

# Engineering Tripos Part IIA, 3G4: Medical Imaging & 3D Computer Graphics, 2021-22

## Module Leader

[Dr Andrew Gee](#) [1]

## Lecturers

Dr Andrew Gee & Dr Graham Treece

## Lab Leader

Dr Graham Treece

## Timing and Structure

Lent term. 16 lectures.

## Aims

The aims of the course are to:

- Introduce state-of-the-art techniques for the acquisition, representation and visualisation of structured 3D data.

## Objectives

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

- Explain the principles of operation of CT, nuclear medicine and diagnostic ultrasound and magnetic resonance imaging.
- Be aware of the advantages and risks associated with these techniques and understand the types of diagnostic problems that each can address.
- Be aware of other types of data to which segmentation and visualisation algorithms can be applied (eg. CAD models).
- Understand the different ways to represent 3D data and appreciate the advantages and disadvantages of each technique.
- Know how to extract surfaces from volumetric data.
- Be aware of the range of computer graphics algorithms and hardware used to visualise 3D data.
- Understand how surfaces can be rendered using suitable illumination and reflection models.
- Know how to visualise voxel arrays directly using volume rendering techniques.

## Content

The main application area considered in the module is diagnostic medical imaging: 3D data is acquired using one of the clinical imaging modalities (e.g. CT), represented as a voxel array or segmented into surfaces, then visualised using computer graphics techniques. While medical imaging is the focus of the course, many of the techniques used to segment, represent and visualise the 3D data sets are generic and can equally be applied to

other types of data, such as CAD models.

### **Medical Image Acquisition (5L, Dr Andrew Gee)**

- X-rays and the Radon transform
- Tomographic reconstruction algorithms in both the spatial and frequency domains
- Emission computed tomography
- SPECT and PET
- Iterative reconstruction algorithms
- 2D and 3D ultrasound
- Introduction to Magnetic Resonance Imaging

### **Extracting information from 3D data (6L, Dr Graham Treece)**

#### **Polygonal representations and efficient storage**

- Parametric curves and surfaces
- Subdivision and display of parametric surfaces

#### **Surfaces from sampled data**

- Thresholding, morphological operators and contours
- Surface extraction - marching cubes

#### **Interpolating sampled data**

- Interpolation of isotropic data
- Distance transforms and interpolation of non-isotropic data
- Unstructured data - RBFs and Delaunay triangulation

#### **Direct surface capture**

- Laser stripe scanners
- Space encoding: the cubicscope

### **3D Graphical Rendering (5L, Dr Andrew Gee)**

- Viewing systems: viewpoints and projection
- Reflection and illumination models: the Phong reflection model
- Surface rendering: incremental shading techniques, hidden surface removal using Z-buffers
- Shadows and textures
- Ray tracing
- Volume rendering
- Computer graphics hardware

### **Coursework**

A computer-based laboratory exploring the visualization and analysis of CT data. Students write algorithms to generate slices through the 3D data set, observing the differences between linear and nearest-neighbour interpolation. They go on to fit surfaces to the data, writing algorithms to calculate the volumes enclosed by the surfaces. Finally, they use OpenGL to visualize the surfaces from different viewpoints and under different lighting conditions, including a "fly-through" visualization mode.

#### Learning objectives:

- To appreciate the 3D nature of the data acquired by many medical imaging devices.
- To investigate how such data can be stored and resliced in a C++ software framework.
- To consider techniques for extracting surfaces from such data.

- To understand how surfaces can be represented by triangular meshes and stored in suitable C++ data structures.
- To analyse properties of such surfaces using basic computational geometry algorithms.
- To experiment with graphical rendering in an OpenGL framework.

### Practical information:

- Sessions will take place in the DPO, during weeks 1-8.
- This activity involves preliminary work (reading the handout, around one hour).

### Full Technical Report:

Students will have the option to submit a Full Technical Report.

## Booklists

Please refer to the Booklist for Part IIA 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](#) [2].

## UK-SPEC

The [UK Standard for Professional Engineering Competence \(UK-SPEC\)](#) [3] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the '[Accreditation of Higher Education Programmes](#)' (AHEP) document [4] which sets out the standard for degree accreditation.

The [Output Standards Matrices](#) [5] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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### Links

[1] <mailto:ahg13@cam.ac.uk>

[2] <http://teaching.eng.cam.ac.uk/content/form-conduct-examinations>

[3] <http://www.engc.org.uk/ukspec.aspx>

[4] <http://www.engc.org.uk/standards-guidance/standards/accreditation-of-higher-education-programmes-ahep/>

[5] <http://teaching.eng.cam.ac.uk/content/output-standards-matrices>