Type of studies: full-time, master degree, 3-semesters with no of hours /week and ECTS

Field of education: Geodesy and Cartography, specialization Photogrammetry and Remote Sensing

No.	Course	Sem. I				Sem. II				Sem. III			
	l - lecture, e - exercices, p - projeckt, E - exam	l	e	p	ECTS	l	e	p	ECTS	l	e	p	ECTS
	General courses including humanities and economics, and major for the field of education												
1	Selected issues of economy law	1			1								
2	Human rights					1			2				
3	Geodetic and Cartographic Law									1	1		2
4	Specialist foreign language										2		1
5	Mathematics		2		3								
6	Selected Topics of Mathematics and Numerical Methods /E	1	2		4								
7	Geophysics	1	1		2								
8	Selected Topics of Physical Geodesy and Geodynamics			1	2								
9	Digital image processing			2	2								
	Profiled courses												
10	Standards in Geographic Information	1			2								
11	Spatial Data Infrastructure	1			2								
12	Cartographic Modelling /E	1		2	3								
13	Photogrammetric Technologies /E	2		2	4								
14	Geostatistics	1		1	2								
15	GIS Technologies	1		1	3								
16	Facultative class 1					1		1	2				
17	Facultative class 2					2			1				
18	Facultative class 3					2			1				
19	Facultative class 4					2			1				
	Specialization courses												
20	Image Data Acquisition Techniques /E					1		1	4				
21	Spatial Orientation of Images					1	2		3				
22	Airborne Laser Scanning					1		2	3				
23	Automation of Photogrammetric Processes					1	1		3				
24	Close-Range Photogrammetry /E					2	2		4		1		1
25	Applications and standards of aerial and satellite photogrammetry									2	1		3
26	Remote Sensing Methods of Image Processing /E					1		2	3				
27	Radar Remote Sensing									1	1		2
28	Hyperspectral Remote Sensing					1	1		3				
29	Diploma Seminar										2		1
30	Diploma thesis												20
	TOTAL	10	5	9	30	16	6	6	30	4	8	0	30

Courses descriptions

General courses including humanities and economics, and major for the field of education

	Selected issues of economy law	1. Basic information on economic law 2. Sources of law, including the economic law 3. Legal entities. an individual and a legal person, methods of their creation and their legal capacity. 4. The principles of representation of legal persons. 5. Basics principles of obligation. Contracts as a source of obligations. The principle of freedom of contracts. Modes of concluding a contract, in particular in the economy. 6. The principles of fulfillment of contractual obligations. Consequences of non-performance or improper performance of the contract. 7. Taking up and running a business. The concept of the entrepreneur. Forms of runnning and requirements for starting a business. 8. Economic freedom and its limitation 9. Registration of running of an individual entrepreneur in the Central Register of Economic Activity, Polish Classification of Economic Activity 10. Company law. Principles of establishing companies. Register of Entrepreneurs of the National Court Register 11. Partnerships and capital companies – main features
	Geodetic and Cartographic Law	Lecture: Tasks of the organs of the geodetic and cartographic service. State geodetic and cartographic repository – management, sharing, fees, licenses. Submission of geodetic and cartographic works. Coordination of utilities network projects. Protection of geodetic controls. Geodetic works in closed areas. Technical standards applicable in surveying. Rules for completing technical reports. Professional qualifications in the field of geodesy and cartography. Exercises: Preparation of a geodetic work application. Preparation of a fee calculation document for materials for the submitted geodetic work, drawing up a license for the above-mentioned geodetic and cartographic materials. Preparation of a technical report for the submitted work and the content of the technical report for a specific assortment of surveying work. Preparation of an application for authentication of geodetic materials resulting from surveying work. Preparation of a notice of completed surveying work. Preparation of an application for coordination of the utilities network project.
	Specialist foreign language	Achieving the B2+ level of knowledge of a foreign language by expanding the specialist vocabulary related to geodesy and cartography and improving other skills that will enable students to communicate freely in a foreign language, prepare effective presentations and write an abstract of a master's thesis, report or texts in a foreign language useful in their professional work.
	Mathematics	Functions of complex variable: function derivative, Cauchy-Riemann equations, holomorfic function. Integration of complex function, Cauchy integral theorem, Cauchy integral formula, Laurent series, residual of the complex function and its application for the computation of integrals. Basic equations of mathematical physics. Partial differential equations of the first and second order and their classification. Differential equations of the string and of the thermal conductivity. Fourier method of the separation of variables. Integration and ultra-tight (deep) integration.
	Selected Topics of Mathematics and Numerical Methods **/E**	The main purpose of the course is to give students theoretical and practical knowledge on the selected methods of random signals analysis. The course will present mathematical background and describe algorithms of empirical data analysis, both in the time and frequency domain. The course will begin with a short introduction to the theory of probability, random variables and their parameters. Next, given is description of the random signals with special attention paid to the properties of stationarity and ergodicity. The basic characteristics of the signals are introduced: mean value and variance, probability density, autocorrelation and power spectral density (PSD) functions, then the joint characteristics: joint probability density, cross correlation and the cross power spectral density (CPSD). The data analysis algorithms will include the classical methods, based on the digital Fourier transform, and the parametric methods focusing on the autoregressive (AR) modeling of time series. The last part of the course is devoted to the application of the linear Kalman filter to the time domain analysis of discrete data. It begins with definition of the linear dynamical system using the state-space formulation, then the filtering equations are derived. The project part of the course includes application of the computer programs for analysis of empirical data.

	Geophysics	The purpose of this course is to give the students a basic knowledge on the folowing subjects: The Earth as a planet. Internal structure of the Earth. Isostasy – postglacial rebound. Plate tectonics: oceanic rifts, subduction zones, orogens, transform boundary. Rheology. Seismology: seismic waves, seismic wave propagation, Richter scale. Earth's magnetic field: parameters, units, constituents, geodynamo hypothesis. Magnetic surveying: magnetic anomalies. Geomagnetic poles, equator and coordinates (calculation of). Paleomagnetism, polarity reversals. Magnetosphere, magnetic storms and solar activity. Hydrological cycle, physical properties (density, optical, acoustic) of oceanic water. Physical oceanography: thermocline, waves, currents, deep-water circulation, oceanic tides. Basic of fluid dynamics. Particular attention is paid to the interactions between geophysics and geodesy. That includes those geophysical theories and models which are used in geodetic practice, as well as the geodetic observations and models which can support geophysical research.
	Selected Topics of Physical Geodesy and Geodynamics	Gravimetric measurements - construction of a gravimeter, preparation for measurement (calibration, adjustment) - calculation exercise: determination of the gravimetric factor from measurements on a calibration basis. Gravimetric measurements - Development of a gravimetric measurement with the calculation of the tidal correction - calculation exercise: preparation of the results of a gravimetric span measurements with relative method. Gravimetric measurements - development of measurement results: calculation of the field correction, calculation of reductions and gravimetric anomalies - calculation exercise: preparation of a map of free air anomalies and the full Bouguer anomaly. Tidal deformations - determination of the deformation of the earth's crust caused by tidal phenomena, static and dynamic tidal model - computational exercise: determination of the deformation of the earth's crust in the neu system for a specific point in a given period. Non-tidal deformations - determination of deformations caused by non-tidal phenomena (atmosphere, hydrology or anthropogenic and local factors) - computational exercise: determination of the Earth's crust deformation in the neu system for a specific point. Implementation of the EVRF2007 system - determination of the increments of geopotential number with the use of real gravimetric measurements and geopotential models - accuracy analysis - computational exercise: determining the increments of geopotential features for a selected leveling line, reduction to zero tide. The phenomenon of isostasy and its importance for the implementation of the geodetic network - computational exercise: modeling of the isostatic effect on the basis of the GNSS time series (Fennoscandia).
		Gravity field of simple geometric solids - elements of geophysical interpretation - computational exercise: modeling of gravity field anomalies resulting from anomalies of subsurface formations. Elements of the gravity field in connecting the natural (related to the plumb line) and geodetic (related to the normal line) coordinate system - computational exercise: reduction of traverse elements from the tacheometric system to the geodetic system related to the GNSS network.
	Digital image processing	1. Registration and development of a digital image 2. Digital image recording formats. 3. Lossy and lossless image compression methods. 4. Basics of image processing in Matlab (Computer Vision System Toolbox TM) 5. Basics of image processing in Python 6. Preprocessing (Matlab) and automatic image vectorization (ArcGIS) 7. Detection and analysis of text on images using the function Optical Character Recognition (OCR) 8. Clustering algorithms and the basics of machine learning for digital image classification. 9. Contextual processing: removing noise from an image through selected low-pass filters and detection characteristic elements of the image through high pass filters 10. Basics of mathematical morphology. 11. Basics of image texture analysis: fractal analysis, GLCM, granulometric analysis.
Profiled courses		

	Standards in Geographic Information	Lectures: 1. Concepts of standard and norms. Objectives and tasks of standardization. 2. The subject, structure, and organization of standardization in GI. OGC standards, ISO standards. 3. Standards formalism, ISO / TS 19103 specification - UML language and ISO 19109 - rules of application schemas. 4. Selected issues from the ISO 19100 series standards: - describing the position (ISO 19107, ISO 19125-1, ISO 19111 and ISO 19112); - temporal scheme (ISO 19108); - data quality (ISO 19157 and ISO 19158); - cataloging methodology (ISO 19110); - metadata (ISO 19115); - XML language - GML (ISO 19136 and ISO 19139). 5. Rules for the use of standards in specific applications.
	Spatial Data Infrastructure	Lectures: The rules of construction of european and national Spatial Data Infrastructure (SDI), the INSPIRE idea and choosen implementing documents. Standardization of geospatial data and services: ISO, CEN and PN standards. Basic definitions: feature class and collection, web service, harmonization, consistency, interoperability. Types and OGC standards of geospatial web services, its applications. Structure of SDI in Poland, the rules of building, the leading organisations. The law acts: transposition the UE law documents to Polish law Order, technical documents of GUGiK (Head Office of Geodesy and Cartography) concerning the reference and thematic databases and cartographic vizualizations. Recources of reference and themtatic data: conceptual models, standards, structures, LoDs, applications. Geoportal.gov.pl as a national SDI access point, its functionality. Metadata - definitions, standards, editors and problem of validation.
	Cartographic Modelling **/E**	Geographic data: DLM (digital landscape model) and DCM (digital cartogrphic model). Basics of the topographic data model. Properties of DLM and DCM models and their practical application. Conceptual models in topographic and thematic databases. Methods of analysis and generalization of geographic information. ISO 19100 series standards for modeling geographic information. Processing of geographic data. Spatial analyzes performed on vector and raster data. Surface modeling. Interpolation methods. TIN model, GRID model. Modeling of the relief surface. Network analyzes. Transformations of spatial data. Basic principles of using databases in cartography. Multimedia techniques in cartographic presentations: multimedia means of expression, software, formats of graphics, animations, sounds and video images, compression algorithms, principles of designing and implementing multimedia compositions. Basics of cartographic visualization of geographic information on the Internet. The specificity of sharing spatial and multimedia data on the Internet, rules of website editing, designing online cartographic publications, designing and configuring geoinformation services, issues of functionality of Internet publications.
	Photogrammetric Technologies **/E**	1. Demand for geoinformation data. The influence of solar lighting and the atmosphere on photographing the Earth's surface 2. Aerial digital camera. Large format cameras. Perspectives; Medium format cameras; Oblique cameras; Direct georeferencing (in flight) - advantages and limitations 3. The quality of present aerial photos. Lens, orthoscopy; Internal camera / photo orientation. Camera calibration. Calibration certificate. 4. The market for aerial photography. Country coverage with aerial photos. State archive of photos. 5. Satellite imaging in the optical range. VHRS systems. VHRS systems - spatial resolution; HRS systems - data openness policy. Constellations of nanosatellites – temporal resolution 6. Airborne laser scanning. Design of area imaging by ALS ; The form of the results, content, formats. Basics of data georeferencing (terrain control network, stages of georeferencing, quality indicators). Coloring the point cloud. Basic products. 7. Digital terrain models. Sources of elevation data. Types of models, structure, basic standardization parameters. Derivative products from DTM. Comparison of ALS point cloud and image data (image matching).

		Standards and state of country coverage with elevation models 8. Microwave interferometry (InSAR). Airborne and satellite InSAR systems. Single pass and repeat pass interferometry. Global coverage of altitude data from InSAR satellite systems. 9. Digital orthophotomap. Process of processing from aerial photos. Standardization parameters. Photo parameters vs. orthophoto parameters. True-ortho, "oblique" ortho. Orthorectification of satellite images. Orthophotomap as a source of topographic databases supply. Standards and state of country coverage with digital orthophotomap. 10. Terrestrial laser scanning. Mobile multisensory systems. Principle of operation of a terrestrial scanner and its application. The principle of integration of MMS and MLS sensors systems. Applications of MMS systems. 11. 3D modeling of buildings. Review and evaluation of data sources, multi source data. 3D modeling standards, CityGML. 12. BSL. Low-altitude photogrammetry. Platforms. Legal regulations; Measurement systems, imaging systems; Elaboration of UAV data. Typical products; Imaging from UAV platforms vs. aerial photography from manned airplanes.
	Geostatistics	Lectures: 1. Introduction to spatial statistics, measurement scales. 2. Basic statistics - central tendency statistics, dispersion statistics, correlation coefficient. 3. Spatial autocorrelation and heterogeneity, the concept of a matrix of weights and the principle of selection. 4. Global and local measures of spatial autocorrelation. 5. Measures of spatial concentration - Lorenz curve and Gini index. 6. Regression and spatial regression - basic concepts and stages of model construction. 7. Selected models of spatial regression. 8. Spatial panel models. 9. Basic concepts of geostatistics - semivariance, semivariogram. 10. Geostatistical methods of data interpolation. 11. Introduction to data mining methods. 12. Selected examples of geostatistics applications. Exercises: Projects involving the analysis of spatial data with the use of geostatistical methods, performed in various GIS class software, as well as statistical programs: 1. Study of spatial dependencies with the use of basic statistics of central tendency and dispersion, various global and local measures of spatial autocorrelation and spatial concentration using the Gini index. 2. The use of spatial regression to investigate the relationship between selected phenomena. 3. The use of geostatistical interpolation methods to create probability maps of the occurrence of a selected phenomenon
	GIS Technologies	Lectures: 1. Basic terminology related to Special Information Systems: ordering of concepts. Evolution of the definition and conceptual scope of SIS. 2. How to understand in the context of SIS: technologies, information technologies and IT technologies. Technology and technique. 3. Basic techniques used in SIS (e.g. data visualization, spatial analysis, saving spatial data in a database, spatial data transformation, automation). 4. Introduction to multi-criteria analyses - methodology, selected approaches and tools. 5. SIS techniques supporting the activities of geodetic and cartographic companies.6. Examples of projects implemented in Poland including public tenders. Project: Implementation of a project based on a local revitalization program of a selected urban municipality (development of small road infrastructure). Obtaining spatial information made available on the municipality's website and adapting it to a pre-created database with selected Topographic database BDOT data, with the appropriate attributes necessary to create simple network analyses, based on both data sources. Simple multi-criteria spatial analyses in a mixed approach (boolean and fuzzy functions) to chart a path between two points. The use of tools to visualize path profiles in 2D and 3D.
	Facultative class 1 - Review of contemporary surveying techniques	The principles of operation of selected measurement systems and the conditions for the use of individual measurement techniques in measurement implementation procedures and methods of determining displacements will be presented. A report will be made on the measurements made by videotachimeter. During the project implementation, the student will use the GNSS signal generator 1. statistical analysis of the measured time series 2. filtering with the use of a moving average and a median filter in a given filtering window 3. Fourier analysis of recorded time series 4. making appropriate charts 5. execution of the report

	Facultative class 1 - Advanced use of Matlab in geodetic a	The principles of operation of selected measurement systems and the conditions for the use of individual measurement techniques in measurement implementation procedures and methods of determining displacements will be presented. A report will be made on the measurements made by videotachimeter. During the project implementation, the student will use the GNSS signal generator 1. statistical analysis of the measured time series 2. filtering with the use of a moving average and a median filter in a given filtering window 3. Fourier analysis of recorded time series 4. making appropriate charts 5. execution of the report
	Facultative class 2 - Spatial data mining	Introduction to Spatial Data Mining. Data preprocessing and spatial data enrichment. Non-classical logics, including fuzzy logic. Rough sets and reducts. Decision trees. Association rules. Spatial concentration analyses. Spatio-temporal trends. Text mining and Twitter spatial data analysis. Big Data. Distributed databases. Distributed data processing
	Facultative class 3 - BIM in investment management	Lectures: BIM Standards and Initiatives; BIM Guides and Execution Planning; Uses of BIM; Levels of BIM; Impact of BIM; The Evolution to Object-Based Parametric Modeling; Parametric Modeling of Buildings; Creating a model based on a point cloud; BIM Environments, Platforms, and Tools Overview of the Major BIM Design Platforms; BIM for Owners and Facility Managers; BEP, Scope of Design Services; BIM Use in Design Processes; BIM for Contractors; Processes to Develop a Contractor Building Information Model; Construction Analysis and Planning; Integration with Cost and Schedule Control and Other Management Functions.
	Facultative class 4 - Machine Learning	1. Introduction to the class. Basic information on unmanned aerial vehicles 2. Legal provisions regarding the use of UAV aviation law 3. Review of photogrammetric UAV platforms and RGB, NIR, multispectral, hyperspectral, LIDAR sensors 4. Planning and development of photogrammetirc missions with the use of UAV 5. Processing of photogrammetric data obtained from the UAV 6. Regulations in the field of geodesy and cartography regarding the use of data from UAV platforms 7. Presentations of exemplary geodetic works using UAV data
	Facultative class 4 - UAV Technologies	Lectures: 1. Introduction to Machine Learning, basic concepts 2. Supervised and unsupervised learning 3. Classification 4. Regression 5. Cluster analysis: hierarchical, k-means, c-means, Kohonen networks 6. Supervised methods: kNN, least distance, maximum likelihood, decision trees, random forests, SVM, Bayes classifier 7. Artificial neural networks: neuron model, multilayer perceptron 8. Training of multilayer perceptron, mathematical model of a neuron 9. Deep neural networks, convolutional neural networks 10. Practical aspects of Machine Learning application in remote sensing 11. Typical problems in Machine Learning: small amount of data, unreliable data, unrepresentative data, overfitting, etc. 12. Methods of increasing model accuracy: extending a set of image features, knowledge transfer from related problems, combined methods 13. Machine learning in time series applications: trend curve fitting, outlier detection, prediction by analytical methods and deep networks (LSTM) 14. Competitive learning and other new trends in Machine Learning, examples of Machine Learning applications in remote sensing and related fields
Specialization courses		
	Image Data Acquisition Techniques /E	1. Review of analog aerial mapping cameras 1.1. Overview of modern analog mapping cameras 1.2. The quality of analog aerial photos 1.3. Analog camera calibration certificate 2. Review of digital aerial mapping cameras 2.1. Advantages of digital imaging 2.2. Concepts of design solutions for digital mapping cameras 2.3. DMC Camera (CCD frame type) 2.4. UltraCam Camera (CCD frame type) 2.5. ADS40 camera (electro-optical scanner with CCD line) 2.6. Medium format digital photogrammetric cameras 2.7. Digital camera calibration certificate 3. New generation digital cameras (DMC II, DMC III) 3.1. Previous digital cameras - characteristics 3.2. Recipient's expectations 3.3. DMC - new generation aerial camera - characteristics 3.4. DMC II - the workflow of the preliminary process

		3.5. DMC II - preliminary elaboration results 3.6. DMC III 3.7. Conclusion 4. Photo quality of digital photos – comparison with analog photos. Technical, organizational and economic conditioning of the implementation of digital camera in production. Coverage of the country with aerial photos 4.1. Advantages of digital imaging 4.2. Power resolving of digital photos, comparison with analog photos 4.3. Technical, organizational and economic conditioning of the implementation of digital camera in production - production results 4.3.1. Background. 4.3.2. Organizational and economic conditioning of the implementation of digital camera in production 4.3.3. Measuring potential of digital images 4.3.4. Systematic distrorsions of digital images 4.3.5. Aerotriangulation with additional parameters (self-calibration) 4.3.6. Examples, conclusions 4.3.7. Content of the digital photos 4.3.8. Summary 4.4. The photo market vs. camera market 4.5. Coverage of the country with aerial photos. Prices for photo services
		5. Photo mission planning for mapping purposes 5.1. Mission planning of topographic photos for the production of the typical photogrammetric products 5.1.1. Basic parameters 5.1.2. Designing of photo scale (resolution of digital photos) 5.1.3. Accuracy of photogrammetric studies 5.1.4. Selecting the camera cone 5.1.5. Division of area of interest into regions 5.1.6. Designing of flight altitude 5.1.7. Designing of photo overlaping 5.1.8. Pin point photography 5.1.9. Specifics of designing of photos over a city for the orthophotomap production 5.1.10. Graphic form of the project 5.2. Realization of the photogrammetric mission 5.2.1. Design and targeting of photogrammetric field control points 5.2.2. Photogrammetric airplanes 5.2.3. Airphoto weather. The selection by day and by season 5.2.4. Elements of the photogrammetric mission navigation
		5.2.5. Navigation tolerances 5.3. Navigation systems. System of airphoto management based on GPS 6. Measurement of elements of camera position in flight. GPS / INS integration. Direct georeferencing 6.1. Measurement of camera position in flight based on GPS 6.2. GPS assisted aerotriangulation 6.3. The INS system 6.4. Measurements of all elements of camera orientation in flight. The idea of GPS / INS integration. Kalman filter 6.5. GPS / INS systems on the market 6.6. Calibration of the GPS / INS systems 6.7. Direct georeferencing by integration of GPS / INS 6.8. Practical use of GPS / INS integration in aerotriangulation 6.9. Direct georeferencing as an alternative to aerotriangulation 6.10. Conclusions 7. Advanced method of ALS data acquisition and georeferencing 7.1. ALS - error sources 7.2. Scanner calibration (based on field tests) 7.3. Calibration of the multisensors measurement platform 7.4. Planning of ALS data acquisition with desired parameters 8. Oblique photos - what for? 8.1. Application in the beginning of aerial photography 8.2. Modern oblique cameras - technical solutions. Oblique camera linking with a laser scanner.
	Spatial Orientation of Images	Lectures: 1. Introduction to aerialtriangulation. 1.1. Methods of orientation of a single photo, a pair of photos, blocks of photos 1.2. Aerial triangulation - definition, general remarks 1.3. Aerial triangulation methods, goal, unknowns 1.4. Coordinate systems used in photogrammetry 2. Camera calibration 2.1. Camera calibration metric 2.2. Project definition, cameras 3. Measurement of points in aerotriangulation 3.1. Weighting of observations. 3.2. Aspects of measurement and functionality of measured control points in aerotriangulation. 3.3. Accuracy requirements for controls 3.4. Error propagation in photogrammetric blocks 3.5. Aerial triangulation results. 3.6. Overview of sample reports from photogrammetric programs: Trimble Inpho, Z / I Intergraph, Pix4D, Metashape Agisoft 4. The role of GNSS / INS observation in the process of aerotriangulation 4.1. Aerotriangulation assisted by GNSS / INS measurements. 4.2. Global Navigation Satellite System - GNSS. 4.3. Inertial Navigation System - INS. 4.4. Kalman filtering. 4.5. Error modeling and calibration of GNSS / INS observations. 4.6. Georeference directly as an alternative to aerotriangulation. 5. Correction of systematic errors in aerotriangulation and self-calibration 5.1. The problem of correcting systematic errors in the aerotriangulation block

		5.2. Characteristics of various models of additional parameters 5.3. Graphical interpretation of Ebner's additional parameters 5.4. Self-calibration 5.5. Examples of using self-calibration in selected programs: Trimble Inpho, Z / I Intergraph, Pix4D, Metashape Agisoft 6. Problems of orientation of oblique photos 6.1. The influence of the sensor selection - field range of the oblique photo, coverage in the block 6.2. Algorithms used in the orientation of obligue images 6.3. Problems of aerotriangulation of a block of oblique images 6.4. Review of oblique image orientation methods 7. The problem of orientation of UAV images 7.1. The specificity of UAV data and the accuracy obtained (the role of the quality of the cameras used and their field range, overlaps 7.2. Self-calibration of small and medium format cameras 7.3. The use of the Structure from Motion method in the orientation of the UAV photo block 8. Orientation of satellite scenes 8.1. polynomial coefficients 8.2. quotient coefficients 8.3. role of the warp measurements in the orientation of satellite scenes 9. Orientation of other images 9.1. issues of orientation of thermal imaging 9.2. issues of orientation of radar images 9.3. issues of orientation of super and
		Project exercises: 1. Development of a block of digital photogrammetric photos (10 hours) a.setting the project b. measurement of the photogrammetric tie points c. analysis of tie point generation parameters d. analysis of the weighting of observations e. analysis of the influence of the distribution of control points and check points f. analysis of reports and compilation of the obtained results 2. Development of a low-altitude block of UAV photos (8 hours) a. setting the project b. performing measurements of the photogrammetric controls c. alignment of observations d. analysis of the results and the influence of factors on the result 3. Development of a block of oblique aerial imagery (8 hours) a.project settings b. performing measurements of the photogrammetric controls c. alignment of observations d. analysis of the results and the influence of factors on the result 4. Orientation of VHRS satellite scenes (4 h) a. Design assumption - sensor definition b. Uploading parameters of external orientation - RPC coefficients c. Measurement of controls d. Influence of the distribution and number of controls on the scene orientation result
	Airborne Laser Scanning	1. ALS data acquisition 1.1. System Components 1.2. Recorded parameters 1.3. Distribution of laser point footprints on the ground surface (optical scanning system). Dependence of point density and uniformity of point density on system and flight parameter. 1.4. Typical parameters of topographic scanners. ALS systems on the market 1.5. ALS data properties 1.6. Data recording formats (LAS ASPRS). Compression 2. Registration of several reflections (echoes). Increasing of of point density by the MPA technique (possibilities and limitations) 3. Registration of the full wave form (fullwave). 3.1. Signal-object interaction 3.2. Signal decomposition - methods 3.3. Possibilities and limitations. Applications 4. Combination of the scanner and the imaging camera 4.1. Connection with a medium format camera. The conditions for the implementation during mission 4.2. ALS point cloud coloring (methodological basis). Typical errors 5. ALS data georeference 5.1. Role of GNSS / INS observations in ALS data orientation 5.2. Classification of errors affecting the accuracy of ALS data 5.3. Division of the study area into blocks and strips 5.4. Adjustment of flight trajectory 5.5. ALS data relative orientation 5.6. Terrain control (reference planes, control planes, distribution, ...)

		5.7. Accuracy indicator / adjustment quality 6. Processing the ALS data 6.1. Filtration. Methods (in detail Axelson's algorithm,...). Building a DTM 6.2. Classification. Typical classes (according to LAS ASPRS). Construction of theDSM 6.3. DTM / DSM quality. Quality standardizing parameters. DTM / DSM parameters versus ALS data parameters 6.4. Illustration and commentary on common errors in ALS data processing 7. Calibration of the scanning platform 7.1. Correlation of planar and altitude errors with the system calibration parameters 7.2. Calibration test field for ALS data 8. Bispectral and multispectral scanning systems 8.1. Bathymetric scanner (specification, depth penetration, ...) 8.2. Multispectral ALS systems (examples of design and final products) 9. Single photon systems (specificity, properties, construction examples, ...) 9.1. Specificity of photon and Geiger-mode systems 9.2. Construction examples, efficiency analysis 9.3. Data quality evaluation of single photon scanners 10. UAV laser scanning systems 10.1. Overview of LIDAR solutions for UAVs 10.2. ULS data orientation methods 10.3. Analysis of the quality and application of ULS data 11. ALS - application examples
	Automation of Photogrammetric Processes	Lecture: 1) Vector data: spatial data types, information - dimensions (2D, 2+1D, 2.5D, 3D); 2) Vector data recording standards and methods - popular vector data recording formats: DXF, SHP, LAS, PTS, PTX, OBJ, WRL; 3) Transformation of vector data - from point to block, manually and automatically (process of aggregation and generalization of vector data); 4) Advanced vector and raster data processing methods; 5) Presentation of commonly used library functions and functions used for automatic processing of vector and raster data; 6) Presnet to use selected APIs of photogrammetric software. Exercises: 1) Fundamentals of programming in Python language, 2) Loading and saving vector data in various formats, 3) Fundamentals of OpenCV library operation, 4) Orientation of SfM images using OpenCV library, 5) Detection of characters encoded in images 6) API Agisoft Metashape
	Close-Range Photogrammetry **/E**	Lecture: Introduction (PTFiT and ISPRS organizations), history of close-range (non-topographic) photogrammetry and problems of modern close-range photogrammetry. Typology and characteristics of studies of close-range photogrammetry. Systems using images for the spatial reconstruction of measured objects: metric, non-metric digital images. Classification of digital cameras and the way of ideas acquiring. Fundamentals of digital photography - image exposure settings. Technological scheme of close-range product development. The geometry of close-range images (depth of field, aperture size, coverage selection, network design). Characteristics of factors influencing the accuracy of photogrammetric elaboration (average error, relative error, dangerous cylinder theory, distribution of binding points, control points, scale difference in the image). Short-range photogrammetric standards (3x3 rules CIPA, Instruction G-3.4, VDI/VDE). Calibration of digital cameras and unconventional measuring systems - types of test fields, radial distortion, tangential distortion, parametric and polynomial model, self-calibration, classical calibration Hallert method, calibration of fisheye lenses.
		Selected issues of automation of the processing of terrestrial digital images used in robotics and machine vision and in the processes of generating photogrammetric products (the problem of applied definitions and standardization of names; off and online data processing; calibration in machine vision and photogrammetry).

		Terrestrial laser scanning technology - data acquisition, data filtering. Modern methods of 3D and 2+1D orientation of TLS data. Automatic 3D modelling - stages of digital image processing, terrestrial laser scanning data processing (basics, manual modelling, semi-automatic modelling processes, skeleton models, and photorealistic models). Methodology of automatic surface reconstruction from point clouds (Poisson's method, Ball-Pivot, etc.). Methods of integrating data from ground scanning and digital images. Methodology for generation of orthoimages in intensity and RGB. Updating GIS/BIM databases with photogrammetric data. Classification of digital systems: off and online, mode of operation, measurement techniques, industrial measurement systems. Special techniques - e.g. laser tracker, beam projection method, multispectral images and ToF cameras. Selected examples of applications of short-range photogrammetry in various economic fields. Exercises: Acquisition and processing of terrestrial laser scanning data: orientation and filtering of point clouds. Generation of orthoimages in intensity, the orientation of terrestrial digital images and generation of RGB orthoimages. Analysis of NMPO quality, interpolation method and GSD selection. Analysis of photogrammetric matrix selection for automatic modelling of short-range objects from terrestrial digital images in Agisoft Metashape. Calibration of non-metric (including low-budget) digital cameras using test fields in Kalib and Agisoft Metashape software.
	Applications and standards of aerial and satellite photogrammetry	Lectures: 1. Standards of photogrammetric studies 2. Products of aerial and satellite photogrammetry in agriculture 3. The role of aerial and satellite photogrammetry in the LPIS system (application, standards, examples of documentation of photogrammetric works under LPIS) 4. The use of photogrammetric data in crisis management (discussion of selected flood prevention and counteraction programs) 5. The role of photogrammetry in the modernization of the building and land register using the photogrammetric method. Assessment of the possibility of using UAVs in the cadastral data update 6. Project of the IT System for Country protection against extraordinary threats (scope of photogrammetric works, examples of order documentation, contractor's reports, photogrammetric data control protocols within ISOK) 7. Effective use of photogrammetric data in hydraulic modelling 8. Application of photogrammetric data and products in security and defense 9. The role of aerial and satellite photogrammetry in creating topographic studies. The use of photogrammetry in BDOT10k production. 10. Aerial and satellite photogrammetry in urban and spatial planning. 11. Measurements of engineering structures with the use of aerial photogrammetry. 12. Discussion of the role of photogrammetric data in the implementation of the CAPAP project (examples of specifications, contractor reports and control protocols of 3D building models) 13. Products of aerial and satellite photogrammetry in forestry and environmental protection 14. Products of aerial and satellite photogrammetry in archeology 15. Use of archival photos in forensic expert opinions.
		Laboratory exercises: 1. Implementation of 2 selected short projects in the field of using pre-processed and oriented data from the aerial and satellite photogrammetry in selected applications, among which student can choose: a. The use of airborne and satellite data in assessment of the condition, inventory of stands, including, inter alia, detection of trees from ALS data, estimation of the amount of biomass, assessment of the health condition of stands using ALS data and vegetation indicators (NDVI, EVI, GRVI, NDWI) from aerial photos and satellite scenes, etc. b. The use of 3D modelling of buildings in selected issues, e.g. analysis of the assessment of the solar potential of buildings, solar analysis, advanced 3D visibility analysis, etc. c. The use of photogrammetric data (aerial photos, ALS, UAV data) in archeology - object detection, automatic vectorization, creating archaeological documentation d. The use of photogrammetric data (RGB orthophotomap, CIR orthophotomap, oblique imagery, digital terrain/surface models, etc.) for selected purposes of the administrative unit e. The use of LIDAR data in the inventory of engineering facilities: power infrastructure, transmission networks, poles, pipelines, etc. f. The use of satellite data in providing the use of 3D products: building models, digital surface t models g. Assessment of the quality, accuracy and compliance with the standard of selected photogrammetric products

	Remote Sensing Methods of Image Processing /E	Lectures: 1. Catalogs and repositories of available satellite data - sources of metadata about current and archive data. Platforms and hubs for data distributing and processing in Poland and around the world (including EarthExplorer, Copernicus / DIAS, Planet, GoogleEngine, EOBrowser. SCIHUB). 2. Satellite data formats. Structure of metadata in various satellite systems. Definitions of individual parameters included in the metadata. 3. Color systems used in the satellite images processing and their application. Color compositions. OIF and its role in the selection of a color composition for various purposes. Assessment of the suitability and quality of the performed processing for thematic interpretation and to actualize spatial databases. Pre-processing of satellite images: global and local analyzes. 4. Orthogonal transformations in the processing of satellite images, including PCA, Tasselet Cap and their applications. 5. Geometric correction of satellite images. Geometric distortions of satellite images and methods of their correction. Resampling methods and their influence on image radiometry. Geometry of distributed satellite images, available processing levels of satellite image products. 6. Radiometric and atmospheric correction of optical satellite images. Sources of radiometric errors. Atmospheric correction methods for optical images. The idea of operation of the models: 6S, MODTRAN, LOWTRAN, ATCOR. Available software (commercial and free) for atmospheric correction of satellite images and its functionality. 7. Methods of image fusion with different spatial and spectral resolutions (MS + PAN).
		Assessment of the quality of the resulting images in terms of preserving spatial and spectral features - review of assessment methods. Quality assessment of image fusion methods from the point of view of their further application. 8. Processing of thermal images. Terms: radiometric temperature, brightness temperature, surface temperature, kinetic temperature, object emissivity. Radiometric and atmospheric correction of thermal satellite images. Methods of atmospheric correction and calculating the surface temperature based on LANDSAT satellite data. Services and software enabling atmospheric correction of thermal images. 9. Applications of thermal images. Multi-time analysis of thermal images in various fields of science and economy.
		Exercises: 1. Analysis of the available remote sensing images. Services / catalogs of available satellite data. Searching the resource of available satellite images, analysis and selection of images for the given task, review of examples of satellite images from satellites of the latest generation. 2. Selection of color compositions taking into account statistical parameters. Evaluation of the informative capacity of color compositions. Calculation of the OIF, interpretation of the OIF value. 3. Optical image preprocessing (LANDSAT or SENTINEL-2): radiometric correction of satellite images.
		Calculation of spectral radiance, spectral reflectance based on satellite data. Atmospheric correction of satellite images - testing of selected methods (DOC, 6S model, ATCOR model, Beam / VISAT, ENVI / Flaash, relative methods). Analysis of the impact of radiometric and atmospheric correction on the results of qualitative (land cover classification) and quantitative (eg NDVI) analyzes. 4. Orthogonal transformations of satellite images and interpretation of their results. 5. PAN and MS image fusion on the example of SPOT5, IKONOS, QuickBird, WorldView-2, GeoEye-1 or Plejades-1A satellite images. Assessment of the quality of the pan-sharpened images in terms of preserving spatial and spectral features using selected methods. Assessment of the suitability of different image fusion methods for the interpretation/detection of various objects. 6. Pre-processing of thermal images: radiometric correction of satellite images. Calculation of spectral radiance, radiometric temperature, brightness temperature, and surface temperature based on LANDSAT and / or ASTER satellite data. Interpretation of the obtained results. Multi-time analysis of surface temperature. During the exercises, students carry out 3 project tasks in the field of: 1. correction of radiometric satellite images 2. PAN and MS image fusion using different methods and assessment of the quality of the obtained resultspan-sharpened images 3. processing and analysis of thermal images.

	Radar Remote Sensing	Lecture: 1. Basics of radar imagery: a. Synthetic SAR antenna b. Components of the radar signal (amplitude, intensity, phase) c. Geometry of radar images d. Formation of radar speckle e. Polarization f. Characteristics of radar wave bands 2. Characteristics of selected satellite radar systems 3. Examples of the applications of radar imagery a. Features affecting the creation of the radar image b. Interpretation of images c. Selected application examples. 4. Classification of the content of radar images: a. Classic b. Polarimetric. 5. Radar speckle: a. Types of filtration of radar speckle: classic, adaptive, morphological, polarimetric, multi-temporal; b. Examples of the use of radar speckle in classification. 6. Radar interferometry: a. Basics of radar interferometry b. Create an interferogram c. Differential Interferometry - DInSAR d. Persistent Scatterers Interferometry - PSInSAR e. Application examples. 7. Integration of radar and optical images. Exercises: 1. Sentinel-1 Data review and acquisition. Various registration formats and data processing levels (SLC, GRD), radar imagery interpretation 2. Basic operations: calibration, mulltilooking, radiometric and topographic correction, calculation of the sigma0 coefficient, creating color compositions from 2 polarization images. 3. Multi-temporal classification of the Sentinel-1 imagery 4. Texture analysis and filtering of radar images in various image processing programs. 5. Processing of Radarsat-2 polarimetric images: polarimetric matrix, quad-pol image content classification 6. Radar interferometry: creation of an interferogram.
	Hyperspectral Remote Sensing	Lectures: 1. The idea and theoretical background of hyperspectral imagery acquisition. Multispectral vs hyperspectral data – the comparison of pros, cons and technological limitations. 2. The review of systems acquiring super- and hyperspectral imagery using different types of sensors – satellite, airborne, UAV and other. 3. The sources of radiometric errors present in hyperspectral imagery, instrumental noise and its source dependent on data registration method. 4. Pre-processing of the data – radiometric, geometric and atmospheric correction of hyperspectral imagery. Dimensionality reduction – a review of methods. 5. Ground-based spectrometric measurements. Spectral libraries and their role in processing of hyperspectral data. 6. Indices and their use. 7. Classification methods suitable for processing hyperspectral imagery. Pixel and sub-pixel classification methods. The review of different algorithms (i.a. Random Forest, Suport Vector Machine, Spectral Angle Mapper, Spectral Correlation Mapper).
		8. The usefulness of hyperspectral imagery in different industry sectors and use-cases – agriculture, forestry, monitoring of environment, detecting material types (e.g. asbestos). Exercises: The exercises have a form of a project which includes all the necessary steps aimed at obtaining a thematical layer and starting from data acquisition. Students are able to choose which thematical layer will be a subject of their project – crop types, forest tree species, roofing types etc. Each project must include: 1. The assessment of image quality level by analysing the Signal to Noise Ratio (SNR). 2. Radiometric and atmospheric correction of hyperspectral imagery. 3. Dimensionality reduction including Minimum Noise Fraction method. 4. Classification including reference data preparation, selection of a suitable algorithm, accuracy assessment and post-processing.
	Diploma Seminar	Principles of writing an Msc thesis, guidelines for the thesis exam, presentations of the scope and progress of the thesis, practicing the ability to present the results of their work