ESE 558 DIGITAL IMAGE PROCESSING
Electrical and Computer Engineering, Stony Brook University, 3 Credits
Prof. Murali Subbarao, Spring 2021
(Subject to Minor Changes)

Catalog description:
It covers digital image fundamentals, mathematical preliminaries of two-dimensional systems, image transforms, human perception, color basics, sampling and quantization, compression techniques, image enhancement, image restoration, **image reconstruction from projections,** and binary image processing.

Text book:

1. ***Digital Image Processing,***
   R. C. Gonzalez and R. E. Woods, Third Edition,
   Pearson Prentice-Hall, ISBN 0-13-168728-x, 2008.

Reference Material:
Published Papers, Patents, Handouts, online resources.

Contact info:
Prof. Murali Subbarao, murali.subbarao@stonybrook.edu
Office Hours: Tue. and Thu.: 10 a.m to 11.00 a.m. and 1 pm to 2 pm.
Place: Room 233, Light Engg. Bldg.

Pre-requisites: Basic background in Linear algebra, Claculus, Probability, and Programming. Projects will be in MATLAB. If you have prior programming experience (as in ESE 224), then you will need 8 hours to learn enough MATLAB for this course.

Syllabus:

1. **Digital Image Fundamentals:** introduction, and applications.
   Image formation in digital cameras and medical imaging devices, spatial and gray-level resolutions, Human Visual System (structure of the eye and brightness perception characteristics), overview of modern image sensors (RGBD, LIDAR, Medical Imagers), modern computing hardware systems (GPU, cloud computing) and software libraries (OpenCV, Matlab, Python) for image processing.
2. **Color Image Models:** human perception of color, color models (CIE, RGB, HSI, CMYK, etc).
3. **Image Processing: Spatial domain techniques**
   Enhancement (pointwise, local, global, histogram transformations), Geometric transformations (2D and 3D scaling, translation, rotation, affine transform) , Image interpolation, Convolution, separable, and Gaussian filtering, general linear filtering, computational complexity of different filtering techniques. Computing image features (edges, corners, sift vector, etc).
4. **Image Processing: Transform domain techniques**
   Fourier transform: continuous and discrete transforms (1-D, 2-D, N-D), properties and applications to filtering, relation to spatial domain techniques, FFT and

computational complexity, related transforms (Discrete Cosine/Sine). Ortho-normal transforms.

5. **Sampling and quantization**
   Optimal quantization, Sampling theorem (1D and 2D), Optimal Sampling (ortho-normal basis and expansions).
6. **Medical Image Processing:**
   a. **X-ray computed tomography (CT)**
      Image formation model, Radon transform, Fourier slice theorem, image reconstruction techniques, Filtered Back Projection algorithm, Total Variation Minimization technique.
   b. **SPECT/PET (Single-Photon/Positron Emission CT):** image formation model and image reconstruction techniques.
   c. **MRI (Magnetic Resonance Imaging):** image formation model, aliasing and unaliasing in parallel MRI.
7. **Image Restoration: image blurring and deblurring**
   Defocus/Optical blur: Point Spread Function (PSF) and related functions (OTF, MTF, PTF, Edge Spread Function), models of PSF (geometric/cylindrical, Gaussian, Calibrated model). Deconvolution/deblurring in the spatial and Fourier domains (inverse filtering), Regularization (e.g. Weiner filtering), Shift-Variant Image blurring and deblurring (by inverting large linear systems of equations) with regularization (SVD/spectral-filtering, regularization based on first and second image derivatives).
   Motion blur and deblurring.
8. **Image/video Compression**
   Coding, spatial, and psycho-visual redundancies, Loss-free compression: Huffman-coding and related techniques, Lossy-compression: Transform coding techniques, Sampling with Discrete Cosine Transform; Wavelet transform; Compression standards-jpeg.
   Video compression: motion estimation and prediction, mpeg.
9. **Image recognition:** image feature vectors, Nearest-Neighbor/Centroid classification, K-nearest Neighbor, Bayesian classification, clustering, Support Vector Machines, Convolutional Neural Nets, transfer learning, deep learning nets.

GRADING

Attending lectures is essential for doing well on written exams. Lectures will specifically prepare students for the exams. There will be 2 open-book exams and a quiz. You will be provided with practice questions that will be similar to the questions on the exams for all the exams.

Programming Project (20%) : There will be an individual programming project using MATLAB. It will take around 20 hours to complete.
Seminar presentation (10%): Each student will have to present a paper published within the last 10 years on a topic of current interest. Length of presentation: 15 minutes.

GRADING
Mid-term Test 1 : 30% (2 hrs., open book) March 10, 2021
Mid-term Test 2 : 30% (2 hrs., open book) April 21, 2021
Final Quiz/Take-home problem set : 10% (30 mins) May 18, Tue., 2.15 pm to 3 pm.
Project : : 20% (MATLAB, around 20 hrs. to complete)
Presentation : 10% (15 minutes on a topic of current interest) May 5, 2021.

Grading Policy
Grades are assigned based on absolute percentage of total marks as below.
A : 93—100 , A- : 88—92 ,
B+ : 83—87, B : 78—82, B- : 73--77
C+ : 70—72, C : 65—69, C- : 61—64,
D+ : 56—60, D : 51—55, F : 0—50

Individual Programming Project: 20%.
Matlab programming language should be learned for completing the project. Project is not difficult and requires about 20 hours of effort.

LEARNING Outcomes: Upon completion of the course, students will have

1. Understood and implemented image enhancement in the spatial and Fourier domains..
2. Understood and able to implement digital image processing algorithms for image filtering, image restoration, and image reconstruction of medical tomographic images.
3. Understood image and video compression algorithms

Student Accessibility Support Center Statement:

If you have a physical, psychological, medical or learning disability that may impact your course work, please contact the Student Accessibility Support Center, ECC (Educational Communications Center) Building, Room 128, (631)632-6748.

They will determine with you what accommodations, if any, are necessary and appropriate. All information and documentation is confidential.
https://www.stonybrook.edu/commcms/studentaffairs/sasc/facstaff/syllabus.php

[In addition, this statement on emergency evacuation is often included, but not required): Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and Student Accessibility Support Center. For procedures and information go to the following website: https://ehs.stonybrook.edu/programs/fire-safety/emergency-evacuation/evacuation-guide-people-physical-disabilities

▪ To access mental health services, call Counseling and Psychological Services at 631-632-6720; Counselors are available to speak with 24/7.

▪ For updated information on the Academic Success and Tutoring Center please check www.stonybrook.edu/tutoring for the most up-to-date information.

▪ For IT Support: Students can visit the Keep Learning website at https://sites.google.com/stonybrook.edu/keeplearning for information on the tools you need for alternative and online learning. Need help? Report technical issues at https://it.stonybrook.edu/services/itsm or call 631-632-2358.

▪ For information on Library services and resources please visit the Continuity of Library Operations guide.