UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Introduction To Digital Imaging and Computer Vision

2627-2-F1702Q013

Aims

The aim of this course is to provide students with a comprehensive and robust foundation in digital image processing and computer vision, specifically tailored to applications in optics, optometry, and ophthalmology.

To achieve this, the course is structured across five core dimensions:

Knowledge and understanding: Students will acquire a fundamental understanding of physical and mathematical models of image formation, including the pin-hole model, spatial/intensity sampling, and the optical or sensor-driven defects inherent to digital cameras. They will grasp the principles underlying image processing, local feature detection, segmentation, and point-based stereometry.

Applying knowledge and understanding: Students will learn to apply point operators, spatial filtering, and denoising algorithms to digital images. Critically, they will apply these computational concepts to calibrate projection models and execute basic triangulation and stereo-matching tasks relevant to optical diagnostics.

Making judgments: Students will develop the capacity to critically evaluate digital image quality, diagnosing whether artifacts are caused by optics or sensors. They will exercise judgment in selecting the appropriate filtering, registration, or segmentation algorithms required to process complex ophthalmic and retinal imagery.

Communication skills: Students will become proficient in communicating technical computer vision concepts, algorithm limitations, and image analysis results clearly to both engineering specialists and fellow eye-care professionals or clinicians.

Learning skills: Students will develop the autonomous learning skills necessary to independently navigate, evaluate, and adopt emerging digital imaging software and advanced computer vision technologies in their future clinical optometric practice or ophthalmic research.

Contents

Image Formation & Optical Defects: Geometry of the pin-hole model and calibration. Spatial/intensity sampling and the sampling theorem. Color camera architectures (Bayer, stacked) and artifacts introduced by lenses and sensors.

Processing, Enhancement & Segmentation: Linear/non-linear point operators, spatial filtering, and denoising. Image registration, local feature detection, and feature-based segmentation. Overview of model-based vision.

3D Stereometry & Clinical Applications: Principles of 3D reconstruction, triangulation, and correlation-based stereo-matching algorithms. Direct application of these computational concepts to diagnostic optics, optometry, and ophthalmology equipment.

Detailed program

1. Image formation
    - Pin-hole model;
    - Spatial and intensity sampling;
    - Sampling theorem (very short review);
    - The need for optics;
    - Defects introduced by optics;
    - Defects introduced by sensor;
    - Colour cameras (bayer, 3-sensors, stacked).
2. A realistic pin-hole projection model
3. Calibration of the projection model
4. Image processing and enhancement
    - Point operators: linear and non-linear;
    - Spatial filtering;
    - Introduction to denoising algorithms;
    - Notes on image registration;
    - Simple local feature detection: point-based, statistics.
5. Image segmentation
    - Segmentation based on local features;
    - Notes on advanced denoising algorithms.
6. Model-based vision (just mentioning)
7. Point-based stereometry
    - Basic terminology;
    - Triangulation and stereo-matching;
    - Stereomatching algorithms (e.g., correlation).
8. Examples of applications of the previous concepts in optics, optometry, ophthalmology
9. AI Based image analysis:

- basics
- applications to denoising
- applications to segmentation
- robustness and validation

Prerequisites

Linear 3D geometry (lines, planes), linear algebra.

Teaching form

Classes and practices, both programming and hands-on.

Textbook and teaching resource

Selected parts from well-known textbooks like, e.g.,

- David A. Forsyth and Jean Ponce, "Computer Vision: A Modern Approach" 2nd edition, Pearson, 2012
- Emanuele Trucco, Alessandro Verri, "Introductory techniques for 3D Computer Vision", Prentice Hall, 1998
- Rafael C. Gonzalez and Richard E. Woods, "Digital Image Processing" 3rd edition, Pearson, 2007

Semester

1st semester

Assessment method

Oral exam

Office hours

Please, send an email to arrange an appointment.

Sustainable Development Goals

GOOD HEALTH AND WELL-BEING | QUALITY EDUCATION