COURSE OUTLINE

(1) GENERAL

SCHOOL	ENGINEERING		
ACADEMIC UNIT	ELECTRICAL AND COMPUTER ENGINEERING DEPT.		
LEVEL OF STUDIES	Undergraduate		
COURSE CODE	**ECE_TEL750**	**SEMESTER**	**7**
COURSE TITLE	DIGITAL IMAGE PROCESSING		

INDEPENDENT TEACHING ACTIVITIES *if credits are awarded for separate components of the course, e.g. lectures, laboratory exercises, etc. If the credits are awarded for the whole of the course, give the weekly teaching hours and the total credits*	**WEEKLY TEACHING HOURS**	**CREDITS**
Lectures	3	
Laboratory	1	
Add rows if necessary. The organisation of teaching and the teaching methods used are described in detail at (4).	4	5

COURSE TYPE *general background, special background, specialised, general knowledge, skills development*	Specialised
PREREQUISITE COURSES:	This course has no prerequisite courses. However, the students should have prior knowledge of: • PROBABILITIES AND STATISTICS • DIGITAL SIGNAL PROCESSING
LANGUAGE OF INSTRUCTION and EXAMINATIONS:	GREEK AND ENGLISH
IS THE COURSE OFFERED TO ERASMUS STUDENTS	YES
COURSE WEBSITE (URL)	https://www.ece.uop.gr/

(2) LEARNING OUTCOMES

Learning outcomes

The course learning outcomes, specific knowledge, skills and competences of an appropriate level, which the students will acquire with the successful completion of the course are described.

Consult Appendix A

- *Description of the level of learning outcomes for each qualifications cycle, according to the Qualifications Framework of the European Higher Education Area*
- *Descriptors for Levels 6, 7 & 8 of the European Qualifications Framework for Lifelong Learning*

and Appendix B

- *Guidelines for writing Learning Outcomes*

The aim of this course is to introduce students to the basic concepts, techniques and algorithms of digital image processing theory and applications. For this purpose, the fundamental principles of digital images are presented. The basic image intensity transforms are studied. Algorithms in the area of spatial filtering of images are presented. Basic categories of digital filters are studied. In addition, image filtering in the frequency domain is also studied. Definitions of the Fourier transform are given in the two dimensions as the expansion of the one-dimensional transform. In addition to Fourier-related transforms, other important image transforms such as Haar, Walsh-Hadamard, and Wavelets are also presented. The basic noise models that appear in the stages of recording, transmitting, and compressing of digital images are presented. Image restoration and reconstruction techniques and

algorithms are studied. The concepts of image compression and the basic compression algorithms are presented. Additionally, line and edge detection algorithms are also studied. Definitions are given for morphological image processing. The basic concepts and techniques of image segmentation with threshold are presented, using region-oriented algorithms, region growing, region merging, and region splitting. Finally, the concepts and algorithms for exporting image features and descriptors are presented together with real-world applications.

Keywords: Image processing, Fourier transform, spatial filtering, wavelets, segmentation, image restoration, growing region, region merging, region splitting, image compression, feature extraction.

Learning outcomes

Upon successful completion of the course, students will be able to:

At the knowledge level:

- Know how to create and represent digital images
- Be familiar with the mathematical tools used in digital image processing
- Understand the meaning of spatial image processing
- Be familiar with basic intensity transforms
- Understand the mechanics of spatial filtering
- Understand filters in the frequency domain.
- Know the basic characteristics of noise models
- Be familiar with the linear, non-linear and adaptive spatial filters used to restore and reconstruct images.
- Understand inverse filtering and limitations.
- Understand Wiener filters and their advantages.
- Understand basic image transforms (Walsh-Hadamart, Haar, Wavelet)
- Understand basic image compression methods
- Understand the basic concepts of mathematical morphology and their applications in digital image processing.
- Understand the characteristics of edges and edge detection algorithms
- Understand the fundamentals and applications of a wide range of features and descriptors used in real-wortld image processing applications.

At the skill level:

- Calculate basic intensity transform techniques
- Calculate and design basic types of spatial filters and ways to apply them.
- Design filters in the frequency domain.
- Design linear, non-linear and adaptive spatial filters for use in image restoration / reconstruction problems.
- Calculate inverse filters of images for image restoration.
- Design Wiener filters for image restoration problems.
- Calculate image transforms
- Design algorithms for morphological analysis of digital images
- Apply edge detection algorithms on images
- Calculate and extract the appropriate features for image processing and image recognition tasks.

At the level of abilities:

- Choose the most suitable filter depending on the problem they have to solve.
- Choose the appropriate image restoration method depending on the degree of image

degradation.

- Choose the appropriate features that best describe the digital image depending on the problem they need to solve.
- Select the appropriate edge detection algorithms in images.
- Collectively use theory principles to solve complex real-world problems from the digital image processing area.

General Competences

Taking into consideration the general competences that the degree-holder must acquire (as these appear in the Diploma Supplement and appear below), at which of the following does the course aim?

Search for, analysis and synthesis of data and information, with the use of the necessary technology	*Project planning and management*
Adapting to new situations	*Respect for difference and multiculturalism*
Decision-making	*Respect for the natural environment*
Working independently	*Showing social, professional and ethical responsibility and sensitivity to gender issues*
Team work	*Criticism and self-criticism*
Working in an international environment	*Production of free, creative and inductive thinking*
Working in an interdisciplinary environment	*……*
Production of new research ideas	*Others…*
	…….

- Search for, analysis and synthesis of data and information, with the use of the necessary technology.
- Decision-making
- Work independently
- Teamwork
- Work in an international environment
- Production of free, creative and inductive thinking

(3) SYLLABUS

Brief description

Digital image processing. Fundamental steps of the digital image processing area. Fundamental principles of digital imaging. Intensity transforms and spatial filtering of images. Filtering in the frequency domain. Image restoration and reconstruction techniques. The wavelet transform. Other types of transforms. Image compression. Basic compression techniques. Morphological image processing. Image segmentation. Image feature extraction. Basic image features and descriptors.

Theory lectures

1. Introduction to Digital Image Processing (DIP).

Origin of DIP. Fields of application. Fundamental steps. Visual perception elements. Image sensing and acquisition. Image sampling and quantization. Basic relationships between pixels. Basic mathematical tools used in digital image processing.

2. Intensity transforms. Spatial image filtering (A)

Basic functions of intensity transforms. Image histogram processing. Basic theory of spatial image filtering.

3. Spatial image filtering (B)

Smoothing (low-pass) filtering. Sharpening (high-pass) filtering. High-pass, bandreject and bandpass filters from low pass filters. Combination of spatial enhancement methods.

4. Filtering in the frequency domain (A)

Theoretical background. Basic mathematical tools. Sampling and Fourier Transformation of sampled functions. Discrete Fourier transform of one variable. Extensions to functions of two variables. Properties of 2-D DFT and IDFT.

5. Filtering in the frequency domain (B)

Basic filtering theory in the frequency domain. Image smoothing using lowpass frequency domain filters. Image sharpening using highpass filters. Selective filtering. The Fast Fourier transform.

6. Image Restoration and reconstruction (A)

A model of image degradation / restoration. Noise models. Restoration in the presence of noise only – Spatial filtering. Periodic noise reduction using frequency domain filtering.

7. Image Restoration and reconstruction (B)

Linear, position invariant degradations. Estimating the degradation function. Inverse filtering. Minimum mean square error (Wiener) filters. Constrained Least squares filtering. Geometric mean filter. Image reconstruction from projections.

8. Other image transforms

Basic theoretical background. Matrix based transformations. Correlation. Bases functions in the time-frequency plane. Base images. Fourier-related transformations. The Walsh-Hadamard transform. The Haar transform.

9. Wavelet Transform

The wavelet transform. Wave packs.

10. Image compression

Theoretical background. Spatial and Time redundancy. Image information measurement. Compression image models. Huffman coding. Golomb encoding. Arithmetic coding. LZW coding. Run-length coding. Symbol-based coding. Bit-plane coding. Block transform coding. Predictive coding. Wavelet coding.

11. Morphological image processing

Erosion and delation. Opening and closing. Hit-or-miss transform. Basic morphological algorithms. Morphological reconstruction. Morphological operations on binary images. Grayscale morphology.

12. Image segmentation

Points, line and edge detection. Thresholding. Segmentation by region growing and region splitting and merging.

13. Feature Extraction

Boundary processing. Boundary feature descriptors. Region feature descriptions. Principle components as feature descriptors. Whole-image features. Scale-invariant feature transform.

Laboratory Exercises

1. Fundamental principles of digital images

Introduction to the programming environment. Import digital images. Basic image transformations. Convert color images to gray scale and binary ones. Image histogram. Numerical operations of images. Image intensity transformations.

2. Spatial image filtering

Basic filtering algorithms. Low-pass and High-pass filters. Linear and non-linear filters. Smoothing (low-pass) and sharpening (high-pass) filters. Two-dimensional filter application of images.

3. Filtering in the frequency domain

The two-dimensional Fourier transform. Fourier image transformations. Filtering in the frequency domain.

4. Image restoration

Basic noise models. Noise statistics. Noise image restoration: Gaussian, salt and pepper. Periodic noise removal. Reverse image filtering. The Wiener filter.

5. Image segmentation

Threshold. Absolute and adaptive threshold. Image edge detection. Derivatives and image edges. Second order derivatives of image.

6. Morphological image processing Basic algorithms for morphological image processing. Erosion and delation. Opening and closing. Basic morphological algorithms. Morphological reconstruction. Morphological operations on binary images. Grayscale morphology.

(4) TEACHING and LEARNING METHODS - EVALUATION

DELIVERY *Face-to-face, Distance learning, etc.*	Face to face in class and in the laboratory. Distance learning via e-Class system (asynchronous tele-education)
USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY *Use of ICT in teaching, laboratory education, communication with students*	• Slides for the teaching of the theoretical part of the course. • Laboratory guides for the laboratory education (one for every laboratory exercise). • Support of the learning process through the e-Class platform (for announcements concerning the course operating regulations, sharing of course's slides, supplementary material, announcements, links and bibliography, and the submission of the semester projects). • Interactive exercises • Proprietary software (Matlab) and open source software (Python, OpenCV, scikit-image) for the laboratory education. • Use of collaborative workspaces for application development and collaborative learning.
TEACHING METHODS *The manner and methods of teaching are described in detail.* *Lectures, seminars, laboratory practice, fieldwork, study and analysis of bibliography, tutorials, placements, clinical practice, art workshop, interactive teaching, educational visits, project, essay writing, artistic creativity, etc.* *The student's study hours for each learning activity are given as well as the hours of non-directed study according to the principles of the ECTS*	

Activity	***Semester workload***
Theory lectures	39
Laboratory Exercises using special software	13
Preparation / Completion of Laboratory Exercises	13
Independent study of lectures and bibliography	25
Job description	10
Project preparation	25
Course Total	***125 hours (5 ECTS)***

STUDENT PERFORMANCE EVALUATION *Description of the evaluation procedure* *Language of evaluation, methods of evaluation, summative or conclusive, multiple choice questionnaires, short-answer questions, open-ended questions, problem solving, written work, essay/report, oral examination, public presentation, laboratory work, clinical*	**A. Evaluation of Theoretical Part:** Written 120-minute final exam that includes: a. Problem solving b. Multiple choice questionnaires c. Short answer questions d. Comparative evaluation of theory data **B. Evaluation of Laboratory work:** Submission of reports (one per laboratory exercise) by each student via e-class platform.

examination of patient, art interpretation, other *Specifically-defined evaluation criteria are given, and if and where they are accessible to students.*	**C. Assessment of Group External Work:** Presentation of an optional semester research project assigned to groups of no more than 4 students. In case of foreign students from exchange programs, the semester project can be submitted in English. **Remarks:** • From the evaluation in the laboratory work, each student receives a PASS/FAIL mark. • In order to be able to participate in the evaluation of the theoretical part of the course, the student must have received a PASS mark in the laboratory work. • The final grade of the course is calculated from the average weighting of the theoretical part grade and the optional semester project with weighting factors of 70% and 30% respectively. • In case a student has not been assigned a semester project, the final grade of the course is calculated only by the grade of the final exam. • The evaluation is done in the Greek language. In case of foreign participant students from exchange programs, the evaluation is also done in English. • The presentation of the semi-annual work can also be done in the English language.

(5) ATTACHED BIBLIOGRAPHY

Suggested bibliography:

In Greek

1. Gonzalez, Κόλλιας Σ. (επιμέλεια), Ψηφιακή Επεξεργασία Εικόνας, 4η Έκδοση, Εκδόσεις Τζιόλα και Υιοί Α.Ε., 2018 (ΚΩΔ. ΕΥΔΟΞΟΥ 68384821)
2. Πήτας Ι., Ψηφιακή Επεξεργασία Εικόνας, Εκδότης Ε. & Δ. Ανικούλα, 2010 (ΚΩΔ. ΕΥΔΟΞΟΥ 68398652)
3. Παπαμάρκος Ν., Ψηφιακή Επεξεργασία και Ανάλυση Εικόνας, Εκδότης Αφοί Παπαμάρκου, 2013 (ΚΩΔ. ΕΥΔΟΞΟΥ 68372511)

In English

1. Dey S., Hands-On Image Processing with Python: Expert techniques for advanced image analysis and effective interpretation of image data, Packt Publishing, 2018
2. Solomon C., Breckon T., Fundamentals of Digital Image Processing: A Practical Approach with Examples in Matlab, Wiley-Blackwell; First Edition edition, 2010
3. Shilkrot R., Escriva D. M., Mastering OpenCV 4: A comprehensive guide to building computer vision and image processing applications with C++, Packt Publishing; 3rd Revised edition edition, 2018
4. Petrou M., Petrou C., Image Processing: The Fundamentals, Wiley-Blackwell; 2nd edition, 2010
5. Gonzalez, Digital Image Processing Using MATLAB, 2nd ed, Mcgraw Hill; Second 2nd Edition edition, 2010
6. Solem J. E., Programming Computer Vision with Python: Tools and algorithms for analyzing images, O'Reilly Media; 1 edition, 2012

Related academic journals:

1. Transactions on Image Processing, IEEE

2. Image and Vision Computing, Elsevier
3. Signal Processing: Image Communication, Elsevier
4. Machine Vision and Applications, Springer
5. EURASIP Journal on Image and Video Processing, Springer
6. IET Image Processing, IET