Course Syllabus

Newly created [Monographs](#) ↗ by Professor Shree Nayar on First Principles of Computer Vision:

What you can explore:

- About: learn more about the faculty and staff behind the specialization
- Research: The Columbia Imaging and Vision Laboratory (CAVE) at Columbia University is dedicated to the development of advanced vision system.
- Monographs and lectures: Take a sneak peek at the lecture notes in advance.

Welcome to First Principles of Computer Vision: Camera and Imaging

This course covers the fundamentals of imaging – the creation of an image that is ready for consumption or processing by a human or a machine. Imaging has a long history, spanning several centuries. But the advances made in the last three decades have revolutionized the camera and dramatically improved the robustness and accuracy of computer vision systems. We describe the fundamentals of imaging, as well as recent innovations in imaging that have had a profound impact on computer vision.

We begin by looking at how an image is formed using a camera lens. We explore the optical characteristics of a camera such as its magnification, F-number, depth of field and field of view. Next, we describe how solid-state image sensors (CCD and CMOS) record images, and the key properties of an image sensor such as its resolution, noise characteristics and dynamic range. We describe how image sensors can be used to sense color as well as capture images with high dynamic range. In certain structured environments, an image can be thresholded to produce a binary image from which various geometric properties of objects can be computed and used for recognizing and locating objects. Finally, we present the fundamentals of image processing – the development of computational tools to process a captured image to make it cleaner (denoising, deblurring, etc.) and easier for computer vision systems to analyze (linear and non-linear image filtering methods).

Course Prerequisites

Learners are required to know the fundamentals of linear algebra and the fundamentals of calculus. No prior knowledge of imaging or computer vision is assumed. The knowledge of any programming language would enable the student to understand how the methods described in the course can be implemented in software. However, the knowledge of a programming language is not required as the course does not have programming assignments.

Learning Objectives

Imaging is fundamental not only to computer vision but also a variety of other fields such as photography, computer graphics, robotics, augmented reality, virtual reality, human-computer interfaces, biometrics, gaming, remote sensing, medical imaging, scientific imaging, etc. This course is designed to achieve the following learning goals:

- Learn how a camera works and how an image is formed using a lens
- Understand how an image sensor works and its key characteristics
- Design cameras that capture high dynamic range and wide-angle images
- Learn to create binary images and use them to build a simple object recognition system
- Develop image processing techniques for enhancing the quality of an image

Course Schedule

This is a graduate-level course, with an estimated 4-6 hours of study time per week.

Grading Policy

- Quizzes count towards 100% of the grade. You will be given 2 attempts for each quiz every 8 hours.
- **A passing grade for the course is 70% or higher.**

Course Outline

Week 1: Introduction

1.1 Overview of Introduction
1.2 What is Computer Vision?
1.3 What is Vision Used For?
1.4 How Do Humans Do It?
1.5 Topics Covered
1.6 About the Lectures
1.7 References and Credits

Week 2: Image Formation

2.1 Overview of Image Formation
2.2 Pinhole and Perspective Projection
2.3 Image Formation using Lenses
2.4 Depth of Field
2.5 Lens Related Issues
2.6 Wide Angle Cameras
2.7 Animal Eyes

Week 3: Image Sensing

3.1 Overview of Image Sensing
3.2 A Brief History of Imaging
3.3 Types of Image Sensors
3.4 Resolution, Noise, Dynamic Range
3.5 Sensing Color
3.6 Camera Response and HDR Imaging
3.7 Nature's Image Sensors

Week 4: Binary Images

4.1 Overview of Binary Images
4.2 Geometric Properties
4.3 Segmenting Binary Images
4.4 Iterative Modification

Week 5: Image Processing I

5.1 Overview of Image Processing I
5.2 Pixel Processing
5.3 LSIS and Convolution
5.4 Linear Image Filters
5.5 Non-Linear Image Filters
5.6 Template Matching by Correlation

Week 6: Image Processing II

6.1 Overview of Image Processing II
6.2 Fourier Transform
6.3 Convolution Theorem
6.4 Image Filtering in Frequency Domain
6.5 Deconvolution
6.6 Sampling Theory and Aliasing

Recommend Readings

Textbooks

- Computer Vision: Algorithms and Applications, Szeliski, R,m Springer
- Computer Vision: A Modern Approach, Forsyth, D and Ponce, J., Prentice Hall
- Robot Vision, Horn, B.K.P., MIT Press
- A Guided Tour of Computer Vision, Nalwa, V., Addison-Wesley
- Digital Image Processing González, R and Woods, R., Prentice Hall
- Optics, Hecht, E., Addison-Wesley
- Eye and Brain, Gregory, R., Princeton University Press
- Animal Eyes, Land, M. and Nilsson, D., Oxford University Press

Papers