Engineering Tripos Part IB, 2P8: Information Engineering, 2025-26

Course Leader

Prof R Cipolla [1]

Lecturers

Prof R Cipolla, Prof R Turner and Prof A Abate [2]

Timing and Structure

Easter Term: Weeks 1-4 - 13 lectures + 3 examples classes, 4 lectures/week

Aims

The aims of the course are to:

- Provide a unified view of information engineering showing how signal processing, computer vision, machine learning and control relate to one another.
- Use example applications drawn from autonomous driving to provide concrete examples of important concepts and subareas of information engineering including computer vision, machine learning and reinforcement learning
- Introduce computer vision including algorithms for 3D reconstruction, registration and object recognition
- Introduce basic concepts in inference, learning and optimisation including maximum-likelihood estimation, Bayes' rule and gradient descent.
- Introduce basic algorithms for planning and the general area of sequential decision making / reinforcement learning

Objectives

As specific objectives, by the end of the course students should be able to:

- Provide example applications of machine perception, machine learning, and autonomous decision making systems.
- Understand the mathematical basis for perspective projection and feature detection; neural networks and parameter estimation; basic planning and reinforcement learning.
- Implement methods to solve simple computer vision and machine learning problems including object detection and segmentation and sequential decision making.

Content

A: Introduction to Autonomous Driving (1L) (Guest lecturer from industry - Dr Roddick from Waymo)

- The anatomy of a self-driving car (Autonomous Vehicle) with description of autonomous driving hardware (the car, sensors, interfaces and actuators)
- Motivate the need for machine perception (computer vision), learning and decision making systems
- Important sub-problems in the data processing pipeline: object detection, localisation and mapping, prediction, planning and action
- Examples of self-driving cars

B: Machine Perception: Introduction to Computer Vision (5L) (R. Cipolla)

- An introduction to computer vision: reconstruction, registration and recognition
- Perspective projection
- Convolution with gaussians and derivatives of gaussians to provide bandpass filters.
- Edge detection using directional filters.
- Scale-space and image pyramids for feature detection
- The SIFT feature descriptor for matching image features.
- Demonstration of state-of-the-art object detection, semantic segmentation and localisation systems
- Examples paper and class

C: Machine Learning: Introduction to Deep Learning (5L) (R. Turner)

- Training a simple classifier: logistic regression and gradient descent
- Neural networks: Multi-layer perceptrons and back propagation
- Neural networks: convolutional neural networks
- Anatomy and training of a convolutional neural network in Tensorflow or PyTorch - network architecture, loss function, weight initialization, batch size, learning rate, epochs.
- Examples paper and class

D: Autonomous Decision Making: Introduction to Planning and Reinforcement Learning (5L) (A Abate)

- Introduction to planning: Shortest path problems, value functions and dynamic programming
- Introduction to reinforcement learning: Q-learning, actor-critic methods, approximations using neural networks
- Identification of open problems
- Examples paper and class

Booklists

Please refer to the Booklist for Part IB Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to Form & conduct of the examinations [3].

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Links
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