CIMET Optical Imaging and Processing

Course name: Optical Imaging and Processing
Course code: CIMET OIP
Course level: Master
ECTS Credits: 5.00

Course instructors: Juan Luis Nieves and Javier Hernández Andrés (University of Granada)
Education period (Dates): 2nd semester
Language of instruction: English

Prerequisite(s): Module "Photonics and Optics Fundamentals" (1st semester)

Expected prior-knowledge: Image formation fundamentals and diffraction phenomenon, Fourier analysis and linear systems.

Aim and learning outcomes:
This course develops an understanding of the fundamentals of diffraction limited and aberrated limited imaging systems. The course covers advanced topics in diffraction, Fourier Optics and optical image processing. Different architectures for optical-based image manipulation will be given, including optical correlation, wavefront coding, recording and manipulation, spatial filtering techniques, optical pattern detection, recognition and extraction, and optical correlators used in inspection industry. This course provides also an opportunity to engage with practical and theoretical aspects of optical and digital holography.

On completion of this course the students will be able to:
- Understand how diffraction and aberrations influence optical image quality.
- Analyze how an optical image can be encoded, manipulated and processed using optical-based techniques, with emphasis on coherent image formation.
- Make appropriate use of Fourier techniques in optical image processing.

Topics to be taught (may be modified):
- Overview of optical imaging: domains of image science. Electromagnetic waves and rays.
- Basics of signal processing. Fourier analysis in two dimensions. Linear systems. Two-dimensional sampling theory: the Whittaker-Shannon theorem.
- Diffraction. The Rayleigh-Sommerfeld formulation of diffraction. Fresnel and Fraunhofer approximations. Fundamentals of wave scattering.
- Diffraction-limited imaging. Image formation with coherent and incoherent illumination. Analysis of optical resolution.
- Frequency analysis of optical imaging systems. Frequency response for diffraction-limited optical systems: coherent and incoherent imaging. Optical transfer function (OTF), modulation transfer function (MTF) and phase transfer function (PTF): characterisation and measures.
- Aberrated imaging systems. Generalized pupil function. Apodization. Image quality in aberrated systems.
- Fundamental of wavefront modulation. Spatial light modulators. Diffractive optical elements.
- Spatial filtering. The VanderLugt filter. The Joint Transform Correlator. Optical pattern recognition architectures: the Matched Filter. Image processing tools for pattern recognition.

- Optical image restoration. Optical Transfer Function for image motion and vibration. Effects of atmospheric blur and target acquisition.
- Optical holography. Recording of digital holograms. Numerical reconstruction of digital holograms. “Inverse problem”: approach to process holograms. Applications.

Practical Laboratory Sessions:

- Simulating diffraction using MATLAB.
- Visualization of diffraction patterns using an optical processor.
- Optical Fourier filtering: practical implementation of a 4f-Fourier processor.
- Digital Fourier filtering: simulations with MATLAB.
- Measure of the modulation transfer function (MTF) of an imaging system.
- Making a transmission hologram.
- Making a reflection hologram.
- Recording of a digital hologram and numerical reconstruction.

Teaching methods: Lectures and lab classes, and homework exercises.
Form(s) of Assessment: Written exam (75%), exercises (25%)

Literature and study materials: Handouts of the material covered in the lectures will be distributed.
<u>Reference book</u>:
Goodman, J.W., “Introduction to Fourier Optics”, 2nd Ed. McGraw-Hill (New York, 1996).

<u>Additional books:</u>
VanderLugt, A., "Optical Signal Processing", Ed. John Wiley & Sons, 1992.
Hariharan, P. "Optical holography. Principles, Techniques and Applications", Cambridge Studies in Modern Optics, Cambridge University Press, New York, 1996.
T. M. Kreis, Handbook of Holographic Interferometry, Optical and Digital Methods. Berlin: Wiley-VCH, 2005.

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