Course Syllabus

[VE556]

[Image Processing]

[Fall 2018]

Course Description:

This course covers the fundamentals of imaging and image processing. Topics includes image formation, sampling, interpolation, representation, enhancement, restoration, analysis, and compression. The topics above are the applications; much of the course will focus on the methods: Fourier transforms, filtering, sampling, wavelets, random processes, etc. Ra ther than attempting to cover as many methods for image processing as is possible, this course discusses the fundamentals in each of the above topics in sufficient depth to facilitate subsequent independent reading of the image processing literature.

Instructor:

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Office: Room 402
Office hour: Mon. 13:00-14:00, Wed. 13:00-14:00

Textbook (Author, Book Title, Publisher, Publication Year, ISBN):

None required. Detailed lecture notes written by Prof. Jeffrey A. Fessler are provided.

Course Prerequisites:

VE401 (Probabilistic Methods in Engineering) & VE451(Digital Signal Processing) or preceded or accompanied by VE501(Probability and Random Process) and graduate standing.

Course Website:

On canvas.

Grading Policy (Assignments %, Project, Exams, etc.):

Homework: 15%

Midterm Exam1: 25%

Midterm Exam2: 25%

Project: 35%

Requests for re-grades of exams must be submitted in writing within one week of exam return. All questions may be re-graded. Letter grades will be assigned using a curve. **The median grade is B+.**

Honor Code Policy:

1) Homework: Homework and solutions will be posted on Canvas only**.** Some subset of the problems from each assignment will be graded (possibly all). Solutions will be provided for all problems. **You are not allowed to post any of the solutions on any website. ABSOLUTELY NO LATE HOMEWORK ASSIGNMENTS WILL BE ACCEPTED. The lowest homework score will be automatically dropped.** About half of the homework assignment points will be Matlab problems. The points assigned to some of these problems may far outweigh those of other such problems. The goal is to develop both analytical skills and computational skills related to imaging.
2) Collaboration: You must attempt to solve all homework problems, and implement all computer programs by yourself. Copying homework solutions from another student or from solutions from previous semesters will be considered violations of the **JI honor code** (http://umji.sjtu.edu.cn/academics/academic-integrity/honor-code/). However, after making a genuine attempt to solve the homework problems, you are encouraged to discuss the answers with other students currently enrolled in Ve556 to check the answers and compare solution approaches. After

such a discussion, you may rewrite your answer as long as you do so individually, without referring to the solutions of other students or to solutions from previous terms. Basically, **the answers you turn in should reflect your own level of understanding, not someone else's.** All solutions submitted must be generated by the person whose name appears on the assignment.

3) Exam: All students must take all exams during the scheduled times. Exceptions must be approved by Prof. Long, in writing stating why you could not attend (severe disease, for example). You must solve all exam problems by yourself. Copying exam solutions from another student or from solutions from previous semesters will be considered violations of the JI honor code. Tentative schedules of exams:

   a) Midterm Exam1 on **Oct. 17, 2018** from 10am-11:40am. Venue: TBD

      During the exam you may use any paper materials you brought with you but no electronic devices.

   b) Midterm Exam2 on **Nov. 21, 2018** from 10am-11:40am. Venue: TBD

      During the exam you may use the lecture notes, any book, individual research on the Internet, and any computational software package. However, if you use any resources other than the course notes or built-in MATLAB functions, then you must cite the source.

4) Project: In lieu of a final exam, students will work in small groups (4-5 students) on image processing projects that apply the tools learned in the course as well as using ideas from the contemporary literature.

   Milestones for the project:

   a) Fri. Oct. 12 5 PM: form your project teams (at the latest)
   b) Fri. Oct. 26 5 PM: written project proposal (upload pdf to Canvas)
   c) Fri. Nov. 23 5 PM: written progress report (upload pdf to Canvas)
   d) Fri. Dec. 7 5 PM: written project reports (upload pdf to Canvas)

      includes peer evaluation form (at end of report)

   e) Fri. Dec. 7 5 PM: individual project self-evaluation (upload form to Canvas)
   f) Fri. Dec. 7 5 PM: oral presentation files (upload pdf to Canvas)
   g) Exam week: team oral presentations to entire class

Teaching Schedule:

On Canvas I will frequently update this lecture-by-lecture list of what topics we cover each lecture.

Week	NO.	Date	lectures and Exams	Comments
1	1	Sep. 10	course policies Image processing overview (pictorial overview) 2D CONTINUOUS-SPACE SIGNALS/SYSTEMS intro / overview 1.1 2D signals (definition, domain dimension, range dimension, discrete-space vs. continuous-space images, image support, value characteristics, analog and digital images, deterministic vs. random images, energy and power images)	
	2	Sep. 12	1.1 2D signals (periodic images) 1.2 2D systems, input-output relationship 1.3 convolution (for LSI systems)	
2	3	Sep. 17	*** 2D FOURIER TRANSFORMS (FT: n-02-four.pdf) 2.1 orthogonal representation of signals， 2D Fourier series 2.2 2D Fourier transform	
	4	Sep. 19	SKIP CH3 - it is superceded by modifications to Ch2 and Ch4 *** Optical imaging basics 3.2 lenses and imaging 4.1 ideal rectilinear sampling 4.2 signal reconstruction 4.3 aliasing	
3	5	Sep. 24	*** 2D discrete-space signals/systems 5.1 2D Kronecker impulse function / properties 5.2 2D systems, input-output relationship	
	6	Sep. 26	5.3 2D convolution 5.4 2D discrete-space Fourier transform (DSFT)	
4	7		National holiday	
	8		National holiday	

5	9	Oct. 8	5.5 Introduction to filter design *** Filters 6 overview 6.1 ideal filter specifications 6.2 IIR filters in 2D / Z transform - not	
	10	Oct.10	7.3 2D DFT 7.4 2D FFT 7.5 FT family relations	
6	11	Oct.15	7.6 Numerical evaluation of CS FT using 2D FFT and fftshift 7.7 frequency-sampling methods for FIR filter design 7.8 DCT	
	12	Oct.17	Midterm Exam 1	
7	13	Oct.22	*** Interpolation Image interpolation 8.0 sinc, separable, linear 8.1 polynomial: nearest ("rect"), linear, bilinear, griddata	
	14	Oct.24	8.2 shift-invariant subspaces / prefilter 8.3 applications	
8	15	Oct.29	*** Image analysis (IA: n-09-analyze.pdf) 9.1 Edge detection basics 9.2 Edge detection using 2nd derivatives and beyond	
	16	Oct.31	9.3 Corner detection - Harris' method *** Image enhancement (IE: n-10-enhance.pdf) [skipped this chapter!] 10.1 Contrast adjustment	
9	17	Nov. 5	10.2 Image sharpening *** Wiener Filter / Spectral estimation / random proc. 11.1 random processes, WSS	
	18	Nov. 7	11.2 Noncausal Wiener filter (MMSE denoising) 11.3 Wiener for deblurring	
10	19	Nov. 12	10.3 Noise smoothing (image denoising) 11.5 Patch-based denoising	
	20	Nov. 14	*** C1 Image restoration 1.1 overview 1.2 conventional discrete convolution model 1.3 continuous to discrete modeling (skip) 1.4 matrix-vector representations of convolution, diagonalization of circulant matrices vs DFT, eigenvalues of circulant matrix	

11	21	Nov. 19	1.6 statistical formulations:LS, ML 1.7 MAP estimation (skip MMSE) MAP with (IID) gaussian prior (cf Wiener filter), circulant analysis overview of model-based image restoration / reconstruction	
	22	Nov. 21	Midterm Exam 2	
12	23	Nov. 26	1.8 regularized/penalized least squares 1.9 mean and variance analysis 1.10 nonquadratic PLS	
	24	Nov. 28	sparsity from Ch. 13 *** SP: regularization based on sparsity 1.11 algorithms for NPLS	
13	25	Dec. 3	Shrinkage for Fair potential *** Image coding quantization	
	26	Dec. 5	waveform coding transform coding JPEG standard (brief)	
14		TBD	team oral presentations to entire class	