Theory of Image Processing (P00809)

Schedule N, Level 11 **10 credit points**
Semester 1: Tuesday and Friday 12.10am, Crew Building 301

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Synopsis

A theory based course on Image Processing techniques concentrating on the mathematical and physical models underlying the processing operations. Digital image representation and sampling aspects are followed by various processing techniques including point by point operations, noise models, filtering and de-convolution techniques, tomographic imaging, edge and line detection, stereo imaging, target tracking and elementary pattern recognition. The course also includes a short theory based assignment.

Syllabus

1. **Introduction:** Use and scope of digital image analysis.
2. **Imaging Systems:** Image formation in optical systems relevant to digital image analysis.
3. **Digital Images, DFT and Sampling Theory:** Digital representation of images, discrete Fourier transforms, properties, symmetries and implementation of DFT, sampling theory and interpolation of digital signals].
4. **Point Processing:** Point-by-point processing, image statistics, histograms, histogram equalisation, Look-up-table implementation.
5. **Noise Models:** Fixed pattern noise, shot noise, Gaussian noise models, signal to noise ratio, quantisation noise.
6. **Convolution Filtering:** Linear filtering in real and Fourier space, shrink & expand filters, threshold filter and median filter.
7. **Image Restoration:** Inverse filter, Wiener filter, CLEAN, Maximum Entropy and other iterative techniques.
8. **Tomography:** Geometry of tomography systems, reconstruction by Fourier Inversion, Back-projection (outlined), fan-beam system (outline).
9. **Edge and Line Detection:** First and second order differential edge detection, Hough Transform for line detection, application of Hough Transform.
10. **Stereo Imaging:** Parallel aligned stereo imaging, converging stereo imaging, automated depth extraction (outline).
11. **Target Tracking & Pattern Recognition:** Target tracking by correlation, basic of statistical pattern recognition, examples of simple classifiers.
12. **Project Assignment:** A theory based assignment starting in Week 6.

Learning Objectives

On completion of this course a student should be able to demonstrate understanding of and be able to solve problems on:

- linear image formation and its underlying assumptions,
- digital representation of image, the discrete Fourier Transform, its properties and implementation, Shannon sampling theorem, interpolation to zeroth and first order,
- first order image statistics, point-by-point processing and histogram manipulation,
- fixed pattern noise and random noise including underlying physics of Gaussian additive noise and methods of it estimation,
- linear filtering in real and Fourier space, non-linear filters including shrink and expand, average threshold and median,
- image restoration by inverse and Weiner filter, outline of CLEAN and maximum entropy restoration,
- tomographic system and reconstruction by Fourier inversion and filtered back projection, outline of fan-beam system.
- edge and line detection by first and second order differential edge detection, Hough Transform and its applications,
- stereo imaging in parallel and converging geometry, outline of automated depth extraction techniques,
- tracking by correlation, basic of statistical pattern recognition, examples of simple classifiers.

Format of the Course

- 16 Lectures on the physical and mathematical basis of Image Processing, first 12 in common with DIGITAL IMAGE ANALYSIS.
- Theory based assignment handed out in week 6, contribute 20% to assessment.
- 4 problem solving workshop (in common with DIA)
- 1 Revision workshop (outwith timetabled hours)

Handouts and Overheads

A copy of the course notes and workshop questions for the relevant sections will be distributed in reduced, A5, format during the lectures. Spare copies of these will be deposited in the School of Physics *Teaching Office*, and will *not* be available at subsequent lectures.

This course has a accompanying WEB site located at

which is fully externally viewable. This will contain

1. course notes, available *after* the relevant lecture.
2. solution to all workshop questions, available *after* the relevant workshop.
3. other relevant material such as outlines of the demonstrations, revision suggestions and external links.

The short booklet *The Fourier Transform, (What you need to know)* will be supplied. This booklet contains, mainly, revision material on the Fourier Transform which is *essential* to the understanding of this course. This material is also available on-line from the above WEB site.

Classification of Workshop Questions

The accompanying *workshop questions* are classified as,

1. No mark, straight forward questions covering the core material of the course. You are expected to attempt all such questions.
2. Questions covering the main core material where the solutions involve either long, or complex mathematical manipulation. You are expected to attempt all such questions, but you may need to look at the solution for the mathematical details.

3. Questions that require you to look up material that is not explicitly covered in the lecture material. These questions normally involve *interesting extensions*, and will frequently be the basis for discussions in the workshops.

4. Questions that require numerical programming either using the supplied JAVA classes, or R-PROJECT. These questions are designed to illustrate the course material. The solutions will typically contain the expected output with some full working JAVA, or R-PROJECT codes via the Website.

5. Difficult (or challenge) questions that either contain extra material or, more often, are tricky examples of the standard course materials. These question are also often mathematically difficult. Some of these will be discussed in the workshops *if time allows*. The quality of the solutions will depend of whether I can solve them!

Simulation and Demonstration Software

There is, an increasing, set of computer demonstrations on the CP Laboratory machines and meteorology, associated with this courses. These will be highlighted during lectures.

There is also a WEB based image processing tutorial reference available from the School of Informatics which you are encouraged to try. There is a link from the DIA/ToIP home page.

Text Books

The most suitable text at this level is:

- RC Gonzalez & RE Woods, *Digital Image Processing*, Addison-Welsey (2003) approx £45.00

Assessment

This course is assessed by:

1. 2 hour written examination in the **December** examination diet (80%).

   The examination format will be:

   (a) Section A: five short compulsory questions, 5 marks each.

   (b) Section B: one long question from a choice of two, 25 marks.

2. Theory based assignment starting in week 6 of Semester 1, submission at end of week 11, Semester 1. (20%)