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**FIRST SEMESTER 2022-2023**

# Course Handout Part II

Date: 29-08-2022

In addition to part-I (General Handout for all courses appended to the time table) this portion gives further specific details regarding the course.

***Course No. : CS F441***

## **Course Title : Selected Topics from Computer Science (Computer Vision)**

## **Instructor-in-Charge : Dr. Aritra Mukherjee**

**Scope and Objectives of the Course:**

1. **Scope:**

The scope of this course includes introduction to digital image format and camera model; point operations, linear and non linear filtering, Fourier transform, pyramids and wavelets, geometric transformation; Feature engineering: points and patches, edges and contours, contour tracking, lines and vanishing points, Segmentation; Image classification, object detection, semantic segmentation, video understanding; Tracking and registration, applications of registration and tracking: Image stitching and alignment, optical flow, stereo vision and depth estimation, structure from motion and SLAM (introductory); 3D scanning, surface representations; Deep learning for computer vision- supervised learning, unsupervised learning, deep neural networks, convolutional networks, more complex models

1. **Objectives:**

* Provide the student with an understanding of the need for Computer Vision
* To gain knowledge on important verticals of computer vision with OpenCV and Python/C++
* To gain basic knowledge on advanced topics such as deep learning for CV, structure for motion, model generation, bio-vision etc.
* To get a rough idea about designing autonomous systems using real time computer vision techniques and incorporation of other sensors to work in tandem with cameras.

**Textbooks:**

1. Computer Vision: Algorithms and Applications 2nd Edition, Richard Szeliski, Springer 2021
2. Computer Vision: A Modern Approach, second edition by David A. Forsyth and Jean Ponce, Pearson, 2012

**Reference books**

1. Deep Learning for Vision Systems by Mohamed Elgendy, Manning 2020

**Course Plan:**

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| **Lecture No.** | **Learning objectives** | **Topics to be covered** | **Chapter in the Text Book** |
| **1** | To introduce Computer Vision- what and why? | Brief history of the subject, different computer vision tasks and why they are needed | T1: chap 1 |
| **2-3** | To get basics of image/video formation and basic transformations | Introduction to digital image format and camera model, Color space, pixel geometry, 2D and 3D transformations and rotations, Lighting and optics | T1: chap 2  T2: chap 1.1 |
| **4-8** | To know about basics of Image Processing | Pixel and color transforms, histogram equalization | T1: chap 3.1  T2: chap 3.3 |
| Linear filtering on color spaces, bandpass and steerable filter. Nonlinear filtering- median and bilateral filtering. Binary image processing | T1: chap 3.2 and 3.3 |
| Fourier transform and applications in filtering. Pyramids and wavelets and need for multiresolution representations. | T1: chap 3.4 and 3.5  T2: chap 4.3 |
| Geometric transformations and mesh based warping and morphing | T1: chap 3.6 |
| **9-14** | To get familiarized with feature engineering, patch, edge, corner and other features | Feature detector and descriptor, various features life SIFT, HOG, BRIEF etc. feature tracking and large scale matching | T1: chap 7.1  T2: chap 5.4 |
| Edge detection and contour detection, LoG, Sobel, Canny, edge kernels, snakes, splines, scissors, level sets | T1: chap 7.2, 7.3 |
| Hough transforms, RANSAC based lines and circles detection, using convex hulls, Vanishing point detection, perspective | T1: chap 7.4  T2: chap 10.1, 10.2 |
| **15-18** | To know about segmentation- for image classification, object detection and video understanding | Graph based segmentations, superpixels, mean shifts, normalized cuts. | T1: chap 7.5  T2: chap 9.3, 9.4 |
| Semantic segmentation (classical approach), dense and sparse approaches, HOG and wavelet based face/object detection, blob based object detection | T1: chap 4.3, 6.3  T2: chap 16.1 |
| **19-22** | To know about registration of landmarks: tracking, image stitching, alignment, optical flow | Pairwise alignment, 2D feature alignment, least square and RANSAC, 3D feature alignment | T1: chap 8.1  T2: chap 11.1 |
| Image stitching by rotational panorama, gap closing, projection on non cartesian coordinate systems | T1: chap 8.2 |
| Global alignment, bundle adjustment, parallax removal, composting, blending | T1: chap 8.3, 8.4  T2: chap 12.1 |
| Translational alignment by hierarchical motion estimation, spline based motion, video stabilization, optical flow (non deep approaches) | T1: chap 9.1, 9.2, 9.3  T2: chap 11.2, 11.3 |
| **23-28** | To know about basics of Epipolar geometry, stereo vision, 3D reconstruction, structure from motion, SLAM | Epipolar geometry, sparse and dense correspondence, essential and fundamental matrices, subpixel estimation disparity map | T1: chap 12.1, 12.2., 12.3, 12.4  T2: chap 7.1 |
| Multiview stereo, scene flow, volumetric and surface reconstruction | T1: chap 12.7  T2: chap 10.6 |
| Geometric intrinsic calibration, pose estimation by iterative nonlinear approach, two frame structure from motion (SFM) by multipoint algorithms, multiframe SFM by bundle adjustment | T1: chap 11.1, 11.2, 11.3, 11.4  T2: chap 8.1, 8.2 |
| Simultaneous Localization And Mapping for SFM, applications in augmented reality, area mapping and robot navigation | T1: chap 11.5  T2: chap 8.3 |
| **29-30** | To know about 3D scanning and surface representations | Range data merging, various scanning techniques (Lidar, structured light etc.), surface interpolation, point and volumetric representation (point cloud and vector based) | T1: chap 13.2, 13.3, 13.4, 13.5  T2: chap 14.1, 14.2 |
| **31-40** | To get the basics of Deep learning (in purview of computer vision): supervised and unsupervised approaches, CNN, different models of CNN for different tasks, spatio-temporal learning, semantic translation | Classical supervised learning: bayesian networks, nearest neighbor, logistic regression, support vector machines, decision trees and forests | T1: chap 5.1  T2: chap 15.2 |
| Classical unsupervised learning: Clustering- KMeans and Gaussian Mixture Models, Principal Component Analysis, Manifold learning | T1: chap 5.2  T2: chap 15.2 |
| Deep neural networks: weights, layers, regularization, normalization, activation functions, loss, gradient descent, backpropagation, training optimization | T1: chap 5.3  R1: chap 2 |
| Convolution neural networks: Kernels, pooling and unpooling, different types of layers (concat, FCN, dropout etc.) Network architectures, various pretrained models, dataset mechanisms, various performance metrics, adversarial examples, self supervised learning | T1: chap 5.4  R1: chap 3, 4, 5 |
| Complex models: 3D CNNs, UNets, RNN, Siamese, Transformer, BERT, GANs | T1: chap 5.5  Online resources |
| **41-42** | To get familiarized with applications in other domains of engineering | Applications in robot vision, biomedical vision, remote sensing, surveillance, agriculture, gaming and simulation etc. | Online resources |

**Evaluation Scheme:**

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| **Component** | **Duration** | **Weightage (%)** | **Date & Time** | **Nature of Component** |
| Mid semester Exam\* | 90 mins | 30% | 05/11 3.30 - 5.00PM | Closed book |
| Comprehensive Exam\* | 180 mins | 40% | 31/12 FN | Closed book |
| Micro Project (10% of evaluation for Mid semester grading) |  | 20% | To be notified | Open book |
| Coding Assignment | TBA | 10% | To be notified | Open book |

Note: minimum 40% of the evaluation to be completed by midsem grading.

**Chamber Consultation Hour:** To be discussed in the classroom/via email as per requirement.

**Notices:**

All notices pertaining to this course will be displayed on the Google Classroom/CS&IS Notice Board, as applicable.

**Make-up Policy:**

Make-up for Mid-semester test may be given for genuine cases with prior permission by IC. For the Comprehensive exam, make-up has to be approved by the IC and scheduled by AUGSD.

**Academic Honesty and Integrity Policy:**

Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable.

**INSTRUCTOR-IN-CHARGE**