

**ESE 457: Fundamentals of Digital Image Processing**  
**Electrical and Computer Engineering, Stony Brook University, 3 Credits**  
**Prof. Murali Subbarao, Spring 2025**  
**(DRAFT 1.0 : Subject to Minor Changes)**

**Catalog description:**

This course covers fundamentals of digital image processing. Basic principles, computational algorithms, and applications are covered. Topics include image formation and sensing, sampling and quantization, image enhancement and histogram analysis, geometric transformations, filtering in the spatial and Fourier domains, edge and feature detection, color image processing, image deblurring, and medical images and computed tomography.

Prerequisites: ESE 305; ESE 224

**Text book:**

1. *Digital Image Processing*,

R. C. Gonzalez and R. E. Woods, Fourth Edition, Pearson, 2017

ISBN-13: 978-0133356724 / ISBN-10: 9780133356724

OR Third Edition, Prentice-Hall, ISBN 0-13-168728-x, 2008.

**Reference Material:**

Many online sources,  
and papers.

**Contact info:**

Prof. Murali Subbarao, murali.subbarao@stonybrook.edu

Office Hours: Tue. and Thu.: 9.30 a.m to 10.30 a.m. and 12.30 pm to 1.30 pm.

Place: Room 233, Light Engg. Bldg.

**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.

#### **Mid-term 1 3/6/2025 Thr**

#### **5. Sampling and quantization**

Optimal quantization, Sampling theorem (1D and 2D), Optimal Sampling (ortho-normal basis and expansions). Aliasing.

#### **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.**

#### **Mid-term 2 4/24/2025 Thr**

#### **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. Deep learning and CNNs, and their applications to image processing for enhancement, restoration, tomography, compression, super-resolution, and segmentation.**

## **GRADING**

Attending lectures is essential for doing well on written exams. Lectures will specifically prepare students for the exams. There will be 2 open notes (up to 100 pages) exams. You will be provided with practice questions that will be similar to the questions on the exams for practice.

**Programming Project (20%) :** There will be individual programming projects using Python/MATLAB. It will take around 20 hours to complete.

**GRADING**

**Mid-term Test 1 :** 35% 3/6/2025 (1 hr 15 min , open notes: up to 50 pages)

**Mid-term Test 2 :** 35% 4/24/2025 (1 hr 15 min , open notes: up to 50 pages)

**Project :** 20% (MATLAB or Python : around 20 hrs. to complete)

**Final exam :** 10% ( Take-home problem set)

**Grading Policy**

Grades are assigned based on absolute percentage of total marks as below.

A : 94—100 , A- : 89—93 ,

B+ : 84—88, B : 78—83, 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/Python 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](http://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.