reconstruction.	LC, LW

* - to be completed only for FULL-TIME education: LC – lectures; LW – laboratory work; SC – practical/seminar classes.

6. LOGISTIC AND TECHNICAL SUPPORT OF DISCIPLINE

Table 6.1. Material and technical support for the discipline

Audience type	Equipment of the auditorium	Specialized educational/laboratory equipment, software and materials for mastering the discipline (if necessary)
Lecture	A lecture hall equipped with specialized furniture, a whiteboard (screen), and multimedia presentation equipment.	
Computer class	A computer room for conducting classes, group and individual consultations, ongoing monitoring and midterm assessment, equipped with personal computers (in the amount of ____ units), a board (screen) and technical means for multimedia presentations.	
For independent work	A classroom for independent student work (can be used for seminars and consultations), equipped with a set of specialized furniture and computers with access to the Electronic Information System.	

* - the classroom for independent work of students MUST be indicated!

7. EDUCATIONAL, METHODOLOGICAL AND INFORMATIONAL SUPPORT OF THE DISCIPLINE

Main literature:

1. Shapiro L. Computer vision / L. Shapiro, J. Stockman; trans. from English. - M.: ¶BINOM. Laboratory of knowledge, 2006. - 752 p.: ill., [8] p. color incl. - (Best foreign ¶textbook)

2. Donald Hearn, M. Pauline Baker. Computer Graphics and the OpenGL Standard, 3rd edition. : Trans. from English. - Moscow: Williams Publishing House, 2005. - 1168 p. (+48 p. color ill.): ill. Access mode: https://yadi.sk/i/J54teYDc3Pnc4s

3. Forsyth, David A., Pons, Jean. Computer vision. A modern approach. : Trans. from English. – M. : Williams Publishing House, 2004. – 928 p.: ill.

Further reading:

1. Potapov A. Computer vision systems: modern tasks and methods. – 2014. ¶– №1 (49). –CONTROL ENGINEERING RUSSIA, pp. 20-26. Access mode: ¶https://controleng.ru/wp-content/uploads/CE_149_sistemy_kompyuternogo_zreniya.pdf

2. Fisenko, V. T. Computer processing and image recognition: a tutorial / V. T. Fisenko, T. Yu. Fisenko. - St. Petersburg: St. Petersburg State University of Information Technologies, Mechanics and Optics, 2008 - 192 p. Access mode: http://pzs.dstu.dp.ua/ComputerGraphics/bibl/fisenko.pdf

Resources of the information and telecommunications network "Internet":

1. RUDN University Electronic Library System and third-party electronic library systems to which university students have access based on concluded agreements

- RUDN University Electronic Library System – RUDN University Electronic Library System https://mega.rudn.ru/MegaPro/Web
- Electronic Library System "University Library Online" http://www.biblioclub.ru

- EBS Yurayt http://www.biblio-online.ru
- Electronic Library System "Student Consultant" www.studentlibrary.ru
- EBS “Knowledge” https://znanium.ru/

2. Databases and search engines
   - Sage https://journals.sagepub.com/
   - Springer Nature Link https://link.springer.com/
   - Wiley Journal Database https://onlinelibrary.wiley.com/
   - Scientometric database Lens.org https://www.lens.org

Educational and methodological materials for independent work of students in mastering a discipline/module:*

1. Lecture course on the subject "Virtual reality and computer vision".

* - all teaching and methodological materials for independent work of students are posted in accordance with the current procedure on the discipline page in TUIS!

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