Universitat de les Illes Balears

Syllabus

Subject

Subject / Group	11301 - Introduction to Mathematical Models in Image Restoration / 1
Degree	Master's in Advanced Physics and Applied Mathematics
Credits	3
Period	1st semester
Language of instruction	English

Professors

Lecturers	Office hours for students					
	Starting time	**Finishing time**	**Day**	**Start date**	**End date**	**Office / Building**
Antonio Buades Capó toni.buades@uib.es	You need to book a date with the professor in order to attend a tutoring session.					
Joan Duran Grimalt joan.duran@uib.es	12:30	13:30	Monday	09/09/2019	16/02/2020	Despatx 222 Anselm Turmeda
	16:30	17:30	Tuesday	09/09/2019	16/02/2020	Despatx 222 Anselm Turmeda
	12:30	13:30	Friday	09/09/2019	16/02/2020	Despatx 222 Anselm Turmeda
	15:30	16:30	Monday	17/02/2020	31/07/2020	Despatx D222 Anselm Turema
	12:30	14:00	Wednesday	17/02/2020	31/07/2020	Despatx D222 Anselm Turema

Context

Over the last decades, digital images and videos have invaded our daily life. Indeed, large amounts of digital photographs captured by commercial cameras and mobile phones, medical images (X-ray, CT scan, MRI scan), images from video surveillance or remote sensing data are produced everyday. Computer vision and image processing have thus emerged as major research areas, the ultimate goal of which is to imitate the performance of the human visual system.

Most of image processing tasks may be viewed as *ill-posed inverse problems*. Inverse because one takes the end result of the physical process of imaging and wants to deduce something about the scene being observed, and ill-posed because much of the information in the scene is discarded or simplified along the processing pipeline. In particular, image restoration consists in recovering the underlying scene from damaged data. The main causes of the degradation are the noise, which is a random phenomenon coming from the quantum nature of light emission, and the blur, which is due to the motion of the camera or of an object during the exposition time, atmospheric turbulences or an incorrect lens adjustment. In order to solve these problems, people aim at finding useful and realistic priors about the solution one expects. The regularization theory, which assumes that the image which is to be reconstructed is sufficiently smooth, has emerged as a promising direction of research.

Date of publication: 01/07/2019

In this course, we study regularization techniques for solving ill-posed inverse image and video processing problems within the variational framework, namely through the minimization of functionals which induce a high energy when the priors are not fulfilled. In order to do this, the student will learn the basics of Mathematical Analysis, Calculus of Variations and Convex Optimization. We will focus on image denoising and deblurring, data fusion, interpolation and conditional filtering of images. We will also study the image registration problem through optical flow techniques and use it for the denoising and super-resolution of video sequences.

Requirements

There are no requirements for this course but it is recommended that the student has programming skills and basic knowledge of Mathematical Analysis, Linear Algebra and Probability. In addition, it is recommended to follow the course 11303 - *Introduction to Subpixel Images* simultaneously.

Skills

Specific

* EMA1 - Ability to understand the specific language of the applications treated (neuroscience, images, dynamic systems) and ability to work in the interdisciplinary field.
* EMA2 - In the field of neuroscience and images, develop the ability to identify and describe a problem mathematically, to structure the available information and to select a suitable mathematical model for its resolution
* EMA4 - Ability to select the most appropriate set of numerical techniques to solve a mathematical model in the field of dynamic systems and digital images and interpret their reliability at the level of the results obtained.
* EMA5 - Capacity to perform the various steps in the process of mathematical modelling in image processing courses: problem statement, experimentation / testing, mathematical modelling, simulation / program, discussion of results and refinement / model rethinking.
* EMA6 - Learn to determine in the field of digital images if the model of a given problem is well formulated and it is mathematically well-posed in a suitable functional framework.
* CE1- Students must possess the learning skills that enable them to combine specialized knowledge in Astrophysics and Relativity, Geophysical Fluids, Materials Physics, Quantum Systems or Applied Mathematics, with the versatility that provides an open training curriculum.
* CE2 - Students must possess the ability to use and adapt mathematical models to describe physical phenomena of different nature.
* CE3 - To acquire edge-line knowledge in the international scientific research context and demonstrate a full comprehension of theoretical and practical aspects, together with the scientific methodology.

Generic

* CG1 - Systematic understanding of a field of study and mastery of skills and methods of research associated with that field.
* CB6 - Possess the knowledge and its understanding to provide the basis or opportunity to be original in developing and/or applying ideas, often within a research context .
* CB7 - Students can apply the broader (or multidisciplinary) acquired knowledge and ability to solve problems in new or unfamiliar environments within contexts related to their field of study.

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* CB9 - Students can communicate their knowledge to specializaed and non-specialized audiences in a clear way and without ambiguities.
* CB10 - Students gain the learning skills that enable them to continue studying in a way that will be largely self-directed or autonomous.

Basic

* You may consult the basic competencies students will have to achieve by the end of the Master's degree at the following address: http://estudis.uib.cat/master/comp_basiques/

Content

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Range of topics

1. Introduction to image processing
    * Digital images
    * Perturbations: noise and blur
    * Image processing pipeline
    * Image restoration and enhancement
2. Mathematical analysis of images
    * Ill-posed inverse problems in image processing
    * Basics on normed spaces and linear operators
    * Regularization techniques: Tikhonov, Total Variation and Nonlocal regularization
    * Functional Analysis and Calculus of Variations
    * Convex and Continuous Optimization: primal-dual formulation
3. Variational models for image and video processing
    * Image denoising and deblurring
    * Image interpolation and conditional filtering
    * Data fusion
    * Image registration: optical flow techniques
    * Denoising and super-resolution of video sequences

Teaching methodology

In-class work activities (0.96 credits, 24 hours)

Modality	Name	Typ. Grp.	Description	Hours
Theory classes	Lectures	Large group (G)	In these sessions, the professor will give the theoretical background of each topic. The engagement, motivation and interest shown by the student will be taken into account.	15
Practical classes	Practical classes	Large group (G)	In these sessions, the student will solve several exercises that will have been previously assigned by the professor. The work carried out by each student and their capacity to explain the resolution of the problems will be taken into account.	7
Assessment	Project exhibition	Large group (G)	The student will present the results of their project and will be evaluated by the professor. The final mark will take into account the oral skills, the quality of the presentation and will be complemented by observation techniques and questions during the exhibition.	2

At the beginning of the semester a schedule of the subject will be made available to students through the UIBdigital platform. The schedule shall at least include the dates when the continuing assessment tests will be conducted and the hand-in dates for the assignments. In addition, the lecturer shall inform students as to whether the subject work plan will be carried out through the schedule or through another way included in the Aula Digital platform.

Distance education tasks (2.04 credits, 51 hours)

Modality	Name	Description	Hours
Individual self-study	Project	The student will submit a report and the source code of a project that will be evaluated by the professor. The project will include a theoretical analysis of a variational model, its numerical implementation and several experiments the results of which must be discussed in the report. The final mark of the project will take into account the quality of the report, the obtained results and the source code. Depending on the timing, this activity will consist of one modular project or two shorter projects handling two different image and video processing problems.	51

Specific risks and protective measures

The learning activities of this course do not entail specific health or safety risks for the students and therefore no special protective measures are needed.

Student learning assessment

Date of publication: 01/07/2019

Frau en elements d'avaluació

In accordance with article 33 of Regulation of academic studies, "regardless of the disciplinary procedure that may be followed against the offending student, the demonstrably fraudulent performance of any of the evaluation elements included in the teaching guides of the subjects will lead, at the discretion of the teacher, a undervaluation in the qualification that may involve the qualification of "suspense 0" in the annual evaluation of the subject".

Practical classes

Modality	Practical classes
Technique	Papers and projects **(non-recoverable)**
Description	In these sessions, the student will solve several exercises that will have been previously assigned by the professor. The work carried out by each student and their capacity to explain the resolution of the problems will be taken into account.

Assessment criteria

Final grade percentage: 20%

Project exhibition

Modality	Assessment
Technique	Oral tests **(recoverable)**
Description	The student will present the results of their project and will be evaluated by the professor. The final mark will take into account the oral skills, the quality of the presentation and will be complemented by observation techniques and questions during the exhibition.

Assessment criteria

Final grade percentage: 20%

Project

Modality	Individual self-study
Technique	Student internship dissertation **(recoverable)**
Description	The student will submit a report and the source code of a project that will be evaluated by the professor. The project will include a theoretical analysis of a variational model, its numerical implementation and several experiments the results of which must be discussed in the report. The final mark of the project will take into account the quality of the report, the obtained results and the source code. Depending on the timing, this activity will consist of one modular project or two shorter projects handling two different image and video processing problems.

Assessment criteria

Final grade percentage: 60%with a minimum grade of 4

Resources, bibliography and additional documentation

Basic bibliography

* Course notes provided by the professor
* Scientific papers provided by the professor

* *Mathematical problems in image processing*, G. Aubert and P. Kornprobst, volume 147 of AppliedMathematical Sciences, 2002
* *Convex Functional Analysis*, A.J. Kurdilla and M. Zabarankin, Birkhauser Verlag, 2000
* Scientific papers and online demos published atdigital Image Processing on Line (IPOL): www.ipol.im