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

**Academy of Engineering**

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

## **WORKING PROGRAM OF THE DISCIPLINE**

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**ADVANCE PYTHON PROGRAMMING FOR SPATIAL ANALYTICS**

(name of discipline/module)

**Recommended for the field of study/specialty:**

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**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):**

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**Artificial Intelligence, Machine Learning, and Space Science**

(name (profile/specialization) of the educational institution of higher education)

## 1. THE GOAL OF MASTERING THE DISCIPLINE

The course "Advance Python Programming for Spatial Analytics " is part of the "Artificial Intelligence, Machine Learning, and Space Sciences" master's program, major 27.04.04 "Control in Technical Systems," and is studied in the second semester of the first year. The course is offered by the department of the partner university. It consists of four sections and ten topics and focuses on tools and methods for designing big geodata processing pipelines and optimizing computations through parallelization and acceleration.

The goal of this course is to develop skills in developing high-performance geoanalytical solutions in Python, mastering advanced methods of processing raster/vector data and spatial modeling, and preparing for the creation of complex GIS applications using modern technology stacks.

## 2. REQUIREMENTS FOR THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the course "Advanced Python Programming for Spatial Analytics" 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)*

<b>Cipher</b>	<b>Competence</b>	<b>Indicators of Competency Achievement (within this discipline)</b>
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 conducting experiments at existing facilities; GPC-9.3 Has the skills to develop methods and conduct experiments at existing facilities with processing of results using information technology;
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	PC-3.1 Able to analyze the results of theoretical and experimental 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 INSTITUTION

Course "Advanced Python Programming for Spatial Analytics" 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 learning outcomes of the course "Advanced Python Programming for Spatial Analytics."

*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*

<b>Cipher</b>	<b>Name of competence</b>	<b>Previous courses/modules, practical training*</b>	<b>Subsequent disciplines/modules, practices*</b>
GPC-9	Capable of developing meth-	Introduction to Geospatial	Dynamics and Control of

<b>Cipher</b>	<b>Name of competence</b>	<b>Previous courses/modules, practical training*</b>	<b>Subsequent disciplines/modules, practices*</b>
	ods and performing experiments at existing facilities with processing of results based on information technology and technical means	Technology;	Space Systems; Geoinformation Systems and Applications; Undergraduate practice / Pre-graduation practice;
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	Introduction to Geospatial Technology;	Undergraduate practice / Pre-graduation practice;

\* - 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 "Advanced Python Programming for Spatial Analytics" 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)
			2
<i>Contact work, academic hours</i>	34		34
Lectures (LC)	17		17
Laboratory work (LW)	17		17
Practical/seminar classes (SC)	0		0
<i>Independent work of students, academic hours</i>	83		83
<i>Control (exam/test with assessment), academic hours</i>	27		27
<b>Total complexity of the discipline</b>	<b>academic hours</b>	<b>144</b>	<b>144</b>
	<b>credit</b>	<b>4</b>	<b>4</b>

## 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	Advanced spatial analysis libraries	1.1	<ul style="list-style-type: none"> <li>- Geoprocessing:</li> <li>- geopandas (spatial joins, overlay operations)</li> <li>- rasterio + xarray (working with multidimensional raster data)</li> </ul>	Using the GeoPandas library to perform spatial operations. Spatial joins for combining data based on geographic location. Overlay operations: intersection, union, difference, and symmetric difference of spatial features. Working with raster and vector data.	LC, LW
		1.2	<ul style="list-style-type: none"> <li>- *Performance:</li> <li>- Vectorization of operations with numba</li> <li>- Parallel processing with dask-geopandas</li> </ul>	Optimizing computational processes when working with large spatial data. Vectorization of operations using the Numba library to speed up code execution. Parallel computing and the use of just-in-time (JIT) compilation. Comparative performance analysis of standard and optimized solutions.	LC, LW
		1.3	<ul style="list-style-type: none"> <li>- Graphs and visualization:</li> <li>- Interactive maps (folium, ipyleaflet)</li> <li>- 3D visualization of relief (pyvista)</li> </ul>	Create interactive maps and geographic visualizations. Use the Folium and ipyleaflet libraries to build dynamic maps with zoom, pan, and interaction capabilities. Add layers, markers, popups, and manage display styles. Integrate interactive maps into web applications and Jupyter Notebooks.	LC, LW
Section 2	Spatial databases and clouds	2.1	<ul style="list-style-type: none"> <li>- PostgreSQL/PostGIS:</li> <li>- Optimization of spatial queries</li> <li>- Integration with Python (geoalchemy2, asyncpg)</li> </ul>	Connecting to spatial databases from Python. Executing spatial queries in PostGIS. Optimizing spatial queries: using spatial indexes (GIST), working with geometric and geographic data types. Converting between GeoDataFrame and PostGIS tables.	LC, LW
		2.2	<ul style="list-style-type: none"> <li>- Cloud platforms:</li> <li>- Working with Google Earth Engine API</li> <li>- Deploying pipelines on AWS Batch</li> </ul>	Working with cloud platforms for spatial analysis. Using the Google Earth Engine API to access multi-petabyte catalogs of satellite imagery and geospatial datasets. Performing computations in the cloud. Authorization, data loading, applying spectral indices, and exporting results. Comparison with local computations.	LC, LW
Section 3	Specialized applications	3.1	<ul style="list-style-type: none"> <li>- Analysis of changes:</li> <li>- Change detection from satellite images (rasterstats, scikit-image)</li> </ul>	Change detection using satellite imagery. Using the rasterstats library to extract statistics from raster data. Applying scikit-image methods to detect differences between images taken at different times. Creating change maps, thresholding, and assessing detection accuracy.	LC, LW
		3.2	<ul style="list-style-type: none"> <li>- Urban analytics:</li> <li>- Calculation of service availability (isochrones with osmnx)</li> <li>- Traffic flow modeling (sumo-py)</li> </ul>	Calculating the accessibility of urban services and infrastructure. Creating isochrones – zones of accessibility based on time or distance. Using the OSMnx library to load, model, and analyze street networks from OpenStreetMap. Visualizing isochrones on maps.	LC, LW

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
				Applications include assessing transport accessibility and the placement of social infrastructure.	
		3.3	- Natural risks: - Flood forecasting with hydrological models (pysheds)	Flood forecasting and hydrological risk analysis. Using the pysheds library to extract river networks, determine flow directions, and calculate catchment areas based on digital elevation models. Water propagation modeling. Integration with precipitation data and floodplain assessment.	LC, LW
Section 4	Development of GIS applications	4.1	- Web GIS: - Dashboard creation (Dash + Plotly) - Geoservices on Flask/FastAPI	Create web applications and dashboards for spatial data. Use the Dash library with Plotly to build interactive geographic visualizations. Integrate maps, charts, tables, and controls into a single interface. Publish dashboards and make them accessible via a web browser.	LC, LW
		4.2	- Architecture: - Microservices for spatial analytics - Deployment to Docker/Kubernetes	Designing scalable spatial analytics solutions using a microservices architecture. Separating functionality into independent services: data loading, processing, visualization, and storage. Interaction between microservices via APIs. Benefits and challenges of a microservices approach in the context of GIS and spatial data. Examples of architectural solutions for large geospatial systems.	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. McClain BP Python for geospatial data analysis. – "O'Reilly Media, Inc.", 2022.
2. Lawhead J. Learning geospatial analysis with Python. – Packt Publishing Ltd, 2015.

### Further reading:

1. Herndon KE et al. Google Earth Engine for archaeologists: An updated look at the progress and promise of remotely sensed big data //Journal of Archaeological Science: Reports. – 2023. –T. 50. – P. 104094.

2. Ngo TP et al. 3D Modeling of Geospatial Data Using PyVista: A Free and Open Source Framework //EAI International Conference on Renewable Energy and Sustainable Manufacturing. – Cham: Springer Nature Switzerland, 2023. –P. 739-755.

### 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 "Urayt" <http://www.biblio-online.ru>
- Electronic Library System "Student Consultant" [www.studentlibrary.ru](http://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 "Advanced Python programming for spatial analytics".

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

**DEVELOPER:**

Associate Professor

*Position, DEPARTMENT*

*Signature*

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Alexandrovna

*Surname I.O.*

**HEAD OF THE DEPARTMENT:**

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