Boston University, College of Engineering
Department of Electrical and Computer Engineering

ENG EC520 A1 – Spring 2023

DIGITAL IMAGE PROCESSING AND COMMUNICATION

Instructor: Prof. Janusz Konrad (PHO443, `jkonrad@bu.edu`)

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Grader: Kshitij Duraphe (`kshitijd@bu.edu`)

Lectures: Monday-Wednesday, 12:20–2:05pm, EPC 204

Discussion hours with TA: Thursday, 6:30-7:30pm (PHO428); Friday, 11am-12pm (PHO536)

Office hours with instructor: Monday 6:30-7:30pm (PHO443) - tentative

Objectives: The goal of this course is to provide the theoretical and practical basis required for the understanding and design of modern image processing and image communication systems. The material covered in the course will concentrate on still images but will also convey concepts from digital video. The students will first learn the theory of image acquisition and representation followed by algorithms used in various image processing 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).

Content: The course will consist of two parts: *foundations* and *applications*. The *foundations* part will start with a brief review of various 1-D signal processing concepts (linearity, shift invariance, causality, stability, filtering) and their extension to multiple dimensions. This will be followed by an introduction to discrete representation of continuous images: M-D sampling theory (generalization of 1-D Nyquist theorem to M-D), and amplitude quantization. Then, an overview of human visual system properties, extensively used in image compression, will be presented. Subsequently, the notion of color and color spaces will be introduced. This part will conclude with an introduction to image modeling (covariance and Markov models) and unitary transforms, and will touch on model-free image processing using neural networks. The *applications* part of the course will cover various uses of the above concepts in practical image processing tasks. First, image enhancement, such as contrast enhancement and noise reduction, will be covered, followed by image restoration (recovery of original image from noisy/distorted observations). Then, elements of image analysis will be introduced, such as edge detection, image segmentation, and image recognition, including some state-of-the-art deep-learning methods. Image compression will be covered at the end, including JPEG. While lectures will include lots of visual examples, the students will verify many results experimentally in homeworks.

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*: sampling grid conversion, color transformation, image enhance-

ment and restoration, boundary extraction, image segmentation, image recognition

- *Digital image compression:* fundamentals of entropy coding (lossless compression), fundamentals of rate-distortion theory (lossy compression), still-image compression (JPEG and foundations of JPEG-2000), elements of video compression

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`): lecture slides, handouts, papers, demos, etc.,
- Piazza (via Blackboard) – discussion forum
- Gradescope (via Blackboard) – homework submission

References: There is no single textbook covering all the material in this course, 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` or `https://services.publishing.umich.edu/publications/ee`, can be useful:

A.E. Yagle and F.T. Ulaby, *Image Processing for Engineers*, Michigan Publishing, 2018

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 Science and Engineering Library for short-time checkouts):

- J.W. Woods, *Multidimensional Signal, Image and Video Processing and Coding*. Academic Press, 2nd edition, 2011 (hardcopy).
- A. Jain, *Fundamentals of Digital Image Processing*. Information and System Sciences Series, Prentice Hall, 1989 (hardcopy).
- A. Bovik, *Handbook of Image and Video Processing*. Academic Press, 2nd edition, 2005 (hardcopy and E-Book through this link).

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 via* a browser. I will discuss pros and cons of these options in the first lecture.

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 use any textbooks when completing your homework, and/or any number of human collaborators (fellow students from EC520), subject to the following strictly-enforced conditions:

- You must acknowledge all your sources (including your collaborators) on the top of your homework.
- You must write all homework/lab answers in your own words.
- You must be able to fully explain your answers upon demand.
- **You may not use any human resource outside of class** (including web-based help services, outside tutors, etc.) in doing your homeworks.

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".

Inclusion: I consider this classroom to be a place where you will be treated with respect, and I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability – and other visible and nonvisible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class.

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`