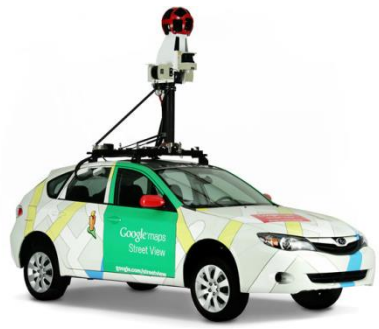
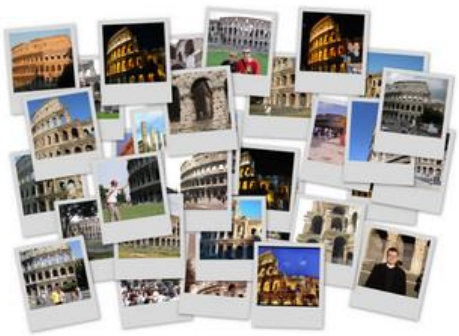
National University of Sciences & Technology (NUST)
School of Electrical Engineering and Computer Science (SEECS)
Department of Electrical Engineering

Computer Vision

What is the technology behind Google Street View? How does the Google Car find its location using images? How can a robot make 3D models from images? How can we train a robot to roam in the city? How does a drone make a 3D map? What is data association? What is robust estimation? In this course we will learn the basics of computer vision and machine learning applied to images. Prerequisites include linear algebra and passion to solve exciting problems.





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CS477 Computer Vision			
Course Code:	CS-477	**Semester:**	Fall 2023
Credit Hours:	3+1	**Prerequisite Codes:**	
Instructor:	Dr. Mohsin Kamal	**Class:**	BEE
Office:	A-217 (SEECS)	**Telephone:**	+92-51-8862128
Lecture Days:	Tuesday and Wednesday	**E-mail:**	dr.mohsinkamal@seecs.edu.pk
Class Room:	CR-20-IAEC	**Consulting Hours:**	Thursday 4:00pm-5:00pm Or by appointment through email
Lab Engineer:	Engr. Kaleem Ullah	**Lab Engineer Email:**	kalim.ullah@seecs.edu.pk
Knowledge Group:	DSSP	**Updates on LMS:**	Weekly

Course Description:

About 50% of the brain area is activated when eyes are working. This indicates that path to unlocking human intelligence is perhaps related to visual processing. How do humans manage to detect objects of different sizes and from different views? How do we manage to exist in a 3D world while perceiving only 2D images with our eyes? This course is about learning the basics of visual processing related to 3D scene modelling from single and multiple views. These concepts will form the basis of various computer vision applications related to surveillance, robotics and medical image processing etc.

Course Objectives:

With a single glance a human interprets the entire scene. How many objects are present in the scene and where they are located? Which person is present in the scene? What will happen next? However, computers lack this capability. We have seen only face detectors so far working in our mobile phones? What is the challenge in understanding the 3D scene, i.e., the identity, the location and the size of the objects present in the scene. Students will be introduced to techniques related to 3D scene modelling from single view and multiple views and they will practiced the implementation of these techniques in the lab.

Course Learning Outcomes:

CLO	Description After the completion of the course the students will be able to:	BT Level	PLOs
1.	**Explain** the single view & multiple view geometry concepts	C2	1
2.	**Investigate** the robust estimation techniques	C3	4
3.	**Analyze** Computer Vision algorithms	C4	2
4.	**Conduct** experiments as well as **analyze** and **interpret** experimental data	P4	4
5.	**Execute** the Computer Vision algorithms using Python	P4	5
6.	**Exhibit** good professional ethics and ethical behavior while **adhering** to lab safety rules.	A3	8
7.	**Function** effectively both individually and as a member of a team	A3	9

Mapping of CLOs to Program Learning Outcomes

PLOs/CLOs	CLO 1	CLO 2	CLO 3	CLO 4	CLO 5	CLO 6	CLO 7
PLO 1 (Engineering Knowledge)	✓						
PLO 2 (Problem Analysis)			✓				
PLO 3 (Design/Development of Solutions)							
PLO 4 (Investigation)		✓		✓			
PLO 5 (Modern tool usage)					✓		
PLO 6 (The Engineer and Society)							
PLO 7 (Environment and Sustainability)							
PLO 8 (Ethics)						✓	
PLO 9 (Individual and Team Work)							✓
PLO 10 (Communication)							
PLO 11 (Project Management)							
PLO 12 (Lifelong Learning)							

Mapping of CLOs to Assessment Modules

Assessments/CLOs	CLO 1	CLO 2	CLO 3	CLO 4	CLO 5	CLO 6	CLO 7
Quiz: 10% of the theory part	✓	✓	✓				
Assignments: 10% of the theory part	✓	✓	✓				
OHTs: 30% of the theory part	✓	✓					
Labs: 25% of the course				✓	✓	✓	✓
End Semester Exam:50% of theory part	✓	✓	✓				

Books:

Text Book:

1. "Computer Vision: Algorithms and Applications". by Richard Szeliski
2. "Introductory Techniques for 3D Computer Vision:". by Emanuel Trucco and Alessandro Verri
3. Lecture Notes
4. Programming Computer Vision with Python by Jan Erik Solem
5. Udacity online course (https://www.udacity.com/course/introduction-to-computer-vision--ud810)
   https://docs.google.com/spreadsheets/d/1ecUGIyhYOfQPi3HPXb-7NndrLgpX_zgkwsqzfqHPaus/pubhtml

Lecture Breakdown:

	Week No.	Topics	Sections	Remarks
	1	Why Computer Vision? The State of the art in Computer Vision.	CLO 1	
	2	Camera Model: How the 2D image is formed from the 3D world? Homogenous Transform, Ideal Points, Ideal Lines, Degree of Freedom of homogenous points and lines, Python examples. Linear Filtering, Gaussian smoothing.	CLO 1	
	3	Transformations in 2D: Transformations (Similarity, Affine, Projective), Invariants for each transform. Python examples.	CLO 1	
	4	Homography: How to view an image from a different angle automatically. Image Stitching: Making a bigger picture from smaller pictures. Direct Linear Transform (Ax = 0), Null space, Forward warping, Inverse warping. Python examples.	CLO 1	
	5	Robust Estimation: Optimization, gradient descent, learning rate. RANSAC: How to fit a line if there are noisy points? How to calculate homography with incorrect data associations? Python examples.	CLO 2	
	6	**OHT-1**		
	7	Transformations in 3D. Rigid Body Transforms. 3D rotations (Roll, Pitch, Yaw), Conventions of a rotation matrix, Unknowns in 3D Pose, Python examples.	CLO 1	
	8	Pin hole camera projection. Intrinsic and Extrinsic Calibration. Camera calibration toolbox.	CLO 1	
	9	Fundamental Matrix. Epipolar line, inliers vs. outliers, how kinect works?	CLO 1	
	10	Stereo Geometry: Making 3D model from two or more views. Structure from Motion (SfM), Bundle Adjustment.	CLO 1	
	11	SIFT & SURF Descriptors: How to find an object appearing at different sizes? Scale and view invariance.	CLO 2	
	12	**OHT-2**		
	13	Augmented Reality: Making a startup application in python.	CLO 3	
	14	Bag of Words / Spatial Pyramid	CLO 2	
	15	Tracking using Kalman filter.	CLO 2	
	16	Discussion on Research Paper and Semester Project	CLO 3	
	17	Misc		
	18	Week 18: ESE		

Lab Experiments:	
Lab 01:	Setting up the PC
Lab 02:	Introduction to Python
Lab 03:	Basic Image Handing
Lab04:	Basic Image Processing Tools
Lab05:	GPU based Machine Configuration/ Introduction to CoLab
Lab 06:	Translating Images for Useful Local Features
Lab 07:	Global Descriptors: Calculating Image Histogram
Lab 08:	Implementing Scale Invariant Feature Transform
Lab 09:	Transforming Images using Singular Value Decomposition
Lab 10:	Calculating Affinity and Homography using DLT Algorithm
Lab 11:	Warp and Register Images to match surroundings
Lab 12:	Stichting Images together to create a panorama of Scholars Avenue NUST
Lab 13:	Implementing Hand Gesture Recognition Application in OpenCV
Lab 14:	Vision and Learning & Github Repository Usage
Lab 15:	***Lab exam will be conducted in week 15***

Tools / Software Requirement:

- MATLAB
- Python

Grading Policy:

Quiz Policy:	The quizzes will be unannounced and normally last for ten minutes. The question framed is to test the concepts involved in last few lectures. Number of quizzes that will be used for evaluation is at the instructor's discretion.
Assignment Policy:	In order to develop comprehensive understanding of the subject, assignments will be given. Late assignments will not be accepted / graded. All assignments will count towards the total (No 'best-of' policy). The students are advised to do the assignment themselves. Copying of assignments is highly discouraged and violations will be dealt with severely by referring any occurrences to the disciplinary committee. The questions in the assignment are meant to be challenging to give students confidence and extensive knowledge about the subject matter and enable them to prepare for the exams. **Note that for programming assignments viva will be conducted. The grading will be mainly based on the viva performance.**
Plagiarism:	NUST maintains a zero tolerance policy towards plagiarism. While collaboration in this course is highly encouraged, you must ensure that you do not claim other people's work/ ideas as your own. Plagiarism occurs when the words, ideas, assertions, theories, figures, images, programming codes of others are presented as your own work. You must cite and acknowledge all sources of information in your assignments. Failing to comply with the NUST plagiarism policy will lead to strict penalties including zero marks in assignments and referral to the academic coordination office for disciplinary action.