Instructor: Prof. Janusz Konrad (office: PHO 443, e-mail: jkonrad@bu.edu)

Lectures: Tue-Thu 3:30–5:15/PRB 146, Office hours: Tue-Thu 5:30-6:30pm

Objectives: This course extends EC520 (“Digital image processing and communication”) to time-varying imagery, such as digital video, and to other types of image sequences (multi-view, multi-modal, etc.). The goal is to provide the understanding of the theory behind various video processing tasks as well as the practical experience in implementing them in a high-level computer language. The material covered in the course will extend numerous concepts from still images (2-D, i.e., $x - y$) to image sequences (3-D, i.e., $x - y - t$) and multi-view sequences (4-D, i.e., $x - y - t - \alpha$), but will also introduce new concepts unique to spatio-temporal data (timeline, motion, motion-induced occlusions, etc.) and spatio-angular data (viewing angle, angle-dependent perspective, angle-induced occlusions, etc.) The course format will be a combination of regular lectures and homework assignments, and of compulsory readings followed by in-class discussions. A very important aspect of the course will be a practical project. Students will select a topic, find suitable literature (with instructor’s guidance) and carry out a simulation in Matlab/Python/C/C++. Upon the completion of this course students will have acquired in-depth knowledge to carry out research related to time-varying imagery and also an understanding of modern applications of video processing (e.g., video analytics, advanced video compression and streaming, stereo vision for autonomous navigation).

Content: The course will start with an accelerated review of EC520 material, including multi-dimensional (M-D) sampling theory, M-D filtering, human visual system properties and digital representation of image data. The distinguishing feature of image sequences compared to still images is the ability to capture scene dynamics. Therefore, a substantial part of the course will be devoted to motion analysis in image sequences, and in particular motion detection and motion estimation. Also, a related concept of video segmentation, i.e., partitioning of video domain into disjoint sets of pixels corresponding to “events” in the observed scene, will be introduced. Although motion in an image sequence is necessarily a space-time concept, its description in the frequency or space/frequency domain has proven beneficial to many video analysis and compression tasks, and will be covered in detail. This will be followed by a discussion of video enhancement methods (noise reduction, super-resolution, error concealment) and recent advances in video compression. The most successful approach to video compression to date, namely the motion-compensated hybrid DCT/DPCM coding, will be introduced first. Then, salient features of the H.26X and MPEG-X families of video compression standards will be highlighted including the current AVC, HEVC and VVC standards. The course will conclude with a discussion of error resilience issues (due to IP or wireless transmission) and means of addressing them. Video processing has been traditionally model-based due to its high computational complexity, however learning-based methods are slowly emerging. Throughout the course, examples of such methods, primarily based on neural networks, will be provided.

Prerequisites: EC520 or EC516 or equivalents, and experience with Matlab or Python.
Tentative outline:

- **Introduction**: scope of the course, historic background on moving images, overview of applications, present and future challenges, basic definitions
- **Review**: spatio-temporal (3-D) sampling and filtering of signals, digital representation of image sequences, human visual system (motion perception)
- **Motion analysis**: motion detection, 2-D motion estimation, 3-D motion estimation
- **Image sequence segmentation**: spatial segmentation (frame-by-frame), temporal segmentation (scene cut detection), spatio-temporal segmentation
- **Spectral analysis of image sequences**: Fourier-, DCT-, and wavelet-domain analysis
- **Video enhancement**: noise reduction, super-resolution, error concealment
- **Video compression**: motion-compensated hybrid DCT/DPCM coding, H.26X and MPEG-X families of compression standards, error resilience in video coding, introduction to motion-compensated wavelet-domain video compression (MCTF)

Grading:

50% Assignments 5 assignments covering theory and practice (Matlab/Python); penalty for late submission; no assignment accepted after one week.

50% Project Project involving experimental work; report and in-class presentation mandatory at the end of the course.

On-line course resources:

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

Course material: The course is primarily based on my lecture notes and various handouts, but I will also use the following book: M. Tekalp, *Digital Video Processing*. Signal Processing Series, Prentice Hall, 2015 (2nd edition only). Additionally, I will make reading material (journal and conference papers) available on the course website. Other references helpful in the course:


Homework: While you may brainstorm approaches to solve homework problems with your EC720 classmates, you must formulate and write your solution by yourself; it must be the result of your individual work. If you collaborate with other EC720 students, you must list their names at the top of the first page of your solutions. Also, you must clearly identify all resources you used in your work: books, papers, on-line resources (e.g., Generative AI tools such as ChatGPT), etc. Copying solutions/answers from other students or sources is considered academic misconduct (see below).
**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. Alternatively, you may use *Python*, but homework hints will be provided for *Matlab* only.

**Project:** The course project is a key element of learning in EC720. Depending on the final class size, the projects may be individual or team-based. Projects may be theoretical, practical or combination thereof. I will offer a list of topics, but you are welcome to propose your own project. Projects will be executed over about 2-1/2 months with a final report and in-class presentation at the end of the course.

**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.