Instructor: Prof. Janusz Konrad (PHO443, jkonrad@bu.edu)
Grader: Haochuan Hu (huhc@bu.edu)
Lectures: Monday & Wednesday, 12:20–2:05pm, EPC 204
Office hours with instructor: Monday & Wednesday 6:30-7:30pm (PHO428)

Objectives: The goal of this course is to provide the theoretical and practical basis required for the understanding and design of modern image processing, analysis and communication systems. The material covered in the course will concentrate on still images but will also touch on concepts from digital video. The students will first learn the theory of image acquisition and representation followed by algorithms used in various image processing, analysis and compression tasks. Those interested in image-related research will build a necessary foundation, while those interested in practical use will gain insight into modern applications such as image enhancement (denoising, HDR), object recognition (people, cars), image coding (JPEG) and image transmission (Zoom, Facetime).

Content: The course consists of two parts: foundations and applications. The foundations part starts with a brief review of key 1-D signal processing concepts (linearity, shift invariance, causality, stability, filtering) and their extension to multiple dimensions. This is followed by an introduction to discrete representation of continuous images: multidimensional sampling theory (generalization of 1-D Nyquist theorem), and amplitude quantization. Then, an overview of human visual system properties, extensively used in image compression, is presented, followed by an introduction to color and color spaces. Subsequently, alternative image representations are introduced by means of unitary transforms. This part is concluded by discussion of image modeling (covariance and Markov models) and an overview of model-free image processing using neural networks. The applications part of the course focuses on the use of these foundational concepts in practical image processing, analysis and compression. First, image enhancement, such as contrast boosting and noise reduction, are covered, followed by image restoration (recovery of original image from noisy/distorted observations). Then, elements of image analysis are introduced, such as edge detection, image segmentation, and object recognition. The course concludes with image compression, including JPEG. Although the course focuses on model-based methods, some learning-based alternatives are also discussed, both based on machine and deep learning. The lectures include visual results of image processing that students verify experimentally in homeworks. A team project is a key part of learning in the course.

Prerequisites: EC381 and EC401 (or equivalents); prior experience with Matlab is essential.

Outline:

- Introduction: scope of the course, historic background, some applications, challenges
- 2-D signals and systems: 2-D signals, linear shift-invariant systems, Fourier transform
- Discrete representation of images: image sampling, image quantization, human visual system, representation of color, image models, image bases and transforms
- Digital image processing: image resizing, color transformation, enhancement, restoration
- Digital image compression: fundamentals of entropy coding (lossless compression), fun-
Fundamentals of rate-distortion theory (lossy compression), still-image compression (JPEG)

- Digital image analysis: boundary extraction, image segmentation, object recognition

**Grading:**

- **25%** Homeworks  
  ≈10 homeworks (≈1 per week): lowest grade discarded; penalty for late submission; no assignment accepted after solutions released.
- **25%** Project  
  Team project involving algorithm development in Matlab, Python, or C/C++/C#; report and in-class presentation.
- **25%** Mid-term exam.  
  Closed-book exam.
- **25%** Final exam.  
  Closed-book exam.

No make-up exams; without a doctor’s note for a missed exam, the grade will be set to 0.

**On-line course resources:**

- Blackboard ([http://learn.bu.edu](http://learn.bu.edu)): lecture slides, handouts, papers, demos, etc.,
- Piazza (via Blackboard) – discussion forum
- Gradescope (via Blackboard) – homework submission

**References:** There is no single textbook covering the course material, and the feedback on past textbooks was mixed. Therefore, lecture attendance is essential. For some topics, a recent textbook, freely available as PDF at [http://ip.eecs.umich.edu](http://ip.eecs.umich.edu), can be useful:


Extensive material will be uploaded to the course web site (lecture slides, handouts with derivations and proofs, demos, etc.), but the following books may also prove useful for various parts of the course (on reserve at the Mugar Library for short-time checkouts):


**Programming:** Each homework will involve the use of Matlab in order to map theory onto practice, and the Image Processing and Computer Vision Toolboxes will be very useful in accomplishing this. If you are on-campus, you can use SIGNET (PHO307) and VLSI (PHO305) labs that have all Matlab toolboxes. You can also install Matlab on your own computer, run a remote session on BU servers, or even run Matlab Online in your a browser. I will discuss pros and cons of these options in the first lecture. If you prefer, you can use Python but no Python-specific programming hints will be provided.

**Academic conduct:** BU takes academic integrity very seriously. The student handbook defines academic misconduct as follows:

“Academic misconduct occurs when a student intentionally misrepresents his or her academic accomplishments or impedes other students’ chances of being judged fairly for their academic work. Knowingly allowing others to represent your work as theirs is as serious an offence as submitting another’s work as your own.”
Please see the student handbook for procedures to be followed should academic misconduct be discovered.

**Collaboration Policy:** You may collaborate with fellow EC520 students on homeworks subject to the following strictly-enforced conditions:

- You must acknowledge all your collaborators at the top of your homework.
- You must write all homework answers in your own words.
- You must be able to fully explain your answers upon demand.
- In homeworks/projects, **you may not use human or automated resources from outside of class**, including outside tutors, web-based help services, generative AI or similar, etc. In some homeworks/projects you may be asked to use generative AI resources in which case you must clearly acknowledge them and describe their use.

**Incompletes:** An incomplete grade will not be given to students who wish to improve their grade by taking the course in a subsequent semester. It may be given for medical reasons where a doctor’s note is provided. The purpose of an incomplete is to allow a student who has essentially completed the course and who has a legitimate interruption in the course, to complete the remaining material in another semester. Students will not be given an opportunity to improve their grade by doing “extra work”.

**Accommodations for Students with Documented Disabilities:** If you are a student with a disability or believe you might have a disability that requires accommodations, requests for accommodations must be made in a timely fashion to Disability & Access Services, 25 Buick St, Suite 300, Boston, MA 02215; 617-353-3658 (Voice/TTY). Students seeking academic accommodations must submit appropriate medical documentation and comply with the established policies and procedures [http://www.bu.edu/disability/accommodations](http://www.bu.edu/disability/accommodations)