University of Isfahan

Photogrammetery Engineering Graduate Program

Curriculum

Department of Geomatics Engineering

Faculty of Civil and Transportation Engineering

University of Isfahan

January 8, 2024

1- Introduction

The curriculum of the surveying-photogrammetry course based on the records of several years of surveying engineering department and based on:

Title of Master's Degree in Photogrammetry, University of Isfahan
Title of master's degree in photogrammetry of KNT University
Title of Master's Degree in Photogrammetry, University of Tehran

2- The importance of photogrammetry

Photogrammetry includes the methods of measuring and interpreting information obtained by different sensors in order to extract the shape and location of objects. Basically, photogrammetry methods can be used in any situation where the objects are exposed to the sensor. The goal of photogrammetry is the three-dimensional reconstruction of an object based on coordinates and geometric elements in the form of images and maps. Determining the position and orientation of the sensor installed on various platforms, reconstructing the three-dimensional shape of the subject and also interpreting the data to identify objects are the three basic steps in photogrammetry. In order to determine the position and orientation of a sensor, and three-dimensional coordinates, it is necessary to extract a mathematical model based on the geometry of the sensor. These mathematical models include all the effective elements in obtaining data by the sensor. Interpreting the obtained data to extract the pattern and identify the objects in the scene and finally form their 3D model is one of the important challenges in photogrammetric processing.

The purpose of this course is to train qualified professionals who have the ability to carry out research and developments in photogrammetry based on data obtained by various satellite, aerial and ground sensors in different fields. (according to the rapid growth of this field in the world).

3- The skills of graduates of the field

1. Carrying out research and application projects of photogrammetry and machine vision
2. Designing and building systems for automatically obtaining spatial information from objects
3. Management, consultation and supervision in the implementation of spatial information production projects, such as the preparation of country coverage maps, cadastre, land surveying and environmental monitoring.
4. Automating the steps of extracting, reconstructing, managing, processing, storing and displaying information obtained by all kinds of sensors located on different satellite, air and ground platforms and their application in designing and managing projects in different fields. civil, environmental, land and water resource management, etc.
5. Using photogrammetric methods in determining the position and 3D quality control of objects.
6. using photogrammetric methods for geometric measurement in industrial, medical, architectural, cultural heritage and etc.
7. Development of real-time positioning algorithms based on various sensors (and navigation) installed on various platforms.
8. Development of new systems based on positioning and online map production to obtain 3D information by robots and drones.
9. Development of algorithms for positioning and scene interpretation of self-driving cars

4- Educational and research program

This educational and research program is a set of lessons (theoretical, seminar and thesis) which is planned to strengthen the scientific ability of students to carry out research activities and to understand the new concepts of photogrammetry. A set of main courses and supplementary education courses for master's and Ph.D. level have been prepared according to table 2 and 3 and clauses 4-1 to 4-4.

Note 1: In addition to the supplementary education courses stated in Table No. 3, the student can, according to the opinion of his supervisor and the approval of the department council, take three credits of courses from the supplementary education courses of the surveying engineering department. He should take other courses such as physics, electronics, telecommunications, statistics and mathematics, geographic information systems, geology, and computer so that the total number of credits in his degree is respected.

4-1- Master's degree

Master's degree students in the field of civil engineering surveying-photogrammetry are required to pass 32 credits including 7 of main courses (table no. 2) equivalent to 19 credits and 2 courses with the recommendation of the supervisor and the approval of the department council, from among the supplementary education courses (table no. 3) are equivalent to 6 credits and the course of the senior seminar and the senior thesis (7 credits).

Note 2: It is not recommended to enter a master's degree student in the education-oriented method for this field, but in case of registration of this type of student, taking other courses from the supplementary education courses (Table No. 3 and Note 1) equivalent to 6 credits, instead of graduation The thesis.

4-2- Doctoral degree

Ph.D. students in civil engineering surveying-photogrammetry complete a total of 36 credits. This number of credits for the students of educational-research method includes six courses (equivalent to 18 credits) from the supplementary education courses (Table No. 3) and the doctoral thesis course is equivalent to 18 credits.

Note 3:

For Ph.D. students in the field of civil engineering surveying-photogrammetry in a research method with the proposal of the supervisor and the approval of the department council, a maximum of 3 courses (equivalent to a maximum of six credits) from among the supplementary education courses (table no. 3) and also a doctoral thesis credit (equivalent to 33 up to 33 credits) is required.

4-3- compensatory lessons

At the master's level, for students whose field of study was not surveying engineering, with the decision of the department council, compensatory courses (maximum 12 credits) from surveying engineering courses are determined for the student.

At the Ph.D. level, the student must take a maximum of 3 courses as compensatory courses from the table of main courses (Table No. 2) with the suggestion of the supervisor and the approval of the department council. In both levels, compensatory courses must be passed successfully, while no credit is assigned to these courses.

4-4- Table of educational and research programs

The summary of the educational and research program for each of the degrees and educational methods in this field according to the approvals of the Ministry of Science, Research and Technology and the approvals of the University of Isfahan, in this field, is described in Table 1.

Table 1 - The number of units required for each of the courses and educational methods of the field of civil engineering mapping - photogrammetry

Research doctorate	Educational-research doctorate	Master's degree	
up to 2 lessons from Table of main lessons	up to 3 lessons from Table of main lessons	up to 12 credits of BSC courses	Compensatory courses

-	-	13	Lessons
3 to 6	18	12 (18 for education-oriented)	Lessons
-	-	1	Seminar Credit
30 to 33	18	zero for education-oriented	Thesis
36	36	32	

- Scope and method in the thesis

The scope of theses in this field includes the issues raised in the skills section of the graduates. Each thesis is based on the theoretical foundations and review of the latest developments in the topics raised in that section, based on the acquisition and pre-processing of satellite, air, ground data and field data collection, to process these data. And also obtaining results and information, during this research, he develops theoretical topics and presents operational and regional-local algorithms and confirms the quality of the results of the methods.

Table 2- The main courses of civil engineering, surveying-photogrammetry

row	Course name	Credit		Hours		Perquisite
		theory	Practical	theory	Practical	
1	Image and signal processing	3	-	48	-	-
2	Point cloud processing	3	-	48	-	1
3	3D optical measurement methods	3	-	48	-	7
4	research methods in earth sciences	1	-	48	-	-
5	Advanced programming for computer vision	3	-	48	-	-
6	Machine learning for computer vision	3	-	48	-	5
7	Digital photogrammetry and machine vision	3	-	48	-	-
total		19				

Table 3- Postgraduate courses in civil engineering surveying-photogrammetry

row	Course name	Credit		Hours		Perquisite
		theory	Practical	theory	Practical	
1	Robot-based mapping	2	-	48	-	-
2	Radar image processing	2	-	48	-	-
3	Platforms and sensors	2	-	48	-	-
4	Spectral image analysis	2	-	48	-	-
5	Self-driving vehicle systems and methods	2	-	48	-	-
6	advanced spatial information systems	2	-	48	-	-
7	advanced statistics	2		48	-	-
8	spatial data Integration	2	-	48	-	-
9	stochastic processes	2		48	-	-
10	advanced optimization algorithms	2		48	-	-
11	Change detection using photogrammetry and remote	2		48	-	-

row	Course name	Credit		Hours		Perquisite
	sensing					
12	neural networks	2		48	-	-
According to Note 1		According to Note				

List of Core and Elective Courses

Core Courses

Digital Photogrammetry and Machine Vision

Basic Information

Place in curriculum, title and semester: core, Digital Photogrammetry and Machine Vision, S1
Number of credits: 3

Course Prerequisites

Course Co-requisites

Image and Signal Processing

Teachers

The person in charge: Dr. Mehran Satari
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, Isfahan, 81746-73441, Iran
Phone number:
Homepage: https://engold.ui.ac.ir/~sattari/
Email address: sattari@eng.ui.ac.ir
Other instructors: ---

Weekly Hours

Theory	Problem Solving	Laboratory	Guided learning
3 h	1 h	---	---

Course Objectives

The digital photogrammetry and machine vision course aims to equip students with advanced knowledge in digital photogrammetry and machine vision. Through rigorous study, students will develop expertise in sensor calibration, image matching algorithms, and 3D visualization techniques. Practical applications and hands-on experience will prepare students for tackling complex spatial data challenges in various fields.

Required Student Resources

References:

1. M. Hassaballah and A. I. Awad, (2020). Deep Learning in Computer Vision: Principles and Applications. CRC Press.
2. S. J. D. Prince, (2012). Computer vision: models, learning, and inference. Cambridge University Press.
3. W. Linder, (2009). Digital Photogrammetry: A Practical Course, Springer, Berlin, Heidelberg.
4. T. F. Schenk, (1999). Digital Photogrammetry, Terra Science.

Web linkes: ---

Student's field trip: ---

COURSE SCHEDULE/OUTLINE/CALENDAR OF EVENTS

Week	Topic
1	Introduction to Digital Photogrammetry and Machine Vision, Homogeneous representation 2D/3D, Transformations, Rotations
2	Sensor Calibration: Camera calibration methods and software tools, Intrinsic and extrinsic parameter estimation, Calibration stability analysis and error propagation
3	Geometry and Orientation: Geometry and Orientation of the single/pair and Triplet images in Homogeneous space, Epipolar geometry and fundamental matrix estimation, Stereo vision and disparity mapping, Multi-view Geometry, Structure from motion (SfM) algorithms
4	Image Matching I: Basic image matching method, feature based matching, correlation-based matching, object-based matching, least square image matching, Forstner Operator
5	Image Matching II: Advanced image matching algorithm, SIFT, SURF, ORB, …
6	Point Cloud Generation I: Point Cloud Generation Algorithm, Global Matching, Image space Semi Global Matching, Deep Networks for image matching.
7	Point Cloud Generation II: Advanced Point Cloud Generation Methods, Deep Network for point cloud generation
8	Multi Image Matching: Multi image least square matching, Object-based multi-image matching, Multi image matching with surface grid, Object-based semi-global image matching,
9	Matching in image sequences: Optical flow steps, 2D object tracking in single camera, 3D object reconstruction from single camera image sequences, Object tracking in multi-camera image sequences.
10	Bundle Adjustment: Block Adjustment, Sparsity of Matrices, Free adjustment and Theoretical Precision, Self-calibration, camera calibration, Outlier detection
11	Orthophoto generation and Image registration: Principles of orthophoto generation, feature-based registration, Image to map registration, semantic image registration, accuracy assessment and validation.
12	Quality Assurance and Control: Automated quality assessment methods for image and point cloud data, Error propagation analysis in photogrammetric workflows, Uncertainty modeling and propagation in 3D reconstruction.
13	Advanced Visualization Techniques: 3D visualization of photogrammetric mapping results using virtual reality (VR) and augmented reality (AR) technologies, Interactive 3D fly-through and walkthrough simulations of mapped landscapes, Integration of photorealistic rendering and lighting effects for immersive map visualization.
14	Advanced Applications: UAV-based photogrammetry for precision agriculture, Cultural heritage documentation and conservation, Disaster monitoring and management using

	photogrammetric techniques

EVALUATION PROCEDURES AND GRADING CRITERIA

Assignments	2 points
Comprehensive Assignment	3 points (at max)
Mid-Term Exam	7 points
Final Exam	8 points
Total Points	20 points

Optical 3D measurement methods

BASIC INFORMATION

Place in Curriculum, title and semester: Main Course

Number of credits: 3

COURSE PREREQUISITES

COURSE CO-REQUISITES

TEACHERS

The person in charge:
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, 81746-73441, Isfahan, Iran
Phone Number: +98 (31) 37935298
Homepage:
Email Address:
Other instructors: -

WEEKLY HOURS

Theory	Problem Solving	Laboratory	Guided learning
3 h	---	---	---

COURSE OBJECTIVES

The aim of this course is to open up the minds of students with the methods of optical three-dimensional measurement and industrial photogrammetry.

REQUIRED STUDENT RESOURCES

1. Luhmann, T., Robsin, S., Kyle, S. Close-Range Photogrammetry and 3D imaging.2019

Forstner, W., Wrobel, B.P., Photogrammetric Computer Vision. Statistics, Geometry, Orientation and Reconstruction. 2018.

Steger C., Ulric M., Wiedemann C., Machine Vision Algorithms and Applications. 2018.

COURSE SCHEDULE/OUTLINE/CALENDAR OF EVENTS

Week	Topic
1	Camera calibration
2	Camera calibration
3	Accuracy optimization
4	Measurement methods with sub-pixel accuracy
5	High accuracy 3D measurement processes

6	High accuracy 3D measurement processes
7	Accurate Industrial Surface Modelling
8	Accurate Industrial Surface Modelling
9	3D motion analysis
10	3D motion analysis
11	3D cameras
12	Database normalization, Query languages, Indexing and storage, Spatial queries
13	3D cameras
14	Shape from motion
15	Shape from sillhoeete
16	Optical scanners

EVALUATION PROCEDURES AND GRADING CRITERIA

Continuous evaluation: Yes
Mid-Term exam: No
Final exam: Yes
Evaluation Project: Yes

Point Cloud Processing and Modeling

BASIC INFORMATION

Place in curriculum, title and semester: core, Point Cloud Processing and Modeling, S2
Number of credits: 3

COURSE PREREQUISITES

Image and Signal Processing

COURSE CO-REQUISITES

TEACHERS

The person in charge: Dr. Mehran Satari
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, Isfahan, 81746-73441, Iran
Phone number:
Homepage: https://engold.ui.ac.ir/~sattari/
Email address: sattari@eng.ui.ac.ir
Other instructors: ---

WEEKLY HOURS

Theory	Problem Solving	Laboratory	Guided learning
3 h	----	---	---

COURSE OBJECTIVES

The course aims to acquaint students with photogrammetry tools, with a special emphasis on laser scanners, and diverse 2.5D and 3D processing methodologies tailored for point clouds derived from satellite, aerial, and terrestrial LiDAR systems. It will cover crucial concepts such as georeferencing, noise reduction, feature extraction, segmentation, classification, object recognition, and 3D modeling of point cloud data. By the end of the course, students will possess the requisite skills to proficiently handle and model point clouds, enabling them to apply these techniques across various domains including geospatial analysis, urban planning, and environmental monitoring.

REQUIRED STUDENT RESOURCES

References:

1. Vosselman, G and Maas H.G., Airborne and Terrestrial Laser Scanning 2010.
2. Shan, J., and Toth, C.K., Topographic Laser Rangigng and Scanning: Principles and Processing 2017.
3. Zhang, G. and Chen, Y., Toward Optimal Point Cloud Processing for 3D reconstruction. 2022
4. Hajji, R. and Oulidi H.J., Building Information Modeling for Smart and Sustainable. 2022.

Web linkes: ---
Student's field trip: ---

COURSE SCHEDULE/OUTLINE/CALENDAR OF EVENTS

Week	Topic
1	Point Cloud Basics: Satellite-based, aerial, and terrestrial laser scanners, Point Cloud Data Format Fundamentals, Point Cloud Pre-processing Fundamentals, Basics and Advanced
2	Point Cloud Engineering I: Point Cloud Feature Extraction Fundamental, Point Cloud Registration Fundamental, Basics and Advanced
3	Point Cloud Engineering II: Point Cloud Feature Extraction Fundamental, Point Cloud Registration Fundamental, Basics and Advanced
4	Point Cloud Representation I: Point Cloud Segmentation and Clustering Fundamental, Basics and Advanced. Point Cloud Classification, Fundamental, Basics and Advanced. Point Cloud Semantic Segmentation
5	Point Cloud Representation II: Point Cloud Segmentation and Clustering Fundamental, Basics and Advanced. Point Cloud Classification, Fundamental, Basics and Advanced. Point Cloud Semantic Segmentation.
6	Point Cloud Analysis and Visualization I: Point Cloud Analysis Fundamental. 3D geometry analysis Basics and Advanced. Point Cloud Visualization Fundamentals. Generation of Visuals.
7	Point Cloud Analysis and Visualization II: Point Cloud Analysis Fundamental. 3D geometry analysis Basics and Advanced. Point Cloud Visualization Fundamentals. Generation of Visuals.
8	Data Structure and Modelling I: Point Cloud Data Structure Fundamentals. Point Cloud Data Structure Basics and Advanced. Point Cloud Modeling Fundamental, Basics and Advanced.
9	Data Structure and Modelling II: Point Cloud Data Structure Fundamentals. Point Cloud Data Structure Basics and Advanced. Point Cloud Modeling Fundamental, Basics and Advanced.
10	Introduction to Full Waveform Analysis: Overview of LiDAR Technology and Full Waveform Analysis, Differences between full waveform and discrete return LiDAR, Principles and advantages of full waveform analysis.
11	Advanced Techniques in Full Waveform Analysis: Pulse Decomposition Analysis, Principles of pulse decomposition, Different decomposition algorithms, Applications and case studies.
12	Airborne LiDAR Data Processing: Airborne LiDAR Data Characteristics and Processing Workflow, Overview of airborne LiDAR systems, Data preprocessing steps for airborne LiDAR, Hands-on session: Preprocessing airborne LiDAR data.
13	Satellite LiDAR Data Processing: Satellite LiDAR Data Characteristics and Processing Workflow, Introduction to satellite LiDAR missions and data products, Preprocessing

	steps for satellite LiDAR data, Hands-on session: Preprocessing satellite LiDAR data.
14	3D Python ADD-ONS I: 3D Python Basics for Point Cloud, Environment and 3D library Set-up. The CC library for Deep Automation. Point Cloud to 3D Voxel / Mesh. Latest Code Tutorial and R&D.

EVALUATION PROCEDURES AND GRADING CRITERIA

Assignments	2 points
Comprehensive Assignment	3 points (at max)
Mid-Term Exam	7 points
Final Exam	8 points
Total Points	20 points

Modern Programming for Computer Vision

Basic Information

Place in Curriculum, title and semester: Main Course,
Number of credits: 3

Course prerequisites

Image Processing, Digital Photogrammetry

Course co-requisites

Teachers

The person in charge:
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, 81746-73441, Isfahan, Iran
Phone Number: +98 (31) 37935298
Homepage:
Email Address:
Other instructors: ---

Weekly Hours

Theory	Problem Solving	Laboratory	Guided learning
3 h	---	---	---

Course Objectives

This course aims to open up the minds of students with advanced programming for computer vision. Finally, having the ability to use existing libraries and implement various algorithms with C++ and Python languages.

References

1. Lippman S., C++ Primer 5th Editin. 2020.
Rever M., Computer Vision Projects With OpenCV and Python. 2020.
Gollapudi S., Learn Computer Vision Using OpenCV with Deep Learning CNNs and RNNs. 2019.
Howse, J., Minichino J., Learning OpenCV for Computer Vision with Python. 2020.

Course Schedule/Outline/Calendar of Events

Week	Topic
1	Introduction
2	Build and Tools
3	Instructions, rules and methods in programming C++
4	Standard libraries in C++ (the C++ STL Library)
5	Input and export files, Introduction to Classes

6	Input and export files, Introduction to Classes
7	Modern C++ Classes
8	Modern C++ Classes
9	Object Oriented Design
10	Object Oriented Design
11	Memory Management
12	Memory Management
13	Templates in C++
14	Templates in C++
15	Final Project

EVALUATION METHOD

Continuous evaluation: Yes.
Mid-Term exam: Yes
Final exam: Yes
Evaluation Project: Yes

Machine Learning for Computer Vision

BASIC INFORMATION

Place in curriculum, title and semester: core, Machine Learning for Computer Vision, S1
Number of credits: 3

COURSE PREREQUISITES

COURSE CO-REQUISITES

TEACHERS

The person in charge: Dr. Hossein Bagheri
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, Isfahan, 81746-73441, Iran
Phone number: +983137935299
Homepage: https://cet.ui.ac.ir/ ~h.bagheri
Email address: h.bagheri@cet.ui.ac.ir
Other instructors: ---

WEEKLY HOURS

Theory	Problem Solving	Laboratory	Guided learning
3 h	yes	---	---

COURSE OBJECTIVES

The purpose of this course is to acquaint students with machine learning algorithms in order to use them in tasks related to computer vision and photogrammetry, such as classification, segmentation and detecting of objects from images.

REQUIRED STUDENT RESOURCES

1. I., Goodfellow, Y., Bengio, & A., Courville, (2016). Deep Learning. MIT Press.
2. C. M. Bishop and N. M. Nasrabadi, (2006). Pattern recognition and machine learning, vol. 4. Springer.
3. M. Hassaballah and A. I. Awad, (2020). Deep Learning in Computer Vision: Principles and Applications. CRC Press.
4. S. J. D. Prince, (2012). Computer vision: models, learning, and inference. Cambridge University Press.

Web linkes: ---
Student's field trip: ---

COURSE SCHEDULE/OUTLINE/CALENDAR OF EVENTS

Week	Topic

1	An introduction to machine learning
2	Regression: linear regression, maximum similarity for linear regression, non-linear functions, overfitting, Bayesian linear regression
3	Classification: Bayesian method, decision tree, logistic regression, softmax regression
4	Ensemble learning: random forest, AdaBoost, gradient-based methods
5	Unsupervised learning: Gaussian mixture model, principal component analysis
6	Stochastic Neighbor Embedding
7	Machine learning for computer vision
8	Neural networks
9	Convolutional neural networks
10	Image classification and CNN
11	Image segmentation and CNN
12	Advanced topics of deep learning applications in computer vision

EVALUATION PROCEDURES AND GRADING CRITERIA

Assignments	2 points
Comprehensive Assignment	3 points (at max)
Mid-Term Exam	7 points
Final Exam	8 points
Total Points	20 points

Image and Signal Processing

Basic Information

Place in curriculum, title and semester: core, Image and Signal Processing, S1
Number of credits: 3

Course prerequisites

Course co-requisites

Teachers

The person in charge: Dr. Hossein Bagheri
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, Isfahan, 81746-73441, Iran
Phone number: +983137935299
Homepage: https://cet.ui.ac.ir/ ~h.bagheri
Email address: h.bagheri@cet.ui.ac.ir
Other instructors: ---

Weekly Hours

Theory	Problem Solving	Laboratory	Guided learning
3 h	yes	---	---

Course Objectives

Programming knowledge is required for all engineering disciplines, especially for Gematics Engineering. It lays the foundation for understanding more advanced concepts such as ground and aerial data collection, navigation, and more. The course is accompanied and supplemented by exercises that are carried out using MATLAB® and Python and image processing tools on the computer.

Required Student Resources

References:

1. Gonzalez R., Woods R., Digital Image Processing 4th Edition. 2020.
2. Richards J.A., Remote Sensing Digital Image Analysis. 2022
3. Chityala R., Pudipeddi S., Image Processing and Acquisition using Python. 2021

Web linkes: ---
Student's field trip: ---

Course Schedule/Outline/Calendar of Events

Week	Topic

1	Basics of digital images
2	Filtering in spatial space and intensity transformations
3	Filtering in frequency space
4	Image retrieval and reconstruction
5	Wavelet transform
6	Color image processing
7	Morphological processing of images
8	Fragmentation of images
9	Feature extraction
10	Classification based on pattern recognition

EVALUATION PROCEDURES AND GRADING CRITERIA

Assignments	2 points
Comprehensive Assignment	3 points (at max)
Mid-Term Exam	7 points
Final Exam	8 points
Total Points	20 points

Elective Courses

Neural Networks

BASIC INFORMATION

Place in curriculum, title and semester: elective, Neural Networks, S2
Number of credits: 3

COURSE PREREQUISITES

COURSE CO-REQUISITES

TEACHERS

The person in charge: Dr. Hossein Bagheri
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, Isfahan, 81746-73441, Iran
Phone number: +983137935299
Homepage: https://cet.ui.ac.ir/ ~h.bagheri
Email address: h.bagheri@cet.ui.ac.ir
Other instructors: ---

WEEKLY HOURS

Theory	Problem Solving	Laboratory	Guided learning
3 h	yes	---	---

COURSE OBJECTIVES

The purpose of this lesson is to introduce the history, theory, applications, capabilities and limitations of different types of neural networks.

REQUIRED STUDENT RESOURCES

References:

1. L., Goodfellow, Y., Bengio, & A., Courville, (2016), Deep Learning, MIT Press.
2. D. Graupe, (2007), Principles of Artificial Neural Networks, Advanced Series in Circuits and Systems, World Scientific.
3. S. Haykin, (2009), Neural Networks: A Comprehensive Foundation, 3rd Edition, Pearson Education.
4. S. Samarasinghe, (2006), Neural Networks for Applied Sciences and Engineering: From Fundamentals to Complex Pattern Recognition, 1st Edition, Auerbach.
5. R.J. Schalkoff, (1997), Artificial Neural Networks, McGraw Hill.
6. L. Fausett, “Fundamentals of Neural Networks: Architectures, Algorithms and Applications”, Prentice Hall, 1994.

Web linkes: ---
Student's field trip: ---

COURSE SCHEDULE/OUTLINE/CALENDAR OF EVENTS

Week	Topic
1	An introduction to artificial neural networks, history, limitations and general concepts
2	Artificial neural network, mathematical modeling of neurons, activation functions, different structures, learning process
3	An introduction to pattern recognition, definitions, pattern generation, the overall structure of the pattern recognition system and its various methods
4	Fully connected multi-layer perceptron, main structure, learning rule in pattern-to-pattern and batch mode, limitations and examples
5	Basics of optimization, types of optimal points and examples, examination of quadratic functions, gradient descent and examples
6	Convolution, convolutional neural network, training and learning techniques
7	Structures of deep convolutional networks AlexNet, VGG, ResNet, Inception, etc.
8	Recurrent neural networks, their applications and limitations, long short-term memory networks
9	Generative deep learning structures, adversarial generative networks and their applications

EVALUATION PROCEDURES AND GRADING CRITERIA

Assignments	2 points
Comprehensive Assignment	3 points (at max)
Mid-Term Exam	7 points
Final Exam	8 points
Total Points	20 points

Spatial Data Fusion

Basic Information

Place in curriculum, title and semester: Elective, Image Fusion in Remote Sensing, S1
Number of credits: 3

Course Prerequisites

Course Co-requisites

Teachers

The person in charge: Dr. Sayyed Bagher Fatemi
Office location: Department of Geomatics Engineering, Faculty of Civil Engineering & Transportation, University of Isfahan, Isfahan, 81746-73441, Iran
Phone number: +983137935332
Homepage: https://engold.ui.ac.ir/~sb.fatemi/
Email address: https://engold.ui.ac.ir/~sb.fatemi/
Other instructors: ---

Weekly Hours

Theory	Problem Solving	Laboratory	Guided learning
3 h	----	---	---

Course Objectives

Introduce image fusion in remote sensing (concepts, levels, methods, quality control methods)

Required Student Resources

References:

1. Mitchell H.B., (2010), Image Fusion: Theories, Techniques and Applications, Springer.
2. Stathaki T., (2008), Image Fusion: Algorithms and Applications, Academic Press.
3. Chaudhuri S., K. Kotwal, (2013), Hyperspectral Image Fusion, Springer.
4. Blum R.S., Zh. Liu, (2005), Multi-Sensor Image Fusion and Its Applications (Signal Processing and Communications), CRC Press.
5. Stathaki T., (2008), Image Fusion: Algorithms and Applications, Academic Press.
6. Poh C.l, J. van Genderen, (2019), Remote Sensing Image Fusion A Practical Guide, CRC Press.

Web linkes: ----

Student's field trip: ---

Course Schedule/Outline/Calendar of Events

Week	Topic

1	Introduction: Importance of data fusion in Earth sciences, reasons for data and image fusion in remote sensing.
2	Data Preparation for Fusion: Preprocessing related to fusion (geometric and radiometric corrections).
3	Explanation of Fusion Levels with Practical Examples.
4	Image Fusion at Pixel Level: Basics, applications.
5	Transformations Required for Image Fusion based on existing categories: Wavelet transform, principal components, and other transformations.
6	Pixel Level Fusion Methods and Categorization: Substitution, etc.
7	Feature Level Fusion: Basics, methods like Feature Stacking.
8	Decision Level Image Fusion: Introduction of combined classifier systems (Combiners, Ensembling).
9	Supervised Decision Level Fusion Methods
10	Unsupervised Decision Level Fusion Methods
11	Ensembling: Basics, methods.
12	Fuzzification in Fusion: Principles of fuzzification, fuzzification at lower fusion levels, fuzzy combination rules in decision functions and probability models.
13	Evaluation of Fusion Results: Methods, levels, metrics (Spectral Quality, Spatial Quality, etc.)
14	Analysis of Remote Sensing Data in Information Systems and practical discussions on integrating remote sensing with other Earth sciences.

EVALUATION PROCEDURES AND GRADING CRITERIA

Assignments	4 points
Comprehensive Assignment	4 points (at max)
Mid-Term Exam	0 points
Final Exam	12 points
Total Points	20 points