**Федеральное государственное автономное образовательное учреждение высшего образования
"Национальный исследовательский университет
"Высшая школа экономики"**

Факультет компьютерных наук
Департамент программной инженерии

Рабочая программа дисциплины
«Разработка геоприложений»
("Geoapplications development")
(на английском языке)

для образовательной программы «Программная инженерия»
направления подготовки 09.03.04 «Программная инженерия»
уровень - бакалавр

Разработчик программы
Р.А. Родригес Залепинос, к.т.н., доцент, rodriges@wikience.org

Одобрена на заседании департамента программной инженерии «___»_____ 2018 г.
Руководитель департамента Авдошин С.М. _____

Утверждена Академическим советом образовательной программы
«___»_____ 2018 г., № протокола_____

Академический руководитель образовательной программы
Шилов В.В. _____

Москва, 2018

1. Course Description

1.1. Course Title, Type and Pre-requisites

The elective course "Geoapplications development" is offered to students of the Bachelor Program "Software Engineering", Computer Science Faculty (National Research University "Higher School of Economics") during the first half of the 3rd academic year (quartiles 1 and 2, one semester).

Total credits – 5, hours in total – 190 (lectures – 32, practical lessons – 32, self-study – 126).

One lecture per week is planned which is accompanied with one practical lesson. The students are expected to devote about 8 hours per week for self-study.

The course has the following assessments: intermediate (one control work at the end of the 1st quartile, two home assignments at both quartiles) and final (one exam at the end of the 2nd quartile).

The mandatory prerequisites for this course are:

- Java programming skills obtained during the course "Software Design" provided for students of the Bachelor Program "Software Engineering" of the Computer Science Faculty during the 2nd academic year in two semesters (1 – 4 quartiles);
- Good knowledge of English language (at least listening and reading, intermediate speaking) since the course is completely given in English.

The experience in desktop, mobile or web development before entering the course is not required but will give more convenience during practical lessons and homework assignment selection.

1.2. Course Abstract

This course gives programming experience with geospatial data as well as related core theory and algorithms. We will use Java and JavaScript to work with diverse libraries, spatial databases and servers to store, process, visualize and exchange geodata. The course is beneficial for any modern software developer due to explosive growth in popularity of geo-aware applications and services.

The knowledge from this course is useful in a broad range of industries which operate with geodata:
— environmental monitoring
— transportation
— urban planning
— agriculture
— insurance
— real estate sector
and many other practically important fields.

Geoapplication is the software program (software application) that works with geospatial data (maps, geographic coordinates, satellite data, etc.). A geoapplication may store, transmit, transform and visualize that data (it may not necessarily include all mentioned ways of geospatial data management).

The course is interdisciplinary in its nature, because:

- Gives programming experience with geospatial data from diverse subject domains (climate, satellite, urban, agriculture, railway, transportation and others);
- Stimulates to use knowledge and skills from other courses including "Software Design" (Java language and software design principles), "Database systems" (SQL and database management systems), "Computer Graphics" (2D and 3D visualization techniques), "Computer Networks" (data transmission) and others.

1.3. Course Site

The course site http://rgeo.wikience.org/ was specially set up to make lecture slides, sample geospatial data, source code for practical lessons, links to software tools and libraries, correct answers to control work and exam questions publicly available. The goal for this is twofold. First, maintaining high-quality course material on-line allows both to contribute to community resources and HSE reputation. Second, a student may add the course to their CV and use its material as a handbook later in future. The course trainer guarantees to keep up the course site as long as it is reasonably possible.

> *Item for student's CV:*
> Course "Geoapplications development": geospatial data storage, processing, visualization and exchange, 2016, http://rgeo.wikience.org/ (Higher School of Economics, Moscow)

1.4. Course Syllabus

This syllabus describes topics to be covered during the course, knowledge and skills that a student will gain after successful accomplishment of the course. It also regulates the assessment types and criteria for marking. The course embraces wide range of modern techniques for geospatial data representation including widely used spatial data file formats, servers that are specifically designed to store, process, disseminate and render spatial data. A considerable portion of the course is devoted to the ways of geospatial data delivery to end users including 2D and 3D visualization engines, corresponding network protocols and frameworks.

The syllabus is prepared for teachers responsible for the course (or closely related disciplines), teaching assistants, students enrolled on the course as well as experts and statutory bodies carrying out assigned or regular accreditations in accordance with

- Educational standards of the National Research University "Higher School of Economics" (HSE);
- Bachelor Program Curriculum "Software Engineering" (area code 09.03.04), 3rd year, 2016–2017 academic year;

2. Learning Objectives

The fundamental property of spatial data is the presence of geographic coordinates (latitude and longitude) as attributes for points (vector data) and cells (raster data). Coordinates locate the spatial data on the Earth's surface (additionally vertical and/or time dimensions may be used). Because of the many peculiarities that spatial coordinates have, specific techniques for their storage, processing and visualization have been designed in the last several decades. Those techniques aim to efficiently work with geospatial data and form a considerable body of knowledge that is briefly introduced in this course.

Upon the accomplishment of this course, a successful student should be able to design and implement parts of a geoapplication that are responsible for reading/writing diverse geospatial file formats, storing and querying geospatial data in database management systems or dedicated servers, transmitting data over the network and visualizing them in 2D or 3D.

3. Learning Outcomes

After completing "Geoapplication development" course, a successful student will:

- Have strong understanding of geospatial concepts and properties unique to geospatial data;
- Be able to programmatically access, transfer, process and visualize geospatial data;
- Acquire skills and experience in modern technologies related to geoapplication development.

A successful student should:

Know:
- The differences between main spatial coordinate systems and their peculiarities;
- The structure of the most common file formats used to store geospatial data;
- Most widely used servers used to store, process and disseminate geospatial data;
- Key elements of the network protocols for geospatial data exchange;
- Basic API features of Web mapping services.

Be able to:
- Read/Write geospatial data programmatically from/to most common file formats used to store geospatial data using corresponding software libraries;
- Programmatically access and issue queries to most widely used servers used to store, process and disseminate geospatial data;
- Design custom network protocol for geospatial data exchange;
- Visualize geospatial data on the Web using a Web mapping service.

Acquire experience in:
- Programmatic work with diverse types of geospatial data;
- Use software libraries and servers to programmatically manage geospatial data.

This course forms the competencies (according to the educational standards of National Research University "Higher Schools of Economics" – 09.03.04 "Software Engineering", Bachelor level, protocol approved on 30.01.2015, №1) described in the table below. More detailed description of the theory and practice that form the listed competencies as well as evaluation criteria are given in the corresponding sections of this syllabus (Course Plan and Course Assessment).

Competencies marked with * (asterisk) are optional and are formed in case student chooses optional activity (see "Alternative ways of assessments" section in this syllabus). The experience from previous academic year (this discipline lasted the whole year during 2015 – 2016) shows that over 80% of students form teams expressing the will to acquire optional competencies.

Competency code	Competency description	The way in which "Geoapplications development" course forms the competency
I. Universal competencies		
УК-1, СК-Б1	Able to learn, acquire new knowledge, skills, including in the area other than the professional	In addition to other material, this course gives knowledge of coordinate reference systems, cartographic projections, geo-referencing and software (GIS) that come from geodesy and cartography (see topic "Coordinates").
УК-3, СК-Б4	Able to solve problems in professional activities on the basis of the analysis and synthesis	– This course is divided onto sections covering wide variety of methods and tools for geospatial data management including storage, exchange, visualization and others. – The course also contains lessons covering generic operations on geospatial raster and vector data. Both provide "bricks" that should be used for synthesizing a software solution to complex geospatial data processing tasks. This could be achieved by analyzing and dividing the given complex task (e.g. homework assignment) onto a sequence of simpler tasks.

Competency code	Competency description	The way in which "Geoapplications development" course forms the competency
УК-5, СК-Б6	Able to work with the information: locate, evaluate and use information from different sources necessary for solving scientific and professional problems (including on the basis of the system approach)	To successfully complete homework assignments, students have to find information about the geospatial data they will use for their project and understand the data. They also need to find the appropriate ways (usually seek for on-line documentation) to manage the data (store, read, exchange, etc.)
УК-6, СК-Б7 *	Able to carry out research, including the analysis of the lems, setting goals and objectives, selecting object and subject of the study, choose research methods, and assess quality of the resulting research	In case of student chooses to do a research (see "Alternative ways of assessments" section in this syllabus).
УК-7, СК-Б8 *	Able to work in a team	Teamwork is highly encouraged to complete final homework assignment but is not mandatory. It is expected that about 50% of students or more will form teams.
II. Professional competencies		
Research activity		
ПК-1, ИК-1 *	Able to apply the basic concepts, principles, theories and facts related to computer science to solve research problems	In case of student chooses to do a research (see "Alternative ways of assessments" section in this syllabus).
ПК-5, ИК-5 *	Able to prepare presentations, scientific and technical reports on the results of the work performed, publish research results in the form of articles/reports/papers on scientific conferences	In case of student chooses to do a research (see "Alternative ways of assessments" section in this syllabus).
Analytical activity		
ПК-6, ИК-6	Able to formalize the subject area of software project and develop specifications for software components	Homework assignments involve programmatic working with geospatial data in diverse subject domains. This requires understanding and formalizing the subject area.
ПК-8, ИК-8 *	Able to prepare commercial offers with solution versions	Students are encouraged to form a startup which involves working with geospatial data (see "Alternative ways of assessments" section in this syllabus).
Project activity:		
ПК-9, ИК-9	Able to create ware for computers and systems of different architecture	The main cross-platform technology used in this course is Java. Software under it runs on diverse platforms without modifications in most cases (MacOS, Linux, Windows). Networking technologies that are covered within this course are also platform interoperable. Students are aslo encouraged to choose homework projects for Web and

Competency code	Competency description	The way in which "Geoapplications development" course forms the competency
		Mobile platforms.
ПК-10, ИК-10	Able to design, construct and test software	Homework assignments should meet careful design and testing state-of-the-art criteria. Test-driven approach via JUnit or TestNg frameworks or other (depending on the language) for quality assurance (QA) should be exploited.
ПК-11, ИК-11	Able to read, understand and highlight the main idea ter reading source code and software documentation	Since the course involves programming and mastering new software libraries, some exam and control work questions are based on the knowledge of source code and documentation of the software tools covered during the course.
Technological activity		
ПК-15, ИК-15	Able to use operating systems, network technology, software interface development tools, use languages and methods for formal specification, database management systems	– students gain experience in generic high-performance network frameworks (they are not limited only to geospatial data exchange over the network): Apache Mina, Netty, Java Sockets – students learn PostGIS, h2gis that are built on top of the several most popular databases to date: PostgreSQL and h2
ПК-16, ИК-16	Able to use diverse software development technologies	Students use during the course (not limited to): object-oriented design, test-driven development, version control systems, Web and Mobile development technologies (depending on the selected topic) and other technologies.
Development activity:		
ПК-17, ИК-17	Able to use basic techniques and software development tools	Students use the following techniques and software development tools for their practical lessons and homework assignments (incomplete list): * Rapid Application Development (RAD): IntelliJ IDEA or Eclipse; * Project build managers: Maven/Gradle.

4. Course Plan

4.1. Course Outline

Students should devote self-study hours to learning material for self-study (about 15–35% of the material from each topic), doing their homework, control work, and exam preparation.

№	Topic name	Course hours, total	Audience hours		Self-study
			Lectures	Practical lessons	
Module 1					
1	Introduction to Spatial Data Management	4	2	2	0
2	Coordinates	4	2	2	10
3	Spatial raster data formats	4	2	2	8
4	Processing spatial raster data	8	4	4	14
5	Spatial vector data formats	4	2	2	10
6	Processing spatial vector data	8	4	4	18
Subtotal:		**32**	**16**	**16**	**60**
Module 2					
7	Spatial vector data management systems	4	2	2	8
8	Spatial raster data management systems	4	2	2	8
9	Visualizing geospatial data in 3D	4	2	2	8
10	Frameworks for rapid development of a geoapplication back-end	4	2	2	8
11	Network protocols to exchange spatial data	4	2	2	10
12	Spatial data on the Web	4	2	2	10
13	Overview of spatial networks and positioning systems	4	2	2	6
14	Recent trends in spatial data management and geoapplications development	4	2	2	8
Subtotal:		**32**	**16**	**16**	**66**
Total:		**64**	**32**	**32**	**126**

Lecture slides are made publicly available at the beginning of each lecture at the course site http://rgeo.wikience.org/ The slides will contain more links to additional Web resources (readings, documentation, tools). Students who experience difficulties in watching the presentation from laser projector should download the slides onto their own laptops or a class PC to be able to comfortably track the lecture.

Information about the geospatial data required for practical lessons, software tools (links to web sites) and libraries (Maven dependencies to be added to project's pom.xml) are published at the course site the day before each practical lesson: http://rgeo.wikience.org/ Students are encouraged to install software tools, resolve Maven dependencies for libraries and download all necessary data before attending classes to save time.

The source code in Java, R, JavaScript, and other languages that is demonstrated during practical lessons will be also publicly available at the course web site http://rgeo.wikience.org/ for each lesson.

4.2. Topic-wise Course Content

Topic 1. Introduction to Spatial Data Management. Course goals, organization, and assessment types. The spatial data and their fundamental differences from other types of data. Two main types of geospatial data (raster and vector). Examples of geospatial data. The notion of georeferencing.

Main types of raster data: remote sensing imagery and numeric model output. Main types of vector data (point, polygon, line, etc.). Key software architecture elements of a typical geoapplication. Where the spatial data are used: examples of geoapplications. Russian and foreign companies that seek developers of geoapplications. Competitions and projects to participate (alternative assessment types).

Introduction to GIS – Geographical Information Systems (during practical lessons): form feeling of sample vector and raster data and metadata using a GIS.

Main readings:
- Chapter 1: S. Shekhar and S. Chawla, Spatial Databases: A Tour, Prentice Hall, 2003. Some chapters (including 1) are available on-line: http://www.spatial.cs.umn.edu/Book/

Additional readings:
- What is raster ta? http://help.arcgis.com/EN/arcgisdesktop/10.0/help/index.html#//009t00000002000000

Geospatial data samples for practical lesson:
- Raster data: Landsat 8 satellite scene covering Moscow (or other place of interest), approximately 1Gb; download any cloud-free scene before attending classes from http://earthexplorer.usgs.gov/
- Vector data: please, find at course site: http://rgeo.wikience.org/

Tools for practical lesson:
- Quantum GIS (QGIS) is freely available at http://www.qgis.org/

Topic 2. Coordinates. Goals of 2D maps creation. Map projection chain (Earth, geoid, spheroid, developable surface, map projection). Datum and its components. Coordinate Reference System (CRS) and its components. Why different coordinate reference systems exist. Spherical orthogonal geographic coordinate system (latitude/longitude), coordinate representation and its peculiarities (distance calculations, convergence at poles, dateline crossing issues). Floating point arithmetic peculiarities with geographical coordinates.

Common Earth ellipsoids, datum, coordinate systems, coordinates, projections. World Geodetic System 1984 (WGS84). Geographic/geodetic/geodesic coordinates. Unprojected data, plate carrée or geographic projection. Universal Transverse Mercator (UTM) projection. Other cartographic projections (geodetic) and their use cases. CRS used in Google Maps and other popular services.

EPSG database. CRS representation formats (PROJ.4, OGC WKT) with examples. CRS transformations, projecting and unprojecting data. Work with geospatial data in different projections. Software libraries facilitating CRS management.

Notes on existing ambiguities in terminology. Short vocabulary of the given terminology.

Main readings:
- M. Neteler, H. Mitasova, Open Source GIS: A GRASS GIS Approach. Third Edition, Springer, New York, 2008. Some chapters are available on-line: http://grassbook.org/ (see chapters on introduction to raster and vector data)
- Лебедева О.А., Картографические проекции (методическое пособие), Новосибирский учебно-методический центр по ГИС и ДЗ, Новосибирск, 2000 (in Russian)

Additional readings:
- WGS84, https://en.wikipedia.org/wiki/World_Geodetic_System
- Spheroid, https://en.wikipedia.org/wiki/Spheroid

- Geoid, https://en.wikipedia.org/wiki/Geoid
- Earth Ellipsoid, https://en.wikipedia.org/wiki/Earth_ellipsoid
- Reference Ellipsoid, https://en.wikipedia.org/wiki/Reference_ellipsoid
- Apache SIS and standards in Geospatial mation, http://events.linuxfoundation.org/sites/events/files/slides/2014-04.pdf
- OGC Standards, http://www.opengeospatial.org/standards/is
- WKT, http://www.geoapi.org/3.0/javadoc/org/opengis/referencing/doc-files/WKT.html
- WGS84, https://en.wikipedia.org/wiki/WGS_84
- EPSG, http://epsg.org, http://epsg.io
- Spatial Reference, http://spatialreference.org/

Topic 3. Spatial raster data formats. Agenda: open raster data in different file formats, read complete raster from a file, subset raster data by dimensions, subsetting types.

Geospatial raster data types (swaths, scenes, gridded data, global regular latitude-longitude grids, Gaussian and other types of grids). Raster metadata and their examples. Cell size of a geospatial raster. List of existing geospatial raster file formats with focus on GeoTIFF, BigTIFF, GeoPackage, HDF, NetCDF, Grib, XDR.

Software libraries used for spatial raster data input/output (GDAL, NetCDF, GeoTools, Apache SIS). Common Data Models (GDAL, Unidata CDM, ISO 19*** Data Model) and their architectures. Differences between data models and their storage schemes.

Main readings:
- S. Nativi, J. Caron, B. Domenico, L. Bigagli, Unidata's Common Data Model mapping to the ISO 19123 Data Model, Earth Sci Inform, № 1, P. 59–78, 2008.
- Unidata Common Data el, http://www.unidata.ucar.edu/software/thredds/current/netcdf-java/CDM/
- GDAL Data Model, http://www.gdal.org/gdal_datamodel.html
- NetCDF, http://www.unidata.ucar.edu/downloads/netcdf
- Reading NetCDF, http://www.unidata.ucar.edu/software/thredds/current/netcdf-java/tutorial/GridDatatype.html
- GDAL, http://www.gdal.org

Additional readings:
- GeoTIFF, https://trac.osgeo.org/geotiff/
- BigTIFF, http://www.awaresystems.be/imaging/tiff/bigtiff.html
- GeoPackage, http://www.geopackage.org/
- NetCDF usage, http://www.unidata.ucar.edu/software/netcdf/usage.html
- HDF 5 Documentation, http://www.hdfgroup.org/HDF5/doc/
- HDF description, https://ru.wikipedia.org/wiki/Hierarchical_Data_Format

Topic 4. Processing spatial raster data. Classes of raster operations. Map (raster) algebra: basic local, focal, zonal and global operations. Interpolation and its basic types. Resampling/regridding. Tiling and multilevel pyramid. Reclassification. Binning. Masking. Window. Correlation. Mosaicking. Reprojection. Affine transformation. Filtering. Radiometric and geometric enhancement. Edge sharpening and detection. Change detection. Image fusion, segmentation and classification. Raster data processing tools: R, ImageMagic, GDAL tools, Orfeo Toolbox, ImageJ, SAGA GIS.

Java Advanced Imaging (JAI), JAI-EXT by IT Solutions. Examples of raster processing with JAI. Case study: calculating NDVI (Normalized Difference Vegetation Index) using Java, JAI and Landsat 8 satellite data.

Main readings:
- Survey chapters: A. Gutierrez, Applying OLAP Pre-Aggregation Techniques to Speed Up Aggregate Query Processing in Array Databases, PhD thesis, 2010.

- Chapter 5: J. Richards, Remote Sensing Digital Image Analysis / [5-th ed.]. — Germany. : Springer-Verlag Berlin Heidelberg, 2013. — 503 p.
- M. Neteler, H. Mitasova, Open Source GIS: A GRASS GIS Approach. Third Edition, Springer, New York, 2008. Some chapters are available on-line: http://grassbook.org/ (see chapter on raster data processing)

Additional readings:
- JAI, https://en.wikipedia.org/wiki/Java_Advanced_Imaging
- GeoSolutions Technical Document: Optimizing Coverage Reprojection, http://demo.geo-solutions.it/share/OptimizingRasterReprojection.pdf (accessed 04 Dec. 2015)
- Лебедева О.А., Картографические проекции (методическое пособие), Новосибир-ский учебно-методический центр по ГИС и ДЗ, Новосибирск, 2000 (in Russian)
- Simonetti D. et al., First Results From the Phenology-Based Synthesis Classifier Using Landsat 8 Imagery // IEEE Geoscience and Remote Sensing Letters, Vol. 12, № 7, 2015.
- GIS-Lab: Создание мозаик изображений в ERDAS IMAGINE, http://gis-lab.info/qa/mosaic.html (in Russian)
- ImageJ, http://imagej.nih.gov/ij/
- ImageMagic, http://www.imagemagick.org/
- Landsat satellite, https://ru.wikipedia.org/wiki/Landsat
- Terra satellite, http://terra.nasa.gov/
- SAGA GIS, http://www.saga-gis.org

Topic 5. Spatial vector data formats. Agenda: open vector data in different file formats, iterate over features, filter features. List of existing geospatial vector file formats with focus on SHP, WKT, KML, KMZ, GML, and GeoJSON. Well Known Text (WKT) features and their syntax. Geospatial vector data structure (features, geometries, attributes, coordinate reference system). OpenStreetMap (OSM) data. Checking vector metadata with GDAL OGR. Reading programmatically vector data from a file using GeoTools. Java Topology Suite (JTS). Other software libraries used for geospatial vector data input/output (Geotoolkit, Apache SIS).

Main readings:
- KML, https://ru.wikipedia.org/wiki/KML
- WKT, http://en.wikipedia.org/wiki/Well-known_text
- OpenStreetMap (OSM), https://en.wikipedia.org/wiki/OpenStreetMap
- OGC Standards, http://www.opengeospatial.org/standards/is
- Java Topology Suite, http://www.vividsolutions.com/jts/JTSHome.htm

Additional readings:
- GeoJSON specification, http://gis-lab.info/docs/geojson_ru.html (in Russian)
- KML specification, https://developers.google.com/kml/
- OGC KML specification, http://www.opengeospatial.org/standards/kml
- GDAL OGR, http://www.gdal.org
- GeoToolkit, http://www.geotoolkit.org/
- Apache SIS, http://sis.apache.org/
- JTS C++ port, https://trac.osgeo.org/geos/

Geospatial data samples for practical lesson:
- Please, find sample data in SHP, KML and GeoJSON formats at course site: http://rgeo.wikience.org/

Topic 6. Processing spatial vector data. Core geometry types according to OGC/ISO standards. Implementation of standards by OpenGIS and Java Topology Suite (JTS). JTS TestBuilder. WKT Specification for geometries. Geometry validation. Basic types of operations on vector data. Set-oriented

operations (union, intersect, difference). Reprojection. Buffering. Affine transformations. Line simplification. Using Java Topology Suite (JTS) to perform operations on geometries.

Topology. Topological properties. Deviations from general topology (border, exterior and interior definitions). Egenhofer matrix model. Topological relationships (contains, covers, intersects, touches, crosses, etc.). Peculiarities of topological relationships.

Indexing vector data and spatial data structures (bounding boxes, R-Tree, GeoHash).

Main readings:
- Chapter 2: S. Shekhar and S. Chawla, Spatial Databases: A Tour, Prentice Hall, 2003. Some chapters are available on-line: http://www.spatial.cs.umn.edu/Book/
- M. Neteler, H. Mitasova, Open Source GIS: A GRASS GIS Approach. Third Edition, Springer, New York, 2008. Some chapters are available on-line: http://grassbook.org/ (see chapter on vector data processing)
- JTS TestBuilder and Java Topology Suite (JTS), also see JTS source code: http://www.vividsolutions.com/jts/JTSHome.htm
- Egenhofer matrix model, https://en.wikipedia.org/wiki/DE-9IM
- OGC specifications, http://www.opengeospatial.org/standards/sfa

Additional readings:
- GeoHash, https://en.wikipedia.org/wiki/Geohash
- R-Tree, https://en.wikipedia.org/wiki/R-tree

Topic 7. Spatial vector data management systems. Spatial queries: motivating examples (demonstrate diversity and challenges in storing and efficient subsetting of geospatial vector data).

Spatial database management system (SDBMS). Popular SDBMS: PostgreSQL and PostGIS, h2 and h2gis, MongoDB spatial extensions, SQLite and SpatiaLite. Mobile GIS data collectors.

Spatial SQL (SQL extension to deal with spatial vector data), basic spatial SQL statements, spatial data types, objects, and functions. Java DataBase Connectivity (JDBC). Programmatic access to geospatial vector data stored in databases using Java.

Main readings:
- Chapter 2: S. Shekhar and S. Chawla, Spatial Databases: A Tour, Prentice Hall, 2003. Some chapters are available on-line: http://www.spatial.cs.umn.edu/Book/
- "OGC Simple Features" – OpenGIS Implementation Specification for Geographic information – Simple feature access – Part 2: SQL tion, http://www.opengeospatial.org/standards/sfs

Additional readings:
- H2gis, www.h2gis.org
- PostGIS features, http://postgis.net/features
- PostGIS documentation, http://postgis.net/documentation
- SpatiaLite, http://www.gaia-gis.it/gaia-sins/
- Ralf Hartmut Güting, An Introduction to Spatial Database Systems, http://dna.fernuni-hagen.de/papers/IntroSpatialDBMS.pdf and *www.di.unipi.it/~confor/talks/SDBMS.ppt*
- Tatyana Budanskaya, Spatial Databases and Spatial Data ment, http://cs.njit.edu/cis731s06/presentations/budanskaya_CS731.pdf
- Mobile data collectors survey, http://www.50northspatial.org/8-mobile-geodata-collectors-android/
- NextGIS SDK for OS Android, http://gisconf.ru/pres/1_22_1800_petryakov.pdf

Topic 8. Spatial raster data management systems. Challenges in storing spatial raster data. Main approaches to store spatial raster data (file-based, BLOB-based).

Raster data dissemination: THREDDS, GeoServer, MapServer, Mapnik, NextGIS, ArcGIS Image Server. Spatial queries to access spatial raster data (coverage requests).

Raster data processing: PostGIS in-db and out-db rasters, RasDaMan, SciDB. SQL raster extensions, SQL raster data processing queries.

Main readings:
- THREDDS, http://www.unidata.ucar.edu/software/thredds/current/tds/TDS.html
- GeoServer, http://geoserver.org/
- Mapserver, http://mapserver.org/
- Mapnik, http://mapnik.org/
- RasDaMan, http://live.osgeo.org/ru/quickstart/rasdaman_quickstart.html
- NextGIS Web, http://docs.nextgis.ru/docs_ngweb/source/layers.html#id2
- SciDB, http://www.paradigm4.com/
- M. Stonebraker, P. Brown, A. Poliakov, S. Raman, The Architecture of SciDB, Scientific and Statistical Database Management, Volume 6809 of the LNCS, P. 1–16.

Additional readings:
- S. Shekhar and S. Chawla, Spatial Databases: A Tour, Prentice Hall, 2003.

Topic 9. Visualizing geospatial data in 3D. Virtual globes: NASA WorldWind, Google Earth, Cesium. Capabilities of a virtual globe not present in 2D maps. Differences between OpenGL, JOGL (Java OpenGL), WebGL.

Generic architecture for visualizing geospatial data. Experience in designing and implementing Climate Wikience. Analysis of several existing 3D geoapplications. Brief Java Swing revision. Sample Java geoapplication to visualize spatial data in 3D using NASA WorldWind and Cesium.

Main readings:
- Cesium, https://cesiumjs.org/
- NASA WorldWind, http://goworldwind.org/demos/
- WorldWind WebGL implementation, http://webworldwind.org/
- Climate Wikience, http://climate.wikience.org/
- WorldWind sources, https://github.com/unofficial-nasa

Additional readings:
- Rodriges Zalipynis R.A., Ivashchuk O.A, Konstantinov I.S., Modern Information Technologies in Environmental Sciences: Climate Wikience // IEEE 8th Intl. Conf. on Intelligent Data Acquisition and Advanced Computing Systems (IDAACS) Sept. 24–26, 2015, Warsaw, Poland.
- Cesium and OL3, http://openlayers.org/ol3-cesium/

Topic 10. Frameworks for rapid development of a geoapplication back-end. An interactive mapping service: goals and problems. Multi-user service problems. Sockets, networking fallacies. Blocking and non-blocking sockets, java.nio. Difficulties of handling multiple connections using blocking and non-blocking sockets. Example of Java application using plain sockets. Architecture of Netty and Apache Mina. Google Protocol Buffers, Apache Thrift and Avro. Designing custom multiuser server.

Main readings:
- Netty Documentation, http://netty.io/
- Mina Documentation, https://mina.apache.org/

Additional readings:
- N. Maurer, Netty in Action, http://topconsulting.ru/wp-content/uploads/2011/03/Netty-In-Action-V5.pdf (this book is freely available on-line)
- Google Protocol Buffers, http://developers.google.com/protocol-buffers/
- Apache Thrift, https://thrift.apache.org/
- Apache Mina conf. PDFs, https://mina.apache.org/mina-project/conferences.html
- Netty short guide, http://docs.jboss.org/netty/3.2/guide/pdf/netty.pdf

Topic 11. Network protocols to exchange spatial data. Definitions: network protocol, messages, event-driven architecture. Key elements of a typical protocol for spatial data access. OSI model. Protocols: WCS (Web Coverage Service), WFS (Web Feature Service), WPS (Web Processing Service), WMS (Web Mapping Service), TMS (Tile Map Service), OPeNDAP, REST API, custom protocols. Designing a custom network protocol for geospatial data exchange.

Main readings:
- WCS, WFS, WMS: http://gis-lab.info/qa/ows.html
- THREDDS description of WCS, https://www.unidata.ucar.edu/software/thredds/current/tds/reference/WCS.html

Additional readings:
- WFS on GIS-LAB, http://gis-lab.info/qa/wfs-begin.html (in Russian)
- ArcGIS resource http://server.arcgis.com/ru/server/latest/publish-services/linux/wcs-services.htm (in Russian)
- WCS in GeoServer, http://docs.geoserver.org/stable/en/user/services/wcs/reference.html
- WCS servers and clients, https://en.wikipedia.org/wiki/Web_Coverage_Service
- OPeNDAP, http://www.opendap.org/
- WPS, http://live.osgeo.org/ru/standards/wps_overview.html
- TMS, http://gis-lab.info/docs/tms-specification-ru.html (in sian), https://wiki.osgeo.org/wiki/Tile_Map_Service_Specification (in English)

REST API examples to geo-enabled services:
- ArcGIS REST Services, http://resources.arcgis.com/en/help/rest/apiref/
- NextGIS Web, http://docs.nextgis.ru/docs_ngweb_dev/doc/developer/toc.html
- CouchDB, http://www.gdal.org/drv_couchdb.html
- IBM Cloudant, http://www.gdal.org/drv_cloudant.html
- CartoDB, http://www.gdal.org/drv_cartodb.html

Topic 12. Spatial data on the Web.

Digital maps: Google Maps, Yandex Maps, OpenStreetMap. Sources of their data. Sample JavaScript geoapplication to visualize spatial data in Google Maps and Yandex Maps.

Leaflet, Mapbox, OpenLayers, CartoDB, ArcGIS Online, TileMill, CartoCSS. Capabilities, API survey. Publishing geospatial data on the Web. Ways of eye-candy presentation of spatial data. Sample web service delivering spatial data.

Main readings:
- Google Maps API, http://developers.google.com/maps/
- OpenStreetMap, http://gis-lab.info/qa/osmshp.html
- Yandex Maps API, https://api.yandex.ru/maps
- Mapbox for developers, https://www.mapbox.com/developers/
- TileMill, http://gis-lab.info/qa/tilemill-begin.html

Additional readings:
- Leaflet, http://leafletjs.com/

- OpenLayers, http://openlayers.org/
- CartoDB, https://cartodb.com/
- ArcGIS Online, http://www.esri.com/software/arcgis/arcgisonline
- Nathan Yau, Visualize This: The FlowingData Guide to Design, Visualization and Statistics, Floating data, Willey Publishing, 2011.
- Flowing Data, http://flowingdata.com
- Examples of vector data rendering algorithms: Alexander Wolff, Graph Drawing and Cartography, https://cs.brown.edu/~rt/gdhandbook/chapters/cartography.pdf
- Building Mapping Solutions with Esri Open Source jects, http://proceedings.esri.com/library/userconf/devsummit-dc14/papers/dsdc_12.pdf

Topic 13. Overview of spatial networks and positioning systems. Types of signal-based positioning. Overview of WiFi and Cellular Positioning. Indoor navigation and iBeacon. Overview of Global Positioning System (GPS) and GLONASS, their applications. GPS orbital, ground and user segments.

Introduction to Content-based Positioning. Geodriven content delivery, geoparsing. geocoding. Location-field Positioning. Geo-fence.

Spatial networks: examples, conceptual and mathematical models, algorithms.

Main readings:
- S. Shekhar, B. Hecht (University of Minnesota, U.S.), "From GPS and Google Earth to Spatial Computing": https://www.coursera.org/course/spatialcomputing

Additional readings:
- iBeacon, https://en.wikipedia.org/wiki/IBeacon
- Geo-fence, https://en.wikipedia.org/wiki/Geo-fence
- GPS, http://www.portativka.com/navigacija-nachinajuschih-a-46.html (in Russian)
- Glonass Vestnik, http://vestnik-glonass.ru/ (in Russian)
- Geoparsing, https://en.wikipedia.org/wiki/Geoparsing
- Geocoding, https://en.wikipedia.org/wiki/Geocoding
- P. Enge, F. van Diggelen (Stanford University), "GPS: An Introduction to Satellite Navigation, with an interactive Worldwide Laboratory using Smartphones": https://www.coursera.org/course/gpslab

Topic 14. Recent trends in spatial data management and geoapplications development. Spatial data mining. Unmanned Aerial Vehicles (UAV) and geo-aware software. Reconstructing urban environment using community photography. Augmented reality. Distributed systems: ChronosServer, Hadoop GeoMesa, GeoTrellis. Summary of the course.

Main readings:
- GeoConference 2015 Proceedings, http://gisconf.ru/materials
- Unmanned Aerial Vehicles, https://en.wikipedia.org/wiki/Unmanned_Aerial_Vehicles
- Augmented reality, https://en.wikipedia.org/wiki/Augmented_reality

Additional readings:
- R.A. Rodriges Zalipynis, ChronosServer: real-time access to "native" multi-terabyte retrospective data warehouse by thousands of concurrent clients, informatics, cybernetics and computing machinery, №14 (188), 2011. – 290 pp. – P. 151 – 161. http://www.wikience.org/chronosserver/
- Open Drone Map, http://opendronemap.github.io/odm/
- Mapillary, http://www.mapillary.com/
- S. Shekhar and S. Chawla, Spatial Databases: A Tour, Prentice Hall, 2003.
- Hadoop GeoMesa, www.geomesa.org
- GeoTrellis, http://geotrellis.io/

4.3. Topics for control work and final assessment

Any question targeted to check the understanding of any topic listed in "Detailed Course Content" section of this syllabus may be asked during the control work or the final exam. To answer the questions successfully, a student will need programming experience obtained during practical lessons in addition to lecture material.

At least two weeks before control work or exam, up to 20 minutes at a lecture or practical lesson will be devoted to "Test Preparation". This preparation is held in the form of joint (all students involved) answering (orally) sample questions similar to control work/exam questions. Please, find test preparation example at:
http://rgeo.wikience.org/pdf/tests/rgeo-course-TestPrepare01.pdf

Please, find control work/exam example at (correct answers are **in bold**):
http://rgeo.wikience.org/pdf/tests/rgeo-course-exam_example.pdf

It is highly recommended for a student to revise material using lecture slides and source code from practical lessons before they come to control work/exam.

It is also recommended to download all the lecture slides again before revision (from the course site), even if a student has downloaded all of them previously (e.g. each time classes start). This is because after the lecture the instructor reserves the right to make modifications to slides including the correction of possible mistakes (if any) and addition of answers to questions asked by students during the lecture or practical lesson to increase their understanding of the material and help them to prepare to the control work/exam.

4.4. Topics for homework assignments

4.4.1. Homework assignment 1

This assignment consists of a series of micro-homework targeted to geospatial software development. Students will receive a task on which they start working in class and finish the development at home. The tasks and requirements for them may be partially formulated in oral form by the instructor.

Please, find examples of topics at the end of lecture slides at the course site: http://rgeo.wikience.org/

4.4.2. Homework assignment 2

In addition to the topics listed, in the beginning of some lectures in quarters 1 and 2, up to 15 minutes will be devoted to "Data surveys". They are held in the form of PowerPoint presentations by the course instructor. Their goal is to present the students the wealth of diverse geospatial data from various subject domains as well as interesting tasks that could be solved using that data. The data are freely available on-line.

Students will have to do their homework assignments in quarter 3 or 4. Before they start doing their homework, they have to choose geospatial data and arrive at a task to be solved with the application they aim to develop. Geospatial data and its management techniques must be central to their work. However, since the area of geospatial data management is new to students they are not aware of the available geospatial data. Data surveys are held to give examples of both data and tasks.

Data surveys will cover climate reanalysis and Earth remote sensing data (including vegetation, air quality), digital elevation models, flood, drought, fires, hurricanes and other extreme events and other types of data. Please, find examples of data surveys at:

Homework topics are not limited to the data described in data surveys. Students may also seek the geospatial data and interesting tasks to solve for their homework assignments on their own.

Students are encouraged to form teams or choose working on a startup, or just interesting projects or research projects related to geospatial data management. Please, see "Alternative ways of assessment".

The topic for home assignment may be proposed by the course instructor, student (should be approved by the instructor), or worked out jointly with the instructor and a student (or group of students in case of teamwork).

In any case, before working on a chosen data and task, students should have their decision approved by the course instructor. The instructor may modify the task and/or data by some considerations including if he/she feels them unrealistic or too easy to implement. The final decision on which data and tasks are right for the homework is left to the sole discretion of the instructor.

In this course, students are highly encouraged to develop a complete and quality-assured geoapplication that can be useful to others, published on the Web, and/or demonstrated at programming competitions and/or personal portfolios.

4. Reading list

This section contains core required and optional reading for this course. Please, refer to "Course Plan" section of this syllabus which has detailed readings lists for each topic.

4.2. Required

- Paul A. Longley, Michael F. Goodchild, David J. Maguire, David W. Rhind, Geographic Information Science and Systems 4th Edition, Wiley, 496 P., 2016.
- Ningchuan Xiao, GIS Algorithms (SAGE Advances in Geographic Information Science and Technology Series) 1st Edition, SAGE Publications Ltd, 336 P., 2016.
- Thomas Lillesand, Ralph W. Kiefer, Jonathan Chipman, Remote Sensing and Image Interpretation 7th Edition, Wiley, 2015.
- Regina O. Obe, Leo S. Hsu, PostGIS in Action, 2nd Edition 2nd Edition, Manning Publications, 600 P., 2015.
- John R. Jensen, Ryan R. Jensen, Introductory Geographic Information Systems (Prentice Hall Series in Geographic Information Science) 1st Edition, Pearson, 432 P., 2012
- Kathryn Keranen, Robert Kolvoord, Making Spatial Decisions Using GIS and Remote Sensing: A Workbook, Esri Press, 300 P., 2013.
- John R. Jensen, Introductory Digital Image Processing: A Remote Sensing Perspective (4th Edition) (Pearson Series in Geographic Information Science) 4th Edition, Pearson, 544 P., 2015
- S. Shekhar and S. Chawla, Spatial Databases: A Tour, Prentice Hall, 2003. Some chapters are available on-line: http://www.spatial.cs.umn.edu/Book/
- M. Neteler, H. Mitasova, Open Source GIS: A GRASS GIS Approach. Third Edition, Springer, New York, 2008. Some chapters are available on-line: http://grassbook.org/
- Лебедева О.А., Картографические проекции (методическое пособие), Новосибирский учебно-методический центр по ГИС и ДЗ, Новосибирск, 2000 (in Russian)

- J. Richards, Remote Sensing Digital Image Analysis / [5-th ed.]. — Germany. : Springer-Verlag Berlin Heidelberg, 2013. — 503 p.
- A. Gutierrez, Applying OLAP Pre-Aggregation Techniques to Speed Up Aggregate Query Processing in Array Databases, PhD thesis, 2010.
- GeoTIFF, https://trac.osgeo.org/geotiff/
- KML, https://ru.wikipedia.org/wiki/KML
- GeoJSON, http://gis-lab.info/docs/geojson_ru.html
- WKT, http://en.wikipedia.org/wiki/Well-known_text
- Java Topology Suite (JTS), http://www.vividsolutions.com/jts/JTSHome.htm
- Google Protocol Buffers, http://developers.google.com/protocol-buffers/
- WCS, http://gis-lab.info/qa/ows.html
- WFS, http://gis-lab.info/qa/ows.html
- NASA WorldWind, http://goworldwind.org/demos
- Google Maps API, http://developers.google.com/maps/

4.2. Optional

- OGC Standards, http://www.opengeospatial.org/standards/is/
- Common Data Model, http://www.unidata.ucar.edu/software/thredds/current/netcdf-java/CDM/
- What is raster ta? http://help.arcgis.com/EN/arcgisdesktop/10.0/help/index.html#//009t00000002000000
- GeoTIFF, https://www.mapbox.com/tilemill/docs/guides/reprojecting-geotiff/
- Landsat satellite, https://ru.wikipedia.org/wiki/Landsat
- Terra satellite, http://terra.nasa.gov/
- Rodriges Zalipynis R.A. et al., Modern Information Technologies in Environmental Sciences: Climate Wikience // IEEE 8th Intl. Conf. on Intelligent Data Acquisition and Advanced Computing Systems (IDAACS) Sept. 24–26, 2015, Warsaw, Poland.
- Nathan Yau, Visualize This: The FlowingData Guide to Design, Visualization and Statistics Floating data, Willey Publishing, 2011.

5. Grading system

The 10-points scale is basic for all types of assessment. The contribution of each activity to the final grade is given in table below.

Activity Contribution Table

Code	Description	Contribution, %
LP	Lecture presence	20
PP	Work during practical lessons	5
CW	Control work	10
HA1	Home assignment 1	30
HA2	Home assignment 2	15
EX	Exam	20
TT	**Total contribution**	

The final grade is calculated according to TT:

Final Grade Calculation Table

Total contribution, %	Final grade
<= 10	0
<=15	1
20	2
30	3
40	4
50	5
60	6
70	7
80	8
90	9
over 95	10

LP and PP are simply the percent of classroom attendance by student expressed in percent (0% never attended, 100% attended all classes).

HA1 percent of accomplishment is calculated as $HA1PA = (T / N)$, where N is the total number of micro-assignments for HA1, and T is the sum of all assignments' marks that were evaluated higher than 5 by the instructor (10-points scale). $HA1 = HA1PA * 3$. The instructor gives 0 points for a micro-assignment that was not shown.

Please note, that the first homework assignment should be defended during a practical lesson within a defined deadline by the instructor (see corresponding section of this syllabus for more details).

Final grade conversion rules from 10-levels grade to 5-points grade is given in table below:

Conversion between 10-levels and 5-levels grading system

10-points scale	5-points scale
1 – unsatisfactory 2 – very bad 3 – bad	unsatisfactory – 2
4 – satisfactory 5 – quite satisfactory	satisfactory – 3
6 – good 7 – very good	good – 4
8 – almost excellent 9 – excellent 10 – brilliant	excellent – 5

If a student is late for a lecture or a practical lesson for more than 20 minutes they will be considered absent. It is prohibited to visit classes wearing shorts; a student will be considered absent in case of violation of this rule; in addition, it will be impossible to defend a home assignment. A home assignment cannot be defended during a break between classes. It is prohibited to use computers, mobile phones, Internet and anything else during lectures for not viewing lecture slides or during practical lessons for not practicing the programming assignment. The instructor will penalize students violating this requirement by subtracting scores from LP and PP. The final mark is rounded upwards. Other marks are being kept precise during the whole course.

6. Guidelines for Knowledge Assessment

6.1. Assessment types and forms

This course has two types of assessment (intermediate and final) with four forms of assessment (one control work, two home assignments, and one final exam). All types and forms of assessment influence on the final grade. The first and the only control work will be held at the end of the first module (quartile). The home assignments assume that a student will develop geoapplications based on the knowledge and experience gained during this course. The first home assignment goes through both quartiles and consists of small projects while the second home assignment is planned on the 2nd module (quartile) and is a single geoapplication. The final exam is planned on the end of the last module (2nd quartile).

The table below summarizes assessment types and forms.

Assessment Table: Assessment types and forms in quartiles (modules)

Assessment type	Assessment form	Quartiles (modules)		Notes
		1	2	
Intermediate	Control work (test)	*		I/O geospatial data, raster and vector data processing
	Home assignment 1 (defense on practical lessons)	*	*	Develop a series of small applications for given course topics
	Home assignment 2 (software development and defense)		*	Develop a data-driven geoapplication that uses vector/raster data from selected subject area
Final	Exam (test)		*	All course material

All results are evaluated according to 10-level scale from 0 (failure) to 10 (excellent) inclusively.

6.2. Control work and exam forms

The control work and exam will be in the form of written tests (1 hour 20 minutes each). They will be designed using state-of-the-art understanding of how a good test should look like. The tests that will be provided are similar to Cambridge English Certification and Oracle Java Certified Programmer exam.

The control work and exam will be held in written form. Printed forms with questions and answer versions will be given to students. Questions and answers are in English. Students are not required to write any answers, correct answer(s) should be circled with pen. Corrections are not allowed (so you can answer the questions using a pencil first or draft sheets). Draft sheets are the opposite side of the exam forms. A student should have a pen with them. The absence of a pen will be considered as control work/exam failure.

Cheating: use of mobile phones, Internet, books, notebooks is prohibited during control work/exam. Communication with other students is prohibited (even asking a neighbor for today's date). Violation of the rules will be penalized.

To avoid confusion, students should provide their surname, name, patronymic, current date, group and signature on the first exam sheet. Repeating names on each exam sheet is not required. Each document has a unique generated ID in its footnotes (e.g. Random Document ID: ndzoyCaK). This is achieved by VBA macro for MS Word that is run before printing each exam sheet.

Evaluation criteria for questions are as follows. Correct answer to a question gives **1.0** points. Answers to questions with multiple choices will be evaluated as follows:

- All correct items were checked without any incorrect ones — 1.0 (full score)
- At least one correct item was checked without any incorrect ones — 0.5 (half of a score)
- At least one incorrect item was checked — 0.0 (no points)

No total points (0 score) gives 0% contribution to the final mark, all correct answers to questions give 20% contribution to the final mark (see corresponding syllabus section for details).

Please, find control work/exam example at (correct answers are **in bold**):
 http://rgeo.wikience.org/pdf/tests/rgeo-course-exam_example.pdf

6.3. Homework assignment form and assessment

6.3.1. Homework assignment 1

This kind of homework ensures regular practical experience of students at home. After the material for a topic is covered by lecture, students receive small programming task for the homework. Students should hand-in the homework in 1 or 2 weeks after it was assigned (concrete deadline will be noted by the instructor for each assignment separately in oral form). The instructor will check the homework only during practical lessons. Thus, absence on a practical lesson devoted to homework assignment control is considered to be homework delay. The instructor penalizes delays by subtracting scores from the final mark of given homework. Student may earn 0 – 10 points for a homework.

In general, the criteria for homework assignments are the same as for homework assignment № 2. However, the importance of each criterion will vary in accordance to the current course topic. The teacher reserves right to ask questions during homework defense to ensure understanding the material by student, source code written, source code authenticity. Questions may be also based on the lecture material. The teacher mark the work according to the percent of questions answered, amount of work done, accuracy of source code and application as a whole, correctness of the application and other sound criteria that are applicable to this kind of work.

These homework assignments (not homework assignments № 2) should be done individually by student. Cheating including code borrowing or its other forms will be penalized down to earning 0 scores for the assignment.

6.3.2. Homework assignment 2

The homework defense will be held in the form of presentation of the developed geoapplication to the groupmates. Each student must submit PowerPoint presentation, complete source codes and architecture description (Microsoft Word document) of their geoapplication for teacher's review. Once all critical comments are fixed, a student submits their work for group review in a dedicated forum topic. Other group members should ask at least 1 question clarifying the geoapplication goals, its internal structure and usage. The activity of asking questions will also contribute to the homework mark. The questions should be constructive; the answers for them may not be evident. The examined student must provide answers to all questions related to home assignment. Based on the gathered questions the student will have to refine their presentation and architecture description. After discussion and refinement are complete, the student submits the final version of their geoapplication. The developed geoapplication should be covered with unit tests via JUnit, TestNg or other framework for quality assurance. Test-driven development (TDD) approach should be applied during the geoapplication development. The quality of tests and coverage percent influence the homework mark. The mark for the geoapplication is given in the accordance to state-of-the-art evaluation criteria common to all courses that require application development during home assignment or other similar assessment activity. The mark for homework will also depend on the variety of geospatial data and their management techniques exploited in the geoapplication (e.g., whether it uses vector as well as raster data, spatial database management systems, visualization, networking frameworks). Tentative topics for home assignments are given in section "Topics for homework assignments".

6.4. Alternative ways of assessments

During the course a student might want to substitute Home Assignment and Exam (and possibly some practical lessons) with other types of activities.

A student (or team of students) may propose a geoapplication project to work on, for ple http://www.wikience.org/ru/темы_проектов/исследуй-климат-сам/. This will result in complex programming experience (teamwork, development of a complete software product, etc.). The resulting project may be presented at corresponding competitions (e.g. IBM Smarter Planet, Microsoft Climate Initiative, Google Earth Engine Awards) or commercialized.

The other way is to tackle a research problem agreed with the course instructor in advance. This includes reading research papers, developing new methods/algorithms, publishing journal or conference research paper(s).

6.5. Exam retake commission

The format of the exam retake is the same as during an ordinary exam format for this course: please, refer to Section 6.2 for details. A student will not be asked any additional questions in oral, written or any other form. The cumulative mark for a student (all items from Section 5 except "EX") will be considered by the exam retake commission. The commission will use the formula for calculating the mark which can be found in Section 6. Item "EX" means the mark that was earned by the student during the exam retake (please, note that exam retake mark contributes to the final course mark with weight 0.2).

7. Methods of Instruction

The considerable part of the course is held in the form of hands on training. Quite often students are expected to try out things covered on slides together with the trainer during a lesson (4 academic hours in class planned for 1 lecture and 1 practical lesson).

Theoretical material on slides largely interleaved with practice. Lectures have forms of PowerPoint presentations (during some lectures students are expected to work with their computers). Practical lessons are provided as programming trainings: instructor defines tasks to be accomplished using Java, geospatial libraries/software and certain geospatial data (according to the current topic).

Instructor helps to overcome difficulties that arise during the implementation of the given tasks by asking leading questions, pointing to corresponding Web resources, documentation. They also suggest improvements to the code.

8. Special Equipment and Software Support

All learning resources are freely accessible via Internet. The corresponding links are given to students. Course instructors do not issue directly to students any software, books, documentation or other material even if they are freely available on the Web.

8.1. Software support

Below is the main list of software that will be used during the course:

- Java Development Kit (JDK) at least 1.6 version
- GeoTools
- GDAL
- Quantum GIS
- PostgreSQL/PostGIS
- Java Topology Suite

- Apache Mina
- Netty
- NASA WorldWind
- Mapbox
- Leaflet
- Carto

Please, find complete list of required resources (software, libraries, etc.) with links to them at the course site: http://rgeo.wikience.org/ Links to minor tools will be given in the lecture slides.

8.2. Remote support

The course site http://rgeo.wikience.org/ (all lecture slides, source code, links to resources and data are publicly available) and, possibly, LMS (notification of students by e-mail, control work/exam results publication, gathering homework assignments) are used for remote course support.

Students may also use the instructor's institutional e-mail arodriges@hse.ru to contact him directly. It is also possible to arrange Skype meeting with the instructor (please, contact him via e-mail to schedule a meeting).

8.3. Technical resources

Students should prefer to take their personal laptops for each practical lesson. This will accelerate their learning and reduce stress since they will be working in familiar and highly personalized programming environment.

The lecturer uses laptop and laser projector for presentations and practical lessons.

Students use Java IDEs like IntelliJ IDEA or Eclipse. In addition, they will use various Java libraries and freely available software for storage, processing and visualization of geospatial data. The concrete software packages that are required to accomplish a given practical task are named at a corresponding practical lesson. The links to sample geospatial data used during the course are issued at corresponding practical lessons and will be also available at the course site http://rgeo.wikience.org

9. Acknowledgements

The author would like to thank Dmitry Baryshnikov (NextGIS developer and GDAL committer) for the review of the topic-wise course content and critical comments.

The author of the program: / R.A. Rodriges Zalipynis /