Engineering Tripos Part IB, 2P8: Information Engineering, 2017-18

Lecturers

Professor R Cipolla and Dr J Lasenby [1]

Timing and Structure

Easter Term: Weeks 1-4 - 14 lectures + 2 examples classes, 4 lectures/week

Aims

The aims of the course are to:

- To teach students about image processing within the context of photo editing software and image search engines (such as Image Google).

Content

There will be quite as strong emphasis on statistical techniques (histograms) and spatial domain filtering methods which will follow on naturally from the material in paper 6 and 7.

A: Photo Editing - Lectures 1-5 (J. Lasenby)

Part A of the course will discuss basic digital image handling techniques and will cover the following topics:

- Cropping, resizing, rotation and morphing - involving basic ideas of interpolation and filtering for shifting/resampling purposes.
- Colour - conversion between different colour spaces (e.g. RGB, YUV and HSV) and adjustment for colour lighting effects such as colour-cast correction and white balancing.
- Histograms - their use in analysis and correction of lighting intensity problems, such as over/under exposure and shadows.
- Segmentation - for purposes such as red-eye correction and independent contrast correction in areas of shadows, mid-tones and highlights.
- Correcting focus problems - sharpening (debluring) filters and problems of noise amplification.
- Correcting noise problems - smoothing filters, problems of blurring, and the use of spatially adaptive filters to optimise sharpening and denoising tradeoffs.
- These will be illustrated with the development of Matlab solutions to a range of common photo editing functions such as found in widely used packages like Adobe Photoshop and Microsoft Digital Image Suite.

NB: All filters will be based on separable 1D Gaussian lowpass filters, with combinations of these to produce bandpass and highpass filters. These can be analysed in the spatial domain, so the 2D Fourier and Z transforms will not be taught.

B: Image Features and Matching - Lecturers 6-10 (R. Cipolla)

Part B will include material on feature and texture descriptors and efficient shift-invariant and rotation-invariant matching techniques using these descriptors. It will cover the following topics:

- Convolution with gaussians and derivatives of gaussians to provide directional bandpass filters.

- Edge detection using directional filters.
- Interest point detection using edge measurement and image autocorrelation measurement.
- Texture descriptors, based on filters or on principle components analysis (PCA) of images
- The SIFT feature descriptor for matching image features
- A case study of a real-time industrial system to match a photograph from a mobile phone to images in a database, and applications of such systems

C: Image Searching and Modelling Using Machine Learning - Lecturers 11-14 (R. Cipolla and M. Johnson)

Part C of the course will focus on the application of modern pattern recognition and statistical machine learning methods applied to image retrieval and related problems. Although all examples will focus on applications to images, the ideas are generally applicable to other domains. We will cover the following topics:

- Representing images as feature vectors
- Image classification using nearest neighbours
- Introduction to Deep Learning: Neural Networks and Convolutional Neural Networks (CNN)
- Network architectures (number of layers, non-linear elements, pooling) and estimation of parameters (training under supervised learning) using back-propagation and stochastic gradient descent.
- A case study of a state-of-the-art image classification and retrieval system.

Booklists

Please see the Booklist for Part IB Courses [2] for references for this module.

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.

IA3

Comprehend the broad picture and thus work with an appropriate level of detail.

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.

D2

Understand customer and user needs and the importance of considerations such as aesthetics.

D3

Identify and manage cost drivers.

S1

The ability to make general evaluations of commercial risks through some understanding of the basis of such risks.

S3

Understanding of the requirement for engineering activities to promote sustainable development.

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).

P5

Awareness of nature of intellectual property and contractual issues.

US1

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

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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