Course Guide
43871 Advanced mechanisms and models of vision

COURSE DATA

Data Subject	
Code	43871
Name	Advanced mechanisms and models of vision
Cycle	Master's degree
ECTS Credits	3.0
Academic year	2022 - 2023

Study (s)

Degree	Center	Acad. year	Period
2175 - M.U. en Optometría Avanzada y Ciencias de la Visión 13-V.2	Faculty of Physics	1	First term

Subject-matter

Degree	Subject-matter	Character
2175 - M.U. en Optometría Avanzada y Ciencias de la Visión 13-V.2	7 - Advanced mechanisms and models of vision	Obligatory

Coordination

Name	Department
LUQUE COBIJA, M JOSEFA	280 - Optics and Optometry and Vision Sciences

SUMMARY

The course focuses on the description of the phenomenology of the human perception of spatial textures and optical flow, the description of the underlying neural architecture and the development of quantitative models that explain them. These models are based on linear transformations (wavelet type) and nonlinear (divisive normalization) adapted to the statistics of natural images and video sequences.

PREVIOUS KNOWLEDGE

Relationship to other subjects of the same degree

There are no specified enrollment restrictions with other subjects of the curriculum.

Other requirements

Although all concepts, both mathematic and perceptual are properly introduced in the sessions, this course is studied more easily by having a minimum basis of linear algebra and being familiar with the Fourier transform and the filter concept.
Also, the students will gain a greater use of supplementary materials and practical sessions if they are familiar with the Matlab software.

OUTCOMES

2175 - M.U. en Optometría Avanzada y Ciencias de la Visión 13-V.2

- Students should apply acquired knowledge to solve problems in unfamiliar contexts within their field of study, including multidisciplinary scenarios.
- Students should be able to integrate knowledge and address the complexity of making informed judgments based on incomplete or limited information, including reflections on the social and ethical responsibilities associated with the application of their knowledge and judgments.
- Students should communicate conclusions and underlying knowledge clearly and unambiguously to both specialized and non-specialized audiences.
- Students should demonstrate self-directed learning skills for continued academic growth.
- Students should possess and understand foundational knowledge that enables original thinking and research in the field.
- Know how to work in multidisciplinary teams reproducing real contexts and contributing and coordinating their own knowledge with that of other branches and participants.
- Participate in, lead and coordinate debates and discussions, be able to summarize them and extract the most relevant conclusions accepted by the majority.
- Use different presentation formats (oral, written, slide presentations, boards, etc.) to communicate knowledge, proposals and positions.
- Proyectar sobre problemas concretos sus conocimientos y saber resumir y extractar los argumentos y las conclusiones más relevantes para su resolución.
- Tener capacidad de análisis crítico de la información especializada en los ámbitos propios del máster.
- Tener un compromiso ético y responsabilidad social, tanto en lo que compete a la componente asistencial ligada a la profesión de óptico-optometrista como a lo que respecta a la investigación clínica.

- Tener capacidad de trabajo en equipos multidisciplinares en el área de las ciencias de la salud.
- Capacidad para trabajar, de forma crítica, con distintos modelos de la visión humana.
- Caracterización de las interacciones binoculares que se producen en la visión espacial. Modelización de los procesos visuales binoculares.
- Saber relacionar el comportamiento psicofísico de la percepción de movimiento con los mecanismos fisiológicos presentes en las áreas V1 y MT del córtex visual.
- Profundizar en las ciencias de la visión como herramienta de conocimiento y apoyo a la especialización en Optometía.
- Conocer la legislación aplicable en el ejercicio profesional, con especial atención a las materias de de igualdad de género entre hombre y mujeres, derechos humanos, solidaridad, protección del medio ambiente y fomento de la cultura de la paz.

LEARNING OUTCOMES

1. Relating the behavior of the psychophysical perception of textures with the properties of the physiological mechanisms present in the retina-cortex visual pathways.

2. Relating the behavior of the psychophysical perception of motion with the physiological mechanisms present in V1 and MT of visual cortex areas.

3. Analyzing the image content and behavior of linear systems in the domain of their own domains and functions standard representation (Fourier, Wavelets).

4. Analyzing the contents of the image sequences and the behavior of linear systems in the Fourier domain 3D.

5. Evaluating the visibility of a certain moving object present in a complex sequence from spatiotemporal contents, frequency and contrast, identifying the cortical mechanisms involved in detection.

6. Managing the standard computational model to make predictions about the visibility of a certain texture present in a complex image from its spatial frequency content and contrast, identifying the cortical mechanisms involved in perception.

7. Evaluating parameters useful for navigation in 3D environments (depths and estimation of impact) from the movement cues (optical flow).

8. Managing the standard computational model for shape classification tasks and/or textures.

DESCRIPTION OF CONTENTS

1. Phenomenology of texture and motion vision

1.1 Psychophysics: (i) frequency selectivity, (ii) masking. Postefectos contrast.
1.2 Physiology: (i) receptive fields of LGN and V1 sensors, (ii) non-linear response of sensors V1.
1.3 Sensitivity to spatiotemporal contrast: window visibility.
1.4 receptive fields of cells in V1 and MT. Sensors spatiotemporal frequency and speed sensors.
1.5 Nonlinearities and motion adaptive phenomena. Post-motion effects.

2. Linear algebra applied to vision sciences
Linear algebra for vision science

2.1 Images and sequences as vectors.
2.2 Linear Representations of Images (base changes).
2.3 Linear systems and matrices. Base own filter system and function.
2.4 Response of a detector system.
2.5 Change of standard representation: Fourier transform, cosine transform, wavelet transform.

3. Optical flow

3.1 Levels of abstraction in motion analysis.
3.2 Temporal evolution of the irradiance in the image plane: Optical Flow.
3.3 Utility of the optical flow information. Optical flow situations translational and advancement. Focus of expansion and impact time. Prediction irradiances.
3.4 Scope of the study of motion vision: spatiotemporal sensitivity and movement without form analysis.
3.5 Equation of optical flow in the space-time domain.
3.6 The problem of opening.
3.7 Equation of optical flow in the domain of spatio-temporal frequencies.
3.8 Methods for calculating the optical flow in the spatial domain and in the Fourier domain.

4. Standard model of texture perception

4.1 Linear transformation: spatial sensor system located and frequencially.
4.2 Role global filter: contrast sensitivity.
4.3 Nonlinear Response: divisive normalization.
4.4 Calculation of distances in the domain of response. Frequency summation and spatial summation.

5. Standard model of motion perception

5.1 Calculation of optical flow sensors by V1 and MT. Subclass.
5.2 Energy response of a sensor system (filter) 3D Gabor a white noise sequence with constant velocity.
5.3 Generalization to non-white sequences.
5.4 Estimation for comparison between measurements and theoretical predictions.
5.5 Non-linear response and post-effects.

6. Practical sessions

Textures. Playing psychophysical and physiological phenomenology by the standard model of perception of textures:
1. Simulation of an experiment measuring the receptive fields of V1, using specific stimuli in different spatial positions.
2. Simulation measurement of CSF achromatic using stimuli of different sinusoidal frequencies.
3. Measurement simulating chromatic CSF using sinusoidal stimuli of different frequencies.
4. Simulation of measurement (nonlinear) response of a sensor to its tuned to different stimulus masking conditions.
5. Simulation Measurement curve incremental contrast threshold stimulus fixed spatial frequency , with different conditions of masking.
6. Simulation of pathologies in the standard model.
7. Measures of perceptual difference between images.

Motion. Playing psychophysical and physiological phenomenology by the standard model of motion perception:
1. Video sequences in Matlab. Generation of synthetic and natural sequences, and analysis of their frequency content.
2. Simulation of the spatiotemporal CSF abnormalities.
3. Simulation of the response of a sensor V1.
4. Simulation of the response of a sensor MT.
5. Measurement tuned curve V1 sensor.
6. As curve tuned sensor MT.

WORKLOAD

ACTIVITY	Hours	% To be attended
Computer classroom practice	8,00	100
Theory classes	8,00	100
Laboratory practices	4,00	100
Seminars	4,00	100
Preparation of evaluation activities	10,00	0
Preparing lectures	28,00	0
Preparation of practical classes and problem	7,00	0
TOTAL	**69,00**	

TEACHING METHODOLOGY

Teaching Metodology

Two types of methods are used :

(A) In the theory sessions the lecture combined with performing numerical experiences professorship is employed. Exposure is used in a whiteboard (tablet- pc) avoiding the use of powerpoint for students will take notes of the mathematical developments while exposing Professor . The whiteboard allows the realization of diagrams and additional notes not present in the original notes . Thus, although students have course notes before (in the virtual classroom) , they are forced to go along with the consequent deductions assimilation of concepts. Furthermore, the theoretical concepts are presented with numerical experiments illustrating and executed directly on these classes. Students also have these routines as supplementary materials in the virtual classroom so that before or after classes , they can independently run these experiments. The purpose of these supplemental materials (in Matlab) is twofold (1) that students understand the relevance of the different parameters of the models and representations used to improve the understanding of the theory by obtaining a booked concrete graphs and calculations, and (2) become familiar with the use of numerical / graphical tool to be used in the practical sessions.

(B) In practical problems (in computer lab classroom) sessions after a brief statement of the problem to be treated (the description of it is also available to students earlier in the virtual classroom) is passed to a session where students work in pairs to begin to solve the problem (with the assistance of the teacher) using Matlab routines that we have prepared for it. The completion of this work requires more time than the duration of practice (distance work) , encouraging students to attend tutoring sessions in groups to solve technical queries . For the practical sessions is important that students have made a previous approach to the problem to be treated, familiar with the routines used. This is achieved with supplementary materials on topics of theory. Optionally, for students with little prior knowledge of Matlab, tutoring can be arranged in groups to try to resolve these deficiencies.

In addition to gradually introduce the tool for the implementation of the models , the aim of the practical sessions is to enabling students to solve a complex problem (which will be the work for the evaluation of the practical part) . In the final practice session a set of papers will be proposed and will be distributed to students in groups so that each group address the solution of the proposed work . These papers will be delivered at the end of the testing period.

EVALUATION

The course grade will be performed according to one of these options:

Option A:

Theory score + Lab score

In this case, the final mark will be obtained as the average of two factors:

(i) 70% depend on an examination of theoretical and practical issues, and

ii) 30% will depend on the mark corresponding to the proposed laboratory tasks and continuous assessment work.

To make use of this option it will be necessary to have attended the practical sessions. If you wish to use option A (accounting for the laboratory grade) without having attended more than 75% of the practical sessions, you will need to take a practical exam (in the computer room) on one of the problems dealt with in the sessions or in the proposed works.

Option B:

Theory-only score

In this case, the note will depend solely on an examination of theoretical and practical issues. The ability to pass the course as option B implies that attendance at practice sessions is optional.

REFERENCES

Basic

- Material general - Material general - General references
  Apuntes del curso (pdfs disponibles en el aula virtual) (pdfs available on the virtual classroom)

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- Transformaciones lineales de imágenes y técnicas de flujo óptico - Transformacions lineals d'imatges i tècniques de flux òptic - Linear transformation of images and optical flow theories
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- Representaciones de imágenes para la clasificación y la compresión de imágenes - Representacions d'imatges per a la classificació i la compressió d'imatges - Image classification and image compression
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  J. Malo & M.J. Luque COLORLAB: Matlab toolbox for color image processing. Universitat de València 2002 http://www.uv.es/vista/vistavalencia/software.html
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- Software específico - Programari específic - Specific software
  J. Malo & M.J. Luque. Rutinas de Matlab desarrolladas para la asignatura y disponibles como materiales complementarios en el aula virtual (Matlab routines available in the virtual classroom).