ESE 358 COMPUTER VISION

Stony Brook University, Electrical and Computer Engg., Fall 2023, 3 credits.

Instructor: Prof. Murali Subbarao
(Draft 1.0. Subject to minor changes)

Catalog Description
Introduces fundamental concepts, algorithms, computational techniques, and applications in visual information processing. Covers image formation models and image filtering, binary image analysis, feature detection, contours, image segmentation, 3D image capture and analysis through stereo, motion, structured-light, and LIDAR, medical images, pattern classification, machine learning, and 3D object recognition.

Prerequisites: ESE 305; ESE 224 or CSE 230,   3 credits

Instructor : Prof. Murali Subbarao   murali.subbarao@stonybrook.edu
Office Hours: Tue.   11.30 am to 1.30 pm
                 Thurs. 11.30 am to 1.30 pm
                 Room 233, Lt. Engg. Bldg.

Pre-requisites: Basic background in Linear algebra, Claculus, Probability, and Programming. Projects will be in Python. If you have prior programming experience (as in ESE 224), then you will need around 12 hours to learn enough Python/Matlab for this course.

Text book:
> *Computer Vision: Algorithms and Applications*, Richard Szeliski, Spinger 2022, 2nd Edition, Available free at **http://szeliski.org/Book/**

References
> **Many online resources.**
> Some examples:

- https://web.eecs.umich.edu/~justincj/teaching/eecs442/WI2021/schedule.html
- Tutorials on Vision using Tensorflow: Convolutional Neural Network (CNN) | TensorFlow Core
- Schedule | EECS 498-007 / 598-005: Deep Learning for Computer Vision (umich.edu)
- Stanford University CS231n: Deep Learning for Computer Vision
- https://browncsci1430.github.io/webpage/
- https://faculty.cc.gatech.edu/~hays/compvision2022fall/
- CS5670 Lectures, Spring 2022 (cornell.edu)

Part I Image Formation Models, Geometric Transformations, and Image Processing

1. *Introduction:* Introduction, Overview, and applications.
2. Digital images for representing 2D, 3D, and moving objects. Human eye and digital camera models.
3. Linear algebra overview. (vectors, points, lines, planes, surfaces, matrices).
4. *Photometric information: Color:* Physics of color, human perception of color, color models (RGB, HSI).

5. *Geometric-information:* Representation of points, lines, planes, surfaces, and shapes in 3D, nature and structure of medical images. Two-dimensional and three-dimensional geometric transformations of images and 3D scenes.
6. *Image filtering:* gray-level transformations, histograms, convolution, noise reduction, spatial and Fourier domain filtering and convolution, Gaussian filtering, and image resolution pyramids.

Part II Image Features: detection and matching

7. *Feature detection*: gradient vector, Canny's edge detection, Harris-corner detector.
8. *Contours:* Model fitting, Total LSE, Least Median Square Error.
9. RANSAC, Hough transform.
10. SIFT vector, image stitching, ICP.

Mid-term test 1 : 25 % : Thr. 10/5/2023 (1 hr 15 mins, Open to 50 sheets or 100 pages of notes material)

Part III Machine Learning, Object Recognition, Neural Nets, and Artificial Intelligence

1. Machine learning principles and techniques for object recognition. Nearest-neighbor, nearest centroid, K-NN.
2. *Machine learning:* clustering techniques, K-mean clustering. PCA.
3. Support Vector Machines.
4. Neural Nets, Convolution Neural Nets,
5. Transformers.
6. Video interpretation.
7. Deep learning, AI.

Mid-term test 2: 25% : Thr. 11/16/2023 (1 hr 15 mins, Open to 50 sheets or 100 pages of notes material)

Part III 3D Imaging, 3D Motion, Medical imaging.

11. *Three-dimensional shape recovery:* 3D from Stereo Images; Stereo Camera model, calibration, matching, rectification.
12. Structured-light, RGBD cameras, Laser and LIDAR, and related techniques.
13. 3D Motion from Video, optical flow, other shape-from-x methods (texture, shading, focus/defocus, Optical flow, etc). Machine and robot vision applications and self-driving cars.
14. *Medical Imaging:* Modes of medical imaging, X-ray Computed Tomography, image reconstruction algorithms.

Final Exam: Take-home problem set (10%) Due 12/13/2023

Programming Projects (30%) : There will be around 3 or 4 programming projects using Python/Matlab. Each project may take around 10 hours for completion.

Project 1: 2D and 3D Geometric transforms, imaging in a pin-hole camera.
Project 2: Image processing, Feature Detection, and Local Feature Descriptor
Project 3: Convolutional Neural Nets for Image Recognition
Project 4: CNN 2

GRADING : Grading is based on absolute total score.

    Mid-term Test 1 :   25% : Thr. 10/5/2023 (1 hr 15 mins, open to 50 sheets or 100 pages of notes)
    Mid-term Test 2 :   25% : Thr. 11/16/2023 (1 hr 15 mins, open to 50 sheets or 100 pages of notes)
    Final Exam   :   10% (Take-home problem set) Due 12/13/2023
    Projects: :   30%
    Homeworks   :   10%

Late submission of assignments
Homeworks: Late submissions are not accepted as the weight for any individual homework is small, around 1% of the overall total. Homeworks help prepare for tests and be engaged in a continuous learning process.
Projects: 10% per day.

See the SBU Blackboard website of the course for all the latest announcements. We will also use piazza.com for question/answers.

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

LEARNING OBJECTIVES: Upon completion of the course,

Students will be able to design and implement computational algorithms to solve problems in the following areas:

   i.   Image formation and geometric transformations.
  ii.   Gray level image analysis, edge detection and local feature descriptor, and image filtering operations.
 iii.   Stereo image analysis, 3D object representation and recognition techniques.
 iv.   Convolutional Neural Networks for Object Recognition.

Minimal Instructional and Student Responsibilities

Please refer to:

https://www.stonybrook.edu/sb/bulletin/current/policiesandregulations/policies_expectations/min_instructional_student_resp.php

Student Accessibility Support Center (SASC) Statement:

If you have a physical, psychological, medical or learning disability that may impact your course work, please contact the Student Accessibility Support Center (SASC), 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.

Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and the staff at the Student Accessibility Support Center (SASC). For procedures and information go to the following website:

> http://www.stonybrook.edu/ehs/fire/disabilities

Academic Integrity Statement:

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty are required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Technology & Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty, please refer to the academic judiciary website at http://www.stonybrook.edu/commcms/academic_integrity/index.html

Critical Incident Management Statement:

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Judicial Affairs any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures.

Minimal Instructional and Student Responsibilities

By accepting responsibility for their education, students enhance the development of their academic, social, and career goals. It is expected that students accept responsibility for their academic choices as part of their educational experience at Stony Brook. Services are available to assist students with academic advising, long-range goals, and career exploration. Students are responsible for reviewing, understanding, and abiding by the University's regulations, procedures, requirements, and deadlines as described in official publications, including, by way of example only, this Undergraduate Bulletin, the University Conduct Code, the Student Handbook, and class schedules.

Responsibilities in the Classroom

Students are expected to attend class regularly unless other arrangements are made; arrive for class on time and leave the class only at the end of class; engage in class discussions and activities when appropriate; exhibit classroom behavior that is not disruptive of the learning environment; secure and turn off all electronic communications and entertainment devices during class time unless otherwise directed by the course instructor. Any use of a cell phone or other unauthorized electronic device during an examination may lead to an accusation of academic dishonesty.

Absentee Policy

Students are expected to report for their examinations and major graded coursework as scheduled. If a student is unable to report for any examination or to complete major graded coursework on time, the student must contact the faculty member immediately. If the student cannot reach the faculty member, then s/he should contact the Director of Undergraduate Studies.

Although faculty will consider each student's request on its own merits and not attempt to define ahead of time the validity of all possible reasons a student might give for missing an examination or the date to turn in major graded coursework, instructors are expected to accept an excuse of significant illness, tragedy, or other personal emergencies and to make reasonable alternative accommodations for the student. It shall be the student's responsibility to provide sufficient documentation to support any such request. Accommodations for other reasons will be at the discretion of the faculty.

Course Responsibilities

Students are expected to observe the requirements for the course and consult with the instructor if prerequisites are lacking; obtain and understand the course syllabus; keep up with the coursework and take all scheduled examinations; address any conflicts in syllabus and exam scheduling with the instructor as soon as possible; review all graded material and seek help if necessary; notify the instructor as soon as possible of any disabilities that might interfere with completion of coursework; complete the course evaluation form fairly and thoughtfully.