Engineering Tripos Part IIA Project, GG2: CT Reconstruction and Visualisation, 2019-20

Leader

[Dr G M Treece](#) [1]

Timing and Structure

Thursdays 9-11am plus afternoons and Mondays 11-1pm

Prerequisites

3G4 useful but not required, some experience of 3F modules recommended.

Aims

The aims of the course are to:

- introduce you to CT scanning and reconstruction, by the development of a CT simulator.
- understand how CT data can be visualised, and become familiar with what is required to do this.
- demonstrate how CT can be used in a variety of real life scenarios.
- by giving you a working knowledge of the entire process, see how physics, maths, computer graphics, etc all interact to generate a useful result.

Content

The aim of this project is to follow the whole process of 3D medical imaging using X-ray Computed Tomography (CT), starting with a scan of a real object, right through to the creation of a new object from the scan. It covers the physics of X-ray material interaction, the design of CT scanners, the maths behind CT reconstruction, the use of computer graphics in CT visualisation, and creation of physical models from CT data using 3D printing.

The first half of the project will introduce you to CT scanning and reconstruction by the development and testing of a simple CT simulator. This will start with an image defining the location and type of various materials, then 'scan' this with a typical CT geometry, and a set of X-ray source and material parameters, and finally reconstruct the data from the scanned measurements using the common technique of filtered back projection. The emphasis is on learning what is involved, and experimenting with the various options (for instance resolution, interpolation techniques, etc), rather than on writing lots of software: most of the components will be supplied.

The second half of the project will concern a variety of 'real life' scenarios. At this point a real object will be scanned, and there may be an opportunity to actually see this happening. Each group will then be tasked with making the best use of the CT data for a scenario of their choice: for instance radiotherapy planning for cancer treatment, or design and assistance with an artificial limb replacement. Each scenario will involve some element of reconstruction (only the raw measurement data from the CT machine will be provided), visualisation (using any of a number of techniques), and model-building from the data (using a 3D printer). Again, the focus is on the investigation rather than writing software. The reconstruction will be an extension of output from earlier in the project, whereas the visualisation and modelling will make use of the many free programs available for this task: selecting and learning the appropriate programs and techniques is a part of the project.

The project will finish with a brief presentation so that each group can show how they have addressed their task to the other students.

FORMAT

You will work in groups of three. In the first part of the project, the groups will be expected to work together on the CT simulator so everyone can acquire the necessary background knowledge. As the project develops each student will take on one part of the collective tasks but will be expected to work in collaboration and present the results as a group. The CT simulation work will be based around some provided functions, which are available both in Matlab and also in Python: you can choose which language you prefer to work in.

Week 1:

Introductory work on X-ray generation, scattering and detection, and CT geometry and scanning. Development of a CT simulator and experiments using this simulator.

Week 2:

CT reconstruction using filtered back-projection and completion of basic CT simulator. Extensions to simulator to include CT noise, beam hardening correction and Hounsfield Units, with associated experiments, leading to interim report.

Week 3:

Real CT scan, provision of raw data, and start of task-based work.

Week 4:

Continue task-based work, presentation of results and final report.

Coursework

Coursework	Due date	Marks
Basic simulator: submitted code and brief results	Middle of week 2	10 (Group)
Interim report (3 sides, + 3 for appendices)	End of week 2	20 (Individual)
Presentation	During last lesson	10 (

		Group)
Final report (8 sides + 2 for appendices)	At end of project	40 (Individual)

Examination Guidelines

Please refer to [Form & conduct of the examinations](#) [2].

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Links
[1] mailto:gmt11@cam.ac.uk
[2] https://teaching24-25.eng.cam.ac.uk/content/form-conduct-examinations