جامعة محمد بن زايد للذكاء الاصطناعي
MOHAMED BIN ZAYED UNIVERSITY OF ARTIFICIAL INTELLIGENCE

Core Courses Syllabi

# CV702 - Geometry for Computer Vision

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| **Title** | Geometry for Computer Vision |
| **Code** | CV702 |
| **Loading** | 4 Credit-hours |
| **Prerequisites** | • CV 701: Human and Computer Vision (or equivalent)<br>• Hands-on experience with Python and Pytorch |
| **Catalog Description** | The course provides a comprehensive introduction to the concepts, principles and methods of geometry-aware computer vision which helps in describing the shape and structure of the world. In particular, the objective of the course is to introduce the formal tools and techniques that are necessary for estimating depth, motion, disparity, volume, pose and shapes in 3D scenes. |
| **Goal** | This graduate level course aims to familiarize students with the fundamental concepts and techniques of geometric computer vision and introduce to them several real-world computer vision applications involving geometry. |
| **Content** | This course covers the following major modules: **(I)** projective spaces and camera calibration, **(II)** epipolar geometry and multiview stereo **(III)** shape from X **(IV)** 3D machine vision applications. |
| **Recommended Textbooks** | 1. R. Hartley and A. Zisserman, *Multiple View Geometry in Computer Vision*, second edition, Cambridge, 2003. ISBN: 0521540518<br>2. Y. Ma, S. Soatto, J. Kosecka, and S. S. Sastry, *An Invitation to 3D Vision: from Images to Geometric Models*, Springer Science & Business Media, 2012. ISBN: 0387008934 |
| **Recommended References & Supplemental Material** | Relevant research papers, tech reports, and surveys for each topic, where needed, are identified in the teaching plan ahead. In addition, the following textbooks will be useful:<br>1. E. Trucco, and A. Verri, *Introductory Techniques for 3D Computer Vision*, Prentice Hall, 1998. ISBN: 0132611082<br>2. C. Wöhler, *3D Computer Vision: Efficient Methods and Applications*, Springer Science & Business Media, 2012. ISBN 9781447141501 |

| Teaching Week | Topics |
|---|---|
| 1 | **Course Overview and Motivation**<br>**Lecture**<br>• Course introduction: historical context and applications of geometry for computer vision<br>**Lab**<br>• A tutorial/refresher on Python and relevant deep learning libraries (e.g., Pytorch) |
| 2 | **Optics and Digital Cameras**<br>**Lecture**<br>• Camera pipeline<br>• Lenses and ray-tracing<br>• Camera sensors: CMOS, CCD<br>**Lab**<br>• Ray tracing for convex and concave mirrors and lenses at different focal lengths |
| 3 | **Projective Spaces and Homography**<br>**Lecture**<br>• Introduction to projective spaces<br>• Homogeneous coordinates in 2D+3D, points, lines, planes, templates (articulated, deformable), homographies<br>**Lab**<br>• Assignment # 1 due |
| 4 | **Optical Flow**<br>**Lecture**<br>• Optical flow: 2D point correspondences<br>• Image alignment and tracking<br>**Lab**<br>• Implement a feature based image registration algorithm |
| 5 | **Camera Models and Camera Calibration**<br>**Lecture**<br>• Camera models<br>• Single-view geometry<br>• Camera calibration<br>• Image stitching<br>**Lab**<br>• Implement an algorithm to detect vanishing points |

| Teaching Week | Topics |
|---|---|
| 6 | **Epipolar Geometry and Stereo Essentials**<br>**Lecture**<br>• Epipolar geometry<br>• Stereo essentials<br>• Fundamental matrices<br>**Lab**<br>• Assignment # 2 due |
| 7 | **Multiview Stereo**<br>**Lecture**<br>• Geometry of multiple views<br>• Multiview stereo, triangulation and rectification<br>**Lab**<br>• Write a function to triangulate pairs of 2D points in the images to a set of 3D points |
| 8 | **Shape from X (Part- 1)**<br>**Lecture**<br>• Shape from X: Reflectance map, shape from shading, photometric stereo, shape from optical flow (moving camera, moving objects)<br>**Lab**<br>• Implement an algorithm that reconstructs a surface using the concept of photometric stereo (Part 1- Compute Albedo) |
| 9 | **Shape from X (Part- 2)**<br>**Lecture**<br>• Shape from X: Rotating camera, silhouettes, space carving, light stripe encoding<br>**Lab**<br>• Implement an algorithm that reconstructs a surface using the concept of photometric stereo (Part 2 - Compute Normals) |
| 10 | **Bundle Adjustment**<br>**Lecture**<br>• Bundle adjustment<br>• Range/Depth image processing<br>**Lab**<br>• Assignment # 3 due<br>• Mapping to CLO<br>• CLO2 (M), CLO3 (H), CLO6 (H) |

| Teaching Week | Topics |
|---|---|
| 11 | **Graphics**<br>**Lecture**<br>• Graphics: View interpolation, reconstruction of geometry, materials and lighting<br>**Lab**<br>• Given two consecutive frames of a video, synthesize the intermediate frame using context aware interpolation |
| 12 | **Pose Estimation**<br>**Lecture**<br>• Pose estimation from two images<br>• Pose from 3D point correspondences<br>• Pose from projective transformations<br>• Pose from point correspondences<br>**Lab**<br>• Study geometry-aware 3D pose estimation using convolutional neural networks and submit a report |
| 13 | **Virtual and Augmented Reality**<br>**Lecture**<br>• Virtual reality (VR)<br>• Augmented reality (AR)<br>• 3D vision applications in VR and AR<br>**Lab**<br>• Write a three page report to identify a new potential application of VR or AR and describe how you would develop and deliver your end solution |
| 14 | **Robotics**<br>**Lecture**<br>• Basics of robotics,<br>• Simultaneous localization and mapping (SLAM)<br>• SLAM applications in autonomous driving, unmanned aerial vehicles (UAVs)<br>**Lab**<br>• Assignment # 4 due |
| 15 | **Guest Lecture & Review**<br>**Lecture**<br>• Guest lecture on a trending topic<br>**Lab**<br>• Review and Exam Preparation |