COURSE MODULE – Advanced Colour and Spectral imaging

COURSE CODE	COSI ACSI
COURSE LEVEL	Master
ECTS CREDITS	5
COURSE INSTRUCTOR/S	Javier Hernández-Andrés; Eva M. Valero; Rafael Huertas
EDUCATION PERIOD	SEMESTER 2
EXPECTED PRIOR-KNOWLEDGE	Color Science, Photonics and Optics Fundamentals, Image Processing and Analysis, Basics skills in Matlab, Basics and Fundamentals on Statistics and Probability, Basic and Fundamentals on Mathematics for Data analysis, Signal and Image Processing.
LANGUAGE OF INSTRUCTION	English

AIM

This course provides the basics and fundamental principles of spectral science, focusing on applied and technological applications in this quite new, hot and broad topic. The core of this course is the multispectral & hyperspectral approach of color imaging, i.e., imaging systems that use more than three acquisition channels. The contents include image capture procedures, spectral characterization of image capture devices, estimation of spectral functions from conventional image capture systems, computations of color differences, evaluation of the accuracy or performance of multispectral images, and a basic description of some of the most relevant applications of multispectral images. To develop their practical and analytical skills, students have to work on case studies, using MATLAB and specific software, as well as different hyperspectral and multispectral systems and equipments.

TEACHING ACTIVITIES

This course is based on flip-teaching, exchanges and discussions between students and instructors, lectures and practical session activities, as well as homework.

COURSE OUTLINE

(topic 1) Why spectral imaging? Preliminary questions, motivation and justification.

(topic 2) Spectral imaging: what is a spectral image? Difference between spectral, multispectral, hyperspectral. How to get a spectral image? CCD, CMOS, LCTF, filters, multiplexed illumination, etc

(*topic 3*) Spectral estimation algorithms: linear and non-linear models, PCA, ICA, NNMF, Neural Networks, POCS, Kernel, noise influence, training sets, deep learning...

(topic 4) Color differences: Threshold, suprathreshold and large color differences. Number of discernible color. Color-difference formulas. Relationships between perceived and measured color differences. Color differences in images.

(*topic 5*) Spectral metrics. Spectral accuracy performance: theoretical and experimental evaluation

(*topic 6*) Applications of and future: high-speed spectral imaging, spectral video imaging, compressive sensing, gonio-chromatic materials characterization, cultural heritage analysis, fluorescence,...

PRACTICAL ACTIVITIES

Training session A: hyperspectral imaging capture with PikaL and PikaNIR devices: rotating stage and linear stage.
Training session B: multispectral capture with Pixelteq camera.
Training sessions A and B will be used to capture images of standard color charts and to implement one spectral estimation algorithm per team. The estimation quality of the results obtained will be discussed and a consensus reached on which is the best algorithm for solving spectral estimation in this case.
Joint Project: the students will be working in teams to develop a Joint Project to solve a particular problem that they find interesting, involving hyperspectral imaging, advanced colorimetry and human perception.

LEARNING OUTCOMES[1]

• *Knowledge* and *Comprehension* of the fundamentals, principles, applications, limits, relationships, of all concepts and topics covered by this course;
• *Application, Analysis, Synthesis* and *Evaluation* skills of the main concepts and topics covered by this course;
• Ability to apply/implement concepts and principles introduced in the lectures on practical tasks and on industrial study cases;
• Ability to self-learn, to understand some problems and to suggest/find solutions to solve these problems.
On completion of this course the students will be able to:
• Demonstrate an understanding of basic multispectral&hyperspectral color science.
• Analyze, compare, implement algorithms for spectral estimation from camera responses.
• Describe, analyze and reason about how multispectral &hyperspectral acquisition devices work and how can they be optimized for a particular application.
• To know the state of the art of spectral color science and some of its most relevant fields of application.

FORM/S OF ASSESSMENT

Written exam (25%), Practical works (50%), Acquired skills (25%)

ASSESSMENT CRITERION

Written exam and Practical works

Excellent - outstanding performance	A
Very Good - above the average standard but with some errors	B
Good - generally sound work with a number of notable errors	C
Satisfactory - fair but with significant shortcomings	D
Sufficient - performance meets the minimum criteria	E
Fail - some more work required before the credit can be awarded	FX
Fail - considerable further work is required	F

Detail of criteria used to assess acquired skills :
• Activities and questionnaires giving evidence of knowing (5%)
• Activities and questionnaires giving evidence of comprehension/understanding (5%)
• Activities and questionnaires giving evidence of analysis (5%)
• Activities and questionnaires giving evidence of synthesis (5%)
• Activities and questionnaires giving evidence of evaluation (5%)

Excellent	A
Very Good - above the average standard	B
Good - generally sound well	C
Satisfactory - but with significant shortcomings	D
Sufficient - performance meets the minimum criteria	E
Fail - some more work required	FX
Fail - considerable further work is required	F

The evaluation of informal learning outcomes will be based on questionnaires and laboratory notebook (self-evaluation, learning diary).

LITERATURE AND STUDY MATERIALS

- J. Y. Hardeberg, “Acquisition and reproduction of color images: colorimetric and multispectral approaches,” (Dissertation.com, 2001). (Revised second edition of Ph.D. dissertation, Ecole Nationale Supérieure des Télécommunications, 1999)
- R. S. Berns, “Principles of Color Technology”, 3rd ed. Billmeyer and Saltzman, John Wiley & Sons, New York, 2000.
- S. Westland, C. Ripamonti, “Computational Colour Science”, John Wiley & Sons, West Sussex, 2004.
- L.W. MacDonald, M.R. Luo, “Colour Image Science”, John Wiley & Sons, West Sussex, 2002.
- Papers from international scientific journals

CONTACT DETAILS

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[1] The meaning of *keywords* in italic used to define Learning Outcomes are detailed in Annex.

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