Engineering Tripos Part IIA Project, GF4: Structure from Motion, 2025-26

Leader

Dr A Tewari [1]

Timing and Structure

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

Objectives

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

- To understand the principles of Structure from Motion, one of the most important computer vision algorithm, through hands-on implementation.
- To develop intuition for key steps such as feature matching, triangulation, and camera pose estimation.
- To explore dense 3D reconstruction and visualisation using open-source tools.
- To gain insight into the challenges and applications of 3D reconstruction from images.
- To see how geometry, optimisation, vision, and graphics combine to form a working 3D pipeline.

Content

The aim of this project is to follow the full pipeline of 3D reconstruction from images using the technique of Structure from Motion (SfM). Students will begin with a sequence of photographs or video frames of a real object or scene and proceed all the way through to a textured 3D model. Along the way, they will learn about multi-view geometry, feature extraction and matching, camera calibration, bundle adjustment, dense reconstruction, and 3D visualisation. The project links concepts in computer vision, geometry, and graphics with hands-on experimentation and investigation.

The first half of the project introduces students to the mathematical and algorithmic foundations of SfM by building a simplified SfM pipeline. They will begin with a set of 2D images, extract visual features, estimate relative camera poses, and triangulate 3D points to obtain a sparse point cloud. I will provide modular Python functions for many components (e.g. feature detection, essential matrix estimation) to allow students to focus on understanding and experimentation, not just software implementation.

The second half of the project turns to a real-world dataset. Students will receive a sequence of photographs taken around a complex object or small scene. Each group will choose a task involving dense reconstruction and rendering: for example, reconstructing a building façade, an archaeological artefact, or a mechanical part. Students will explore open-source tools like COLMAP to achieve a complete reconstruction. They will identify the cases where SfM works well, and where it does not.

The project culminates in a short presentation and a report, showcasing the pipeline, reconstruction quality, and any creative solutions to problems encountered along the way.

Week 1:

- Introduction to epipolar geometry, camera models, and SfM pipeline.

- Experiments with feature detection (SIFT, ORB), matching, and fundamental matrix estimation.
- Pose estimation and triangulation to obtain sparse reconstructions.

Week 2:

- Bundle adjustment and error analysis.
- Extensions to include camera calibration, RANSAC, and scale ambiguity resolution.
- Submit minimal pipeline and preliminary results (interim report).

Week 3:

- Receive real dataset. Begin full SfM reconstruction using external tools.
- Prepare intermediate dense point clouds or meshes.

Week 4:

- Complete model creation and visualisation.
- Prepare and deliver final presentation and report.

Coursework

Coursework	Due Date	Marks
Interim Report	End of Week 2	25 (individual)
Minimal SfM Pipeline	Mid-week 2	10 (group)
Final Report	Friday of 4th Week	45 (50% individual, 50% group)

Examination Guidelines

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

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Links
[1] mailto:at2164@cam.ac.uk
[2] https://teaching.eng.cam.ac.uk/content/form-conduct-examinations