Extended Syllabus

Course Title	Visual Odometry and Augmented Reality	Semester	2022-2
Credit	3	Course Number	AIE6660
Class Time	월수 10:30 ~ 11:45	Enrollment Eligibility	

Instructor's Photo	Name: 서용덕	Homepage:
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Ⅰ. Course Overview

1. Description

1. 디지털 카메라에서 획득한 영상을 분석하여 카메라의 움직임(motion, odometry)을 계산하는 방법에 대하여 학습한다.
2. 증강현실 (비디오 + 컴퓨터 그래픽스) 구현에 필요한 기본적인 모델링, 수학적 개념, 추정 방법에 대하여 학습한다.
3. 영상정보로부터 카메라 모션 정보와 3차원 정보를 획득하기 위한 최적화 방법에 대하여 학습한다.

2.Prerequisites

Computer Programming in C/C++ or Python

- C/C++ is highly recommended because most of image processing and computer vision algorithms require a lot of computation time
- The source codes for the class are mostly written in C/C++ in Linux environment.
- Students may use Python language.

- Deep neural network will be not used for this class.
- Knowledge of OpenGL programming is not required for the class but would be useful.

3. Course Format (%)

Lecture	Discussion	Experiment /Practicum	Field study	Presentations	Other
50%	%	25%	%	25%	%

4. Evaluation (%)

Mid-term Exam	Final exam	Quizzes	Presentations	Projects	Assignments	Participation	Other
30%	35%	%	%	15%	20		%

Ⅱ. Course Objectives

Knowledge:

Skill:

Attitude:

Ⅲ. Course Format

(* In detail)

Ⅳ. Course Requirements and Grading Criteria

Examples of curriculum-based writing homeworks/activity: all writing exercises requested by classes, including reports, discussion and presentations

Ⅴ. Course Policies

VI. Materials and References

The class does not have a main textbook. Parts of the following references will be used.

References:

1. Computer Vision: Algorithms and Applications, 2nd ed., Richard Szeliski, https://szeliski.org/Book/
2. Multiple View Geometry in Computer Vision, Richard Hartley and Andrew Zisserman
3. Computer Graphics Using OpenGL (2nd Ed.), Francis S. Hill
4. Programming Computer Vision with Python: Tools and Algorithms for Analyzing Images, Erik Solem, http://programmingcomputervision.com/
5. Augmented Reality: Principle and Practice, Dieter Schmalstieg, Tobias Hollerer, 2016 https://arbook.icg.tugraz.at/
6. Robotics, vision and control by Peter Corke, https://library.sogang.ac.kr/search/detail/CAT000000711881
7. https://vnav.mit.edu/ MIT 16.485 - Visual Navigation for Autonomous Vehicles, 2022
8. https://rpg.ifi.uzh.ch/teaching.html Vision Algorithms for Mobile Robotics, 2021
9. www.opencv.org
10. https://github.com/gaoxiang12/slambook2

Ⅶ. Course Schedule

(* Subject to change)

Week 1 (dd/ mm)	**Learning Objectives**	Overview
	Topics	Introduction to AR/XR/MR/VFX and Computer Vision
	Class Work (Methods)	
	Materials (Required Readings)	
	Assignments	
Week 2 (dd/ mm)	**Learning Objectives**	2D geometry, transformations, and image transformation
	Topics	1. Linear algebra revisited: rotation as change of frame basis 2. Reference frames, rotation, translation 3. Understand R & t
	Class Work (Methods)	

	Materials (Required Readings)	
	Assignments	Linear/bilinear interpolation for geometric image transformation - Forward/backward mapping
Week 3 (dd/ mm)	**Learning Objectives**	2D affine transformations
	Topics	- R, t, shear, scale - Homogeneous coordinate representation - Triangular image warping in 2D by a sequence of 2D elementary transformations -
	Class Work (Methods)	
	Materials (Required Readings)	
	Assignments	Triangular image warping for 3 correspondences
Week 4 (dd/ mm)	**Learning Objectives**	2D projective geometry
	Topics	- Generalized homogeneous coordinates - Effect of perspective projection through a pin-hole camera - Transformation in projective space
	Class Work (Methods)	
	Materials (Required Readings)	
	Assignments	Perspective rectification - Specify 4 correspondences - Warp to rectify a view of a rectangle
Week 5 (dd/ mm)	**Learning Objectives**	Pin-hole camera model and camera calibration
	Topics	- Pin-hole model - Normalized image plane, lens distortion, and image space transformation - Camera calibration: from modeling to parameter optimization - CV camera vs GL camera: a demo of opengl rendering on a view of the calibration checker board.
	Class Work (Methods)	
	Materials (Required Readings)	
	Assignments	1. Camera calibration with opencv 2. DIY undistort the image by linear warping

Week 6 (dd/ mm)	**Learning Objectives**	3D geometry
	Topics	- Linear algebra revisited: R, t, and basis change - Projection and rigid motion: understand the meaning of the pose matrix - Multiple views and multiple poses
	Class Work (Methods)	
	Materials (Required Readings)	
	Assignments	Display all the camera poses in a graphic world.
Week 7 (dd/ mm)	**Learning Objectives**	Camera rotation in 3D as a 2D projective transformation
	Topics	To solve the problem of obtaining a new image by a 3D-rotated camera without taking a new photo. Understand the meaning of pure rotation as a projective transformation: new view generation, panorama stitching, and auto-calibration of a camera
	Class Work (Methods)	
	Materials (Required Readings)	
	Assignments	Novel view generation by image warping for a given R in 3D.
Week 8 (dd/ mm)	**Learning Objectives**	Mid-term exam
	Topics	
	Class Work (Methods)	
	Materials (Required Readings)	
	Assignments	
Week 9 (dd/ mm)	**Learning Objectives**	Image feature detection & matching
	Topics	Harris, FAST corner detectors BRIEF, ORB SIFT feature descriptors RANSAC a robust parameter estimation method.
	Class Work (Methods)	

	Materials (Required Readings)	
	Assignments	RANSAC computation for automatic panorama image stitching or image feature computation such as a line or a conic.
Week 10 (dd/ mm)	**Learning Objectives**	Two view geometry
	Topics	- R, t revised. - Stereo vision (as an aligned two view system) - Epipolar geometry
	Class Work (Methods)	
	Materials (Required Readings)	
	Assignments	Stereo image rectification
Week 11 (dd/ mm)	**Learning Objectives**	Visual odometry
	Topics	- Triangulation - Solving PnP problems
	Class Work (Methods)	
	Materials (Required Readings)	
	Assignments	Two view motion analysis
Week 12 (dd/ mm)	**Learning Objectives**	Nonlinear optimization & Bundle adjustment
	Topics	- Nonlinear optimization formulation - Gauss-Newton method - LM method
	Class Work (Methods)	
	Materials (Required Readings)	
	Assignments	DIY Solving PnP by minimizing the reprojection error. - Pose estimation from scratch
Week 13 (dd/ mm)	**Learning Objectives**	Parametrization of Rotation matrices
	Topics	- Parametrizations: RPY, Angle-axis, quaternion - Lie group, Lie algebra, and optimization

	Class Work (Methods)	
	Materials (Required Readings)	
	Assignments	
Week 14 (dd/ mm)	**Learning Objectives**	Filters and optimization for visual motion analysis
	Topics	- BA & Kalman filter - Pose-graph optimization
	Class Work (Methods)	
	Materials (Required Readings)	
	Assignments	
Week 15 (dd/ mm)	**Learning Objectives**	Selected topics in AR/MR and Computer Vision
	Topics	
	Class Work (Methods)	
	Materials (Required Readings)	
	Assignments	
Week 16 (dd/ mm)	**Learning Objectives**	Final exam / term-project
	Topics	
	Class Work (Methods)	
	Materials (Required Readings)	
	Assignments	

Ⅷ. Special Accommodations

IX. Aid for the Challenged Students