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:

01.04.02 APPLIED MATHEMATICS AND INFORMATICS

(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):

SPACE MISSION AND SYSTEM DESIGN

(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 "Space mission and system design" in the 01.04.02 "Applied Mathematics and Informatics" major 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)
UC-7	Able to search for relevant sources of information and data, perceive, analyze, memorize, and transmit information using digital tools, as well as algorithms when working with data obtained from various sources in order to effectively use the information obtained to solve problems; evaluate information, its reliability, and draw logical conclusions based on incoming information and data	UC-7.1 Searches for the necessary sources of information and data, perceives, analyzes, remembers and transmits information using digital means, as well as with the help of algorithms when working with data obtained from various sources in order to effectively use the information received to solve problems; UC-7.2 Conducts an assessment of information, its reliability, builds logical conclusions based on incoming information and data.;
PC-1	Able to formulate goals and objectives of scientific research in the field of applied mathematics and computer science, computer technology and modern programming technologies, and select methods and means for solving problems	PC-1.1 Possesses fundamental knowledge obtained in the field of mathematical and (or) natural sciences, programming and information technology; PC-1.2 Able to find, formulate and solve standard problems in his own research activities in the field of applied mathematics and computer science, computer technology and modern programming technologies; PC-1.3 Has practical experience in research activities in the field of applied mathematics and computer science, computer engineering and modern programming technologies.;
PC-2	Able to apply modern theoretical and experimental methods for developing mathematical models of objects and processes under study related to professional activities in the field of training and participate in their implementation in the form of software products	PC-2.1 Knows modern theoretical and experimental methods for developing mathematical models, innovative design tools and elements of architectural solutions for information systems; PC-2.2 Able to develop and implement algorithms for mathematical models based on languages and packages of applied modeling programs; PC-2.3 Has practical experience in developing options for implementing information systems using innovative tools.

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

Course "Virtual Reality and Computer Vision" refers to the part formed by the participants of educational relations 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***
UC-7	Able to search for relevant sources of information and data, perceive, analyze, memorize, and transmit information using digital tools, as well as algorithms when working with data obtained from various sources in order to effectively use the information obtained to solve problems; evaluate information, its reliability, and draw logical conclusions based on incoming information and data		Advanced Methods of Remote Sensing and Geoinformation Systems; Web Application Development and Security; Practical Training and Research in Dynamics and Control of Space Systems (online from RUDN Mission Control Center) / Research work; Technological Training; Pre-Graduation Internship in Industry;
PC-1	Able to formulate goals and objectives of scientific research in the field of applied mathematics and computer science, computer technology and modern programming technologies, and select methods and means for solving problems		Pre-Graduation Internship in Industry; Practical Training in Receiving Remote Sensing Data from Satellites and its Interpretation (online from RUDN Mission Control Center) / Research; Practical Training and Research in Dynamics and Control of Space Systems (online from RUDN Mission Control Center) / Research work; Technological Training; Advanced Methods of Remote Sensing and Geoinformation Systems; System Design; Dynamics and Control of Space Systems;
PC-2	Able to apply modern theoretical and experimental methods for developing mathematical models of objects and processes under study related to professional activities in the field of training and participate in their implementation in the form of software products		Advanced Methods of Remote Sensing and Geoinformation Systems; System Design; Project "Drone Systems Engineering. Part 1"; Pre-Graduation Internship in Industry; Practical Training in Receiving Remote Sensing Data from Satellites and its Interpretation (online from RUDN Mission

Cipher	Name of competence	Previous courses/modules, practical training*	Subsequent disciplines/modules, practices*
			Control Center) / Research; Practical Training and Research in Dynamics and Control of Space Systems (online from RUDN Mission Control Center) / Research work; Technological 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 4 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	*20*		*20*
Lectures (LC)	10		10
Laboratory work (LW)	10		10
Practical/seminar classes (SC)	0		0
Independent work of students, academic hours	*88*		*88*
Control (exam/test with assessment), academic hours	*36*		*36*
Total complexity of the discipline	**academic hours**	***144***	*144*
	credit	***4***	*4*

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, LW
		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, LW
		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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