COURSE MODULE – APPLIED ADVANCED COLORIMETRY

COURSE CODE	COSI AAC
COURSE LEVEL	Master
ECTS CREDITS	5
COURSE INSTRUCTOR/S	Prof. Luis Gomez Robledo (UGR), Prof. Rafael Huertas (UGR) with the assistance of guest lecturer(s)/expert(s) or industrial(s).
EDUCATION PERIOD	SEMESTER 2
EXPECTED PRIOR-KNOWLEDGE	Courses: "Applied Colour Science" (1st semester) and "Human Perception and Cognition" (2nd semester). Basic colorimetry: color-matching functions, standard illuminants, spectral reflectance or transmittance, computation of tristimulus values and CIELAB coordinates, knowledge in physiology of color vision: photoreceptors, mechanisms of color vision. Matlab and MSExcel knowledge
LANGUAGE OF INSTRUCTION	English

AIM

This course completes basic colorimetry principles acquired in color science. It covers topics as: color differences, industrial colorimetry, color appearance and color imaging technology. In the course are presented the state or the art in these topics, their historical evolution and present development discussing the last research works published about them. The teaching methods are lecture, laboratory sessions and homework exercises. Additional seminars will be organized to introduce specific topics or applications to enlarge the covering of colorimetry. Practical and analytical skills are developed through homework exercises and laboratory sessions related with practical and industrial cases. For practical works students use MATLAB and specific software, as well as different measurement systems and equipment.

COURSE OUTLINE

(topic 1) COLOR DIFFERENCES

1.1. Color Difference Experiments: Color matching and color threshold experiments. Threshold, suprathreshold and large color differences. Number of discernible colors. Color discrimination in 1-2-3 dimensions.

1.2. Color-Difference Formulas: Visual and computed color differences for industrial applications. Historical development of most relevant color-difference formulas. CIELAB-based color difference formulas: JPC79, CMC, BFD, LCD, etc. The CIE94 and CIEDE2000 color difference formulas. Parametric effects in color-difference evaluation. Very small and large color differences.

1.3. Relationships between Perceived and Measured Color Differences: Components in PF/4 index. The STRESS index. Intra and inter-observer variability measurements in color-difference experiments.

1.4. Advanced Color Difference Formulas: DIN99, CAM02, OSA-UCS based color-difference formulas. Reliable experimental datasets.

(topic 2) INDUSTRIAL COLORIMETRY

2.5. Color food industry: Color in soil science. Color in virgin olive oils and other liquids substances.

2.6. Color indices: Color rendering indices. Evaluation of daylight simulators. Whiteness indices. Color fastness. Fluorescence and phosphorescence.

2.7. Colorant Formulation: Bouguer-Lamber-Beer law and Kubelka-Munk theory.

2.8. Color emotions and color preferences.

(*topic 3*) COLOR APPEARANCE MODELS

3.9. Fundamental Definitions and Reviews: What is a Color Appearance Model? Review of Physiology (optics of the eye, retina and mechanisms of color vision). Review of Psychophysics (Stevens' law and threshold experiments).

3.10. Descriptions and Phenomena of Color Appearance: Color appearance terminology. Color appearance phenomena. Color appearance attributes: gloss, translucency, texture. Viewing conditions.

3.11. Chromatic Adaptation Transforms (CAT): Light, dark, and chromatic adaptation. Corresponding-colors. Models: Von-Kries, Retinex theory, Nayatani et al., Herding, CAT02.
3.12. Color Appearance Models (CAM): CIELAB and CIELUV. Nayatani et al. Hunt. Other Color Appearance Models (RLAB, ATD, LLAB). CIECAM97s. CIECAM02.

(*topic 4*) INTRODUCTION TO COLOR IMAGING TECHNOLOGY

4.13. Introduction to devices characterization: Characterization of computer displays. Characterization of cameras. Characterization of printers.
4.14. Color Printing Technologies: Letterpress, halftone, offset lithographic printing, gravure.
4.15. Introduction to Color Gamut Mapping and Color Management: Color spaces for gamut mapping. Basic computational geometry of gamut mapping. Gamut mapping algorithms. Color management systems. Evaluating gamut mapping.
4.16. Image Quality: Color differences in images. Image appearance model iCAM. Image quality evaluation. Compressed image quality. Optimal color reproduction of natural scenes.

PRACTICAL ACTIVITIES

1.1. Instrumental measurement of metameric color pairs. Computation of color differences for metameric and non-metameric color pairs using different color-difference formulas.
1.2. Visual assessments of color pairs using anchor pair and gray scale methods.
1.3. Performance of different color difference formulas in car industry.
2.1. Computation of color rendering index and evaluation of daylight simulators of commercial light booths.
2.2. Colorant formulation using liquid samples.
2.3. Emotional responses under color stimuli.
3.1. Estimation of lightness, chroma and hue.
3.2 Computation of corresponding colors.
3.3 Determination of corresponding colors by memory matching and comparison with model predictions.
3.4. White balance and chromatic adaptation.
3.5. Study of adaptation.
4.1. Display characterization and calibration.

LEARNING OUTCOMES[1]

On completion of this course the students will be able to:
• Understand differences between color matching and color thresholding
• Know the fundamentals of color science through color matching methods
• Ability to distinguish between measured color difference and perceived color difference.
• Judge the conditions of evaluation a threshod, suprathreshold or large color difference.
• Know the fundamental and development of color differences formulae.
• Understand and evaluate the uniformity of the color spaces.
• Understand that the color spaces try to reproduce the behavior of the human visual system
• Criticize the different methods that evaluate color difference formulas
• Present some alternatives to the current color spaces and metrics
• Criticize the last advanced color difference formulas proposed
• Know the techniques to measure and specify the color of different foods.
• Demonstrate lacks in current proposed color indices
• Present new alternatives to these indices
• Determine the quantity of pigments necessary to create a desired color
• Apply and relate color and linguistic terms
• Understand limitation of basic colorimetry
• Describe a color appearance model
• Discover the color appearance terminology and attributes
• Explain the color appearance phenomena
• Compute corresponding colors with different models
• Describe different CAMs
• Compare advantages and drawbacks of the models
• Evaluate the models
• Understand the need of device characterization
• List the printing technologies
• Justify color gamut mapping

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

• Describe the requirements for consistent color reproduction across different media
• Be aware of last appearance model
• Evaluate image quality
• Know current approaches to evaluate color differences in images

FORM/S OF ASSESSMENT

written exams (30%), homework/lab reports (50%), seminar (20%).
External examiner will be considered to assure double correction of the exam.

ASSESSMENT CRITERION

Written exam lab sessions and Homework/seminar presentations

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%)

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

LITERATURE AND STUDY MATERIALS

Reference book:
• “Color Appearance Models”, Second Edition. M.D. Fairchild. Wiley-IS&T Series in Imaging Science and Technology, Chichester, UK (2005).
• “Colour Imaging Vision and Technology”. L.W. MacDonald, M.R. Luo. John Wiley & Sons, West Sussex, (1999).
• “Color Gamut Mapping”. J. Morovic. John Wiley & Sons, West Sussex, (2008).
• “Computational Colour Science”. S. Westland, C. Ripamonti. John Wiley & Sons, West Sussex, (2004).
• “Colour Image Science”. L.W. MacDonald, M.R. Luo. John Wiley & Sons, West Sussex, (2002).
• “Principles of Color Technology”, 3rd ed. R. S. Berns, Billmeyer and Saltzman. John Wiley & Sons, New York, (2000).
• “Colorimetry. Understanding the CIE Sytem”. K. Witt. “CIE Color Difference Metrics” (Chapter 4). Ed: J. Schanda, Wiley-Interscience 2007.
• Tutorials, lectures and notes provided by the course instructor.
Additional books:
• “Colorimetry. Fundamentals and Applications". N. Ohta and A.R. Robertson. Wiley (2005).
• “Digital Color Management: Encoding Solutions”. E.J. Giogianni, T.E. Madden. Addison Wesley (1992).
• “Colour Engineering, Achieving device independent colour”. P. Green & L. MacDonald. John Wiley & Sons Ltd, (2002).
• “The Reproduction of Colour”. R.W.G. Hunt. Foutain Press, (1995).
• “Colour Physics for Industry”. R. McDonald. Society of Dyers & Colourists, (1997).
• “The Science of Color”, second edition. S.K. Shevell. Elsevier, (2003).

CONTACT DETAILS

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