Master's Department of Engineering Sciences

Name of the unit: Computer vision

Lecturer: Xavier Clady (xavier.clady@sorbonne-universite.fr)
Course code: UM4RBI23-Image
Student workload: 14h of lectures, h of tutorial sessions, 16h of lab sessions@
Credits: 3 ECTS

Specialization tracks:				
	- E3A :	☐ CIMES	☐ Syscom	☐ IPS
	- AR :	☐ ROBOT	☐ SI	☐ MeDH
	- MECA :	☐ MS2	☐ MF2A	☐ CompMech
		☐ ACOU	☐ EE	☐ EE APP

Semester offered: ☐ S1 ☒ S2 ☐ S3 ☐ S4
Language of instruction: ☐ French ☐ English
Targeted audience: ☐ Engineering Sciences students ☐ Other (specify):
Localization : ☒ PMC Campus ☐ Other (specify):

Course Overview

Like AI, computer vision is experiencing significant growth as a tool for perception, creation, and measurement, and is increasingly integrated into our daily lives (video conferencing, smart objects, etc.). Complementing the image processing, machine learning, and pattern recognition courses, this course aims to introduce students to the physics and photometric, colorimetric, and geometric modeling of vision sensors, as well as to the estimation of their parameters. Practical applications will provide concrete experience of these models, their associated tools, and some of their potential applications. At the end of this course, combined with those in AI, students will be familiar with the theoretical knowledge and key technical skills that will enable them to become versatile engineers, capable of designing complete experimental devices, i.e., from sensors to present and future applications in the field of vision.
Keywords: Image formation, color spaces, technological elements of industrial cameras (technologies, exposure time, resolution, optics, focal length and aperture, distortion, etc.), geometry for vision (linear algebra, DLT, system resolution by SVD, pinhole model, calibration, projective geometry, affinity, homography, etc.), detection of points of interest (Harris-Stephen, DLOG, FAST, etc.), local descriptors (patches, SIFT, Hog, ORB, DISK, etc.), matching and related concepts (distances, SAD/SSD/Lowe, accuracy, robustness, outliers, aliasing, RANSAC, etc.), contributions of deep learning to the detection, description, and matching of points of interest.

Prerequisites

Students should have previously acquired the following prerequisites to follow this course:

- Mathematics: matrix representation of data, matrix equations, geometry, trigonometry, statistics (covariance matrix, histogram, etc.)
- Image processing: gradient, convolution, filters, Gabor filters, contour/region, histogram
- Pattern recognition: kNN, applications in computer vision (object detection, object classification, image categorization, etc.)
- Machine learning: automatic learning, deep learning.
- Python programming (basic algorithms)
- (desirable) Python image processing libraries (Pillow—extension of Python Imaging Library (PIL), OpenCV, scikit-image)

Intended Learning Outcomes

By the end of this course, students will be able to:

1. Discovery Design: vision sensor and its main characteristics: technologies, focal length, resolution/denomination, sensor size, gain/offset, focus, sensitivity/spectral response/gamma correction, etc.; Ability to draw up hardware specifications;

2. Design: Implementation of industrial cameras in an experimental setup (color calibration, white balance, calibration, spectral analysis)

3. Analysis: Analyzing an image processing problem: defining the specifications of an algorithm suited to the task, data, and hardware constraints

4. Implementation: Perform the processing defined in the design phase to optimize the parameters and meta-parameters of an algorithm.

5. Evaluation: Develop an appropriate experimental protocol for analyzing the performance of an image processing algorithm; establish an automated field truth.

6. Apply: Use geometry models and tools for vision in a practical application.

Indicative Teaching Sequence and Methods

Week	C/TD/TP*	Content	Preparation	Learn. outc.
S1	C1 / C2	Image formation	Prerequisite 1	AAV 1 et 2
S2	C3 / C4	Color spaces, camera technology components	Prerequisite 1	AAV 1 et 2
S3	C5 / C6	Geometry for vision: mathematical elements, camera model and calibration, plane geometry and applications.	Prerequisite 1, 4	AAV 6
S4	C7 / C8	Points of interest (detection, description, and matching; conventional and deep learning methods)	Prerequisite 1, 4	AAV 6
S5	TP1	Study of the operation of an industrial camera	All Prerequisite	AAV 2 à 6
S6	TP2	Implementation of a test bench for image processing algorithms		AAV 2 à 6
S7	TP3	Implementation of geometry models and tools for vision in an application (1/2)		AAV 2 à 6
S8	TP4	Implementation of geometry models and tools for vision in an application (2/2)		AAV 2 à 6

* C/TD/TP respectively corresponds to lectures, tutorials and lab sessions.

Sequence of the unit:
Theunit is divided into two successive sequences:
- Sequence 1: all theoretical, technical, and technological concepts are covered in lectures (1 hour 45 minutes), then
- Sequence 2: implementation in a series of four practical sessions (4 hours)

Indicative Assessment of Intended Learning Outcomes (1st session)

Week	Individ./group	In-person/remote	Type of exam	Evaluated outcomes	Scale %
S6	Individual	In-person	Quiz	AAV1,2 et 6	30 %
S6-11	Individual	In-person	Labs	AAV2-6	30 %
S12	Individual	In-person	Written	AAV1-6	40 %

2nde session of exam

Session	Individ./group	In-person/remote	Type of exam	Evaluated outcomes	Scale %
2	Individual	In-person	Written		70 %
1	Individual	In-person	Labs	AAV2-6	30 %

Bibliographic references

- C. Demant, B. Streicher-Abel, C. Garnica, Industrial Image Processing - Visual Quality Control in Manufacturing, 2nd Edition, 2013
- A. Hornberg, Handbook of Machine Vision, Wiley, VHC-Verlga, Weinheim, 2006
- N. Vandenbroucke, Système de vision industrielle, Techniques de l'Ingénieur, S7799, 2015
- A Trémeau, C. Fernandez-Maloigne, Image Numérique Couleur de l'acquisition au traitement, Dunod, 2004
- Richard Hartley, Andrew Zisserman, Multiple View Geometry in Computer Vision 2nd edition, 2004

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