UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

"Computational Imaging"

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Short Abstract: The course will focus on modern image processing and computer vision problems with a strong computational flavor. We will start with image representations from a linear algebraic standpoint – from the classical Fourier to 2-D discrete cosine (DCT) and wavelet transforms, and finally sparse signal representations. Based on this foundation, two key areas will be emphasized: a.) the fundamental generative problem of image resolution enhancement, popularly known as image super-resolution. Both model based and machine-learning methods will be covered, culminating in their combination. b.) the discriminative problem of image classification and segmentation (pixel level classification). The goal will be to show how optimization principles help in the design of prior guided (or domain enriched) learning frameworks that can integrate the robustness merits of classical model based techniques with the superior modeling capacity of machine learning and artificial intelligence (AI) techniques such as modern deep learning architectures.

Course Contents in brief:

Day 1 (4 hours): Course Overview and Mathematical Preliminaries

1. The anatomy of an image: historical context and new challenges
2. Linear Algebra Review
3. Convex Optimization Review
4. 2-D Fourier Transform: Interpretation and Visualization

Day 2 (4 hours): Image Transforms

1. 2-D Discrete Cosine Transform
    a. Analytical derivation
    b. Energy compaction principle
    c. Connections to DFT
    d. Compression demo
2. 1-D and 2-D Wavelet Transforms (the evolution from STFT)
    a. Wavelets for joint time-frequency localization

    b. Mallat pyramid algorithm for fast computation of 1-D/2-D DWT
3. Applications of image transforms in compression, denoising

Day 3 (4 hours): Image Super-resolution

1. Introduction of image super-resolution
2. Model-based multi-frame image super-resolution methods
3. Sparsity based super-resolution methods
4. Deep learning-based image super-resolution

Day 4 (4 hours): Discriminative Problems – Image Classification and Segmentation

1. Sparsity based methods (use linear algebra and optimization review)
2. Dictionary Learning (use linear algebra and optimization review)
3. Deep Learning methods
4. Applications: face recognition, medical image analysis for diagnosis

Total # of hours of lecture: # 16 hours, 4 hours per day.

References:

[1] Gonzalez and Woods, Digital Image Processing, Pearson 4th Edition, 2017.
[2] V. Monga, Handbook of Convex Optimization Methods in Imaging Science, Springer, 2018.

CV of the Teacher

CV – a brief bio sketch is attached.

Final Exam: Written Exam in person to be taken on Day 5, Open Book, Open Notes.

Room and Schedule

Room: *Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Via G. Caruso 16, Pisa – Ground Floor*

Schedule: April 17th - 21st, 2023

Day1 – 9 AM – 1 PM

Day2 – 9 AM-1PM

Day3 – 9 AM-1 PM

Day4 – 9 AM – 1 PM

Day5 (Friday) – Project assigned to be completed and submitted by following Monday.