Engineering Tripos Part IIB, 4F12: Computer Vision, 2022-23

Module Leader

Prof R Cipolla [1]

Lecturers

Prof R Cipolla and Dr Ignas Budvytis [2]

Timing and Structure

Michaelmas term. 16 lectures (including 3 examples classes). Assessment: 100% exam

Aims

The aims of the course are to:

- introduce the principles, models and applications of computer vision.
- cover image structure, projection, stereo vision, structure from motion and object detection and recognition.
- give case studies of industrial (robotic) applications of computer vision, including visual navigation for autonomous robots, robot hand-eye coordination and novel man-machine interfaces.

Objectives

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

- design feature detectors to detect, localise and track image features.
- model perspective image formation and calibrate single and multiple camera systems.
- recover 3D position and shape information from arbitrary viewpoints;
- appreciate the problems in finding corresponding features in different viewpoints.
- analyse visual motion to recover scene structure and viewer motion, and understand how this information can be used in navigation;
- understand how simple object recognition systems can be designed so that they are independent of lighting and camera viewpoint.
- appreciate the commerical and industrial potential of computer vision but understand its limitations.

Content

- ***Introduction*** (1L)
  Computer vision: what is it, why study it and how ? The eye and the camera, vision as an information processing task. Geometrical and statistical frameworks for vision. 3D interpretation of 2D images. Applications.

- ***Image structure*** (4L)
  Image intensities and structure: edges, corners and blobs. Edge detection, the aperture problem and corner detection. Image pyramids, blob detection with band-pass filtering. The SIFT feature descriptor for matching. Characterising textures.

- ***Projection*** (4L)
  Orthographic projection. Planar perspective projection. Vanishing points and lines. Projection matrix, homogeneous coordinates. Camera calibration, recovery of world position. Weak perspective and the affine camera. Projective invariants.

- ***Stereo vision and Structure from Motion*** (2L)
  Epipolar geometry and the essential matrix. Recovery of depth by triangulation. Uncalibrated cameras and the fundamental matrix. The correspondence problem. Structure from motion. 3D shape examples from multiple view stereo.

- ***Deep Learning for Computer Vision*** *(5L)*
  Basic architectures for deep learning in computer vision. Object detection, classification and semantic segmentation. Object recognition, feature embedding and metric learning. Transformers for computer vision and self-supervised learning.

- ***Example classes***
  Discussion of examples papers and past examination papers will be integrated with lectures.

Booklists

Please refer to the Booklist for Part IIB 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].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [4] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

IA2

Demonstrate creative and innovative ability in the synthesis of solutions and in formulating designs.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

D1

Wide knowledge and comprehensive understanding of design processes and methodologies and the ability to apply and adapt them in unfamiliar situations.

D4

Ability to generate an innovative design for products, systems, components or processes to fulfil new needs.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US2

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

US4

An awareness of developing technologies related to own specialisation.

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Links
[1] mailto:rc10001@cam.ac.uk
[2] mailto:rc10001@cam.ac.uk, ib255@cam.ac.uk
[3] http://teaching.eng.cam.ac.uk/content/form-conduct-examinations
[4] http://teaching.eng.cam.ac.uk/content/uk-spec