**Extended Syllabus**

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

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| **Instructor's**  **Photo** | **Name: 서용덕** | **Homepage:** |
| **E-mail:** [**yndk@sogang.ac.kr**](mailto:yndk@sogang.ac.kr) | **Telephone: 02 705 8896** |
| **Office: GA215**  **Office Hours:** | |

**Ⅰ. Course Overview**

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| 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. |
| 1. Course Format (%) |
| |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Lecture | Discussion | Experiment  /Practicum | Field study | Presentations | Other | | 50% | % | 25% | % | 25% | % | |
| 1. Evaluation (%) |
| |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Mid-term Exam | Final exam | Quizzes | Presentations | Projects | Assignments | Participation | Other | | 30% | 35% | % | % | 15% | 20 |  | % | |

**Ⅱ. Course Objectives**

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| Knowledge:  Skill:  Attitude: |

**Ⅲ. Course Format**

(\* In detail)

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**Ⅳ. Course Requirements and Grading Criteria**

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

**Ⅴ. Course Policies**

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**Ⅵ. Materials and References**

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| 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](http://www.opencv.org) 10. <https://github.com/gaoxiang12/slambook2> |

**Ⅶ. Course Schedule**

**(\* Subject to change)**

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| **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**

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**Ⅸ. Aid for the Challenged Students**

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