Teaching Plan:
Biomedical Image Analysis (BIA)

1. Description of the course

Name of the course: Biomedical Image Analysis

Year: Third **Quarter:**First

Studies: Biomedical Engineering Degree

Course Code: 22130
Number of credits ECTS: 5
Total number of dedication hours: 125

Coordinator: Gemma Piella
Professors and languages: Gemma Piella (Catalan, English), Antonio R. Porras (Spanish, English)

2. Introduction to the course

Biomedical Image Analysis is a compulsory course in the third year of the Biomedical Engineering Degree. The course is an introduction to the fundamentals of image processing and analysis of biomedical images with special emphasis on its biomedical applications.

The syllabus of the course includes enhancement and restoration techniques, shape analysis and feature extraction, and introduction to segmentation and registration techniques.

The theoretical elements are the basis of the lectures, but an equally relevant part is the implementation of algorithms related to the studied concepts of image processing and analysis. This practical component constitutes a large part of the individual work of students inside and outside the classroom, and will be evaluated in seminars and laboratory classes. Various group activities and delivarables during the course will require students to develop teamwork as well as information seeking strategies and oral and written communication skills.

It is highly recommended for students to have a basic knowledge of linear algebra, calculus and numerical methods, signals and systems (in particular, random processes, Fourier transforms and filters) and biomedical imaging systems. Such prior knowledge is essential for understanding and following the course.

The natural continuation of *Biomedical Image Analysis* is the optional course *Advanced Analysis of Biomedical Images*, which delves into the issues of segmentation and quantification (although applied to the cardiovascular system). Another related course is *Analysis and Interpretation of Images*, an optional course in Audiovisual Systems Engineering degree, which deals in detail with tools and algorithms to extract and recognize shapes and objects present in an image or video.

3. Skills to be acquired

Skills to develop during the course according to the teaching plan of the bachelor's degree.

Transversal skills	Specific skills
Instrumentals G1. Capacity for analysis and synthesis G2. Capacity for planning and organization G3. Ability to apply knowledge to analyze situations and solve problems Systemics G4. Capacity to apply with flexibility and creativity the acquired knowledge, and to adapt them to new contexts and situations G5. Ability to progress in the process of training and learning independently and continuously G6. Motivation to achieve quality Interpersonals G7. Ability to work in a team	1. Ability to solve mathematical problems that can arise in engineering. Ability to apply knowledge of linear algebra, calculus, numerical methods, random processes and statistical 2. Identification and mastery of basic concepts of linear systems and functions, related transforms and their application to solving problems specific to engineering 3. To develop and implement computational techniques for signal analysis with applications in diagnostics and multimodal monitoring 4. To design and implement technology solutions related to the acquisition, processing, modeling, visualization and interpretation of biological, physiological and clinical signals and variables that contribute to the prevention, diagnosis, treatment and rehabilitation

4. Contents

Block I: Fundamentals of digital imaging

- Image processing and related fields
- Image models
- Sampling and quantization
- Interpolation

Block II: Imgage enhancement. Intensity transformation and spatial filtering

- Contrast adjustments, histograms, equalization
- Linear filters. Smoothing, sharpening and contours detection. Convolution and correlation.
- Nonlinear filters

Block III: : Imgage enhancement. Filtering in the frequency domain.

- Fourier transform. Properties and applications.
- Filtering in the frequency domain
- Multiresolution analysis

Block IV: Image restoration

- Linear degradation models. Deconvolution.
- Noise and noise removal (in the spatial and frequency domain)

Block V: Geometric transformations

- Basic geometric transformations
- Applications: image registration

Block VI: Mathematical morphology

- Basic morphological operators
- Applications to image processing and analysis

Block VII: Feature extraction

- Point, lines and contour detection
- Thresholding
- Applications: segmentation

5. Methodology

The course is organized into three types of activities: lectures, seminars and laboratories.

Lectures (10 sessions of 2 hours) introduce the context and the theoretical knowledge of the subject. These sessions include also classroom demonstrations and exercise solving.

Labs (6 sessions of 2 hours) and seminars (5 sessions of 2 hours) focus in the resolution of practical problems and in the implementation of algorithms (with Octave and/or Matlab) related to the concepts explained in the lectures. Each practical session has associated one lab session and one seminar session, with the exception of the first one which consists only of one lab session. One of the objectives of the course is to develop an image analysis project. Students will present the project during the last practical session.

Previously to each class session, lab guides and lessons material will be available through Moodle so that students can prepare the corresponding session. Lab reports will be delivered through Moodle at the end of each practical session (thus, at the end of each corresponding seminar except for the first practice which will be delivered at the end of the lab session). Additionally, a draftversion of each practice will be delivered at the end of each lab.

6. Evaluation

The assessment elements of the course are included in the following table, which also indicates the weight of each element in the evaluation grade, the conditions required to pass (minimum) and what elements are recoverable (in July).

	ELEMENTS	WEIGHT	JULY
Written test	1 Final individual exam	40%	Recoverable
Partial written test	2 Follow-up individual exams	20%	Non recoverable
Execution assessment	Practical sessions(60% reports + 40% project). Global grade of practical sessions should be >=5 (over 10)	40%	Non recoverable

There will be **two individual partial written exams** to keep track of the concepts explained in the lectures and practical classes (laboratories and seminars). These tests have a weight of 20% (10% each) in the final grade and are not recoverables.

Th final individual written exam will be at the end of the quarter (during the examination period). All knowledge (theoretical and practical) acquired in the course will be evaluated. This test has a weight of 40% in the final grade and it is recoverable in July.

Participation in the practical sessions is a prerequisite for passing the course. It is necessary to have at least a score of 2 (out of 4 points) in the global grade of practical sessions in order to pass the course. Practices are carried out in teams of 1 or 2 people. They account for 40% of the final grade. They will be evaluated through the delivery of reports and commented code,

the development and presentation of a project and, eventually, an oral defense of some of the contents studied in class. The practices are not recoverable in July, and they are assessed using a scale of 4 (0,1,2,3,4 without decimals). The grade will be assigned according to the following criteria:

Grade	Criteria
0	Absent or very poor job with serious errors, or text / code copied (from Internet or from another source)
1	The code does not work as expected and / or there are some major errors in the report, some basic concepts are misunderstood.
2	The code works as expected but there are some errors in the report, some misunderstood concepts.
3	The code is well done and the report is well written and without errors
4	The code is well done and the report is well written and without error: answers have been reasoned and justified. Additionally, the student has done more than was requested in the lab guide (for example, he/she has implemented some additional filter or has performed a more detailed analysis).

If the final amount of points is greater than or equal to 5 but the mininum required for the practical part has not been reached (2 points out of 4), the final grade will be 4.9.

7. Bibliography and learning resources

Basic bibliogrpahy:

- C. Gonzalez and R.E. Woods. ***Digital Image Processing***, Addison-Wesley, 1992.

·Complementary bibliography:

- K.R. Castleman, ***Digital Image Processing***, Prentice Hall, 1996
- P. Suetens, ***Fundamentals of Medical Imaging,*** Cambridge University Press, 2009
- Isaac Bankman (Ed), ***Handbook of Medical Imaging: Processing and Analysis Management (Biomedical Engineering***

Learning resources. Learning material of the course.

Each presential session has its corresponding learning material, available to students through Moodle. This material consists of: slides, supplementary texts, lab guides, software and various sources of information.

8. Time commitment

Blocks	Lectures (h)	Seminars (h)	Laboratories (h)	Out of class study (h)
Block 1	2		2	3
Block 2	4	2	2	12
1r part. Ex.	1			6
Block 3	6	2	2	16
Block 4	1	1	1	4
Block 5	1	1	1	4
2nd part. Ex.	1			6
Block 6	2	1	1	7
Block 7	2	1	1	7
Recap	2	2	2	6
Final Exam	2			10
Total	22 (+2h ex final)	10	12	81

125 hours in total = (5 ECTS * 25)

44 hours (in class) +81 hours (out of class)

9. Programmed activities

Schedule of in-class activities

Week	Theory (2h)	LAB (2h)	SEMINAR (2h)	Partial Exams (1h)
1	Block 1. Fundamentals			
2	Block 2. Intensity transformation and spatial filtering	L1. Basic operations with MATLAB		
3	Bloc k2. Intensity transformation and spatial filtering	L2. Intensity transformation and spatial filtering	Wrap up L2	
4	Block 3. Filtering in the frequency domain			**1st exam**
5	Block 3. Filtering in the frequency domain	L3. Filtering in the frequency domain		
	Block 3. Multiresolution analysis			
6	Block 4. Restoration and Block 5. Geometrical transformations		Wrap up L3	
7	Block 6. Mathematical morphology	L4. Restoration and geometrical transformations	Wrap up L4	

8	Block 7. Feature extraction			**2nd exam**
9	Revision. Biomedical image analysis applications	L5. Feature extraction and mathematical morphology	Wrap up L5/ Project Work	
10		L6. Project work	Project presentations	