

Computer Science Project Proposal

Constructing 3D models from image sequences

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Introduction and Description of the Work

The aim of this project is to extract a partial 3D model of a small object from a sequence of plain images and then to export the model into a 3D geometry format such as PLY. The resulting file can then be rendered and processed by MeshLab or similar mesh processing software.

The main focus of the project is to obtain a partial wireframe model from a sequence of images taken from pre-established locations with respect to the object. An open-source ray tracer will be used in order to set up a static scene consisting of the object to be reconstructed placed in a well-lit environment against a white background. The sequence of images to be inputted into the 3D model constructor will be acquired by taking digital snapshots of this scene from the pre-established locations, thus imitating the process of photographing the object with a pre-calibrated camera. The project is designed to be later extended to support real camera input.

What follows is a description of a technique which might be used in order to obtain the image sequences. The setup is described here in terms of photographing real objects in order to emphasize the fact that the project can naturally be extended to interact with a real camera. However, for the purposes of this project, this technique will be imitated by digitally constructing the equivalent snapshots of an existing 3D model in an attempt to reconstruct its shape:

Define an origin on a perfectly horizontal table and place the camera there facing a white background. Place an object of a pre-determined maximum height at a fixed distance from the origin in front of the camera. Take the first picture. Rotate the object by 30 degrees counter clockwise and take the second picture. Repeat until 12 pictures are taken. Input the pictures in the order in which they were taken. This process is assumed to have taken place in well-lit environment with no major light differences between pictures in the same set.

The outcome of any 3D model constructor used on this input is considered to be a partial solution because the input provides no information about the shape of the object as seen from above and below.

Starting Point

I am planning to use an open-source ray tracer such as POV-Ray in order to create image sequences from an existing 3D model in an attempt to recreate its shape. I will also be using the feature detection and feature matching functionalities of OpenCV.

Resources Required

Some open source libraries will be used as described in the previous section. They can be downloaded freely from <http://www.povray.org/> and <http://opencv.org/> respectively.

MeshLab will be used in order to view the resulting 3D model. It can be downloaded from <http://meshlab.sourceforge.net/>.

No special hardware resources will be required unless the extension to provide support for camera interaction is undertaken. The project is aimed at home users so the digital camera to be used should have no specific requirements. To ensure this I will be using my own cameras.

I am also planning to use my own machine, doing regular backups to github and to PWF. I can resume the development on any of the machines in the Computer Lab should my machine suddenly fail.

Substance and Structure of the Project

To ensure the successful completion of the project, the workload has been divided into the following manageable chunks:

1. **Research:** get familiarized with epipolar geometry and with the algorithms mentioned in this section.
2. **Module design:** split the project into modules, establish how they interact, construct the corresponding UML diagrams.
3. **Test harness:** implement the test harness using POV-Ray. Given a 3D model, the test harness will generate the image sequences to be inputted into the partial 3D model constructor by taking snapshots of the rendered model from each of the pre-established locations in turn. This module will be used in order to evaluate the success of the project by adding a measured error to the snapshots and measuring the accuracy of the outputted 3D model. Error can be added by rendering the object at a distance ϵ from the specified location, or by adding blur etc.
4. **First prototype:** implement triangularization in order to get the first prototype of a partial 3D constructor.
5. **Refinement of the partial 3D constructor:**

The project consists of the following main sections:

- write digital renderer to provide calibrated input for the modules to follow - this module will be later used to evaluate the results by adding a measured error to the inputs and comparing the outputs
- computing the geometric relation between neighbouring images
- compute a dense set of correspondences between neighbouring images stereo rectification, stereo matching, dense depth map
- reconstructing the 3D object shape (a wireframe) overlying a 2D triangular mesh on top of one of the images to build corresponding 3D mesh by wrapping vertices of the triangles in 3D space by using depth maps OR volumetric depth map integration, Kalman filters

For the extensions:

- add a calibration module in order to support for real camera input (as opposed to digital snapshots generated by the renderer).

Success Criteria

The following must necessarily be achieved for the project to be considered a success:

- A tool for constructing 3D models from a sequence of digital snapshots produced as described in the introduction has been implemented. The tool will be evaluated and shown to be working by applying it on a input consisting of consistent snapshots of a cube.

Possible Extensions

- Add a camera module in order to provide support for real camera input (instead of using digital snapshots generated using a ray tracer).
- Add shadowing to the outputted 3D mesh.
- Add texture to the outputted 3D mesh.
- Implement structure-from-motion and self-calibration: this would allow the users to input virtually any set of pictures representing an object as long as any consecutive pictures have a large overlap (i.e.: no need to pre-establish the camera pose for each photo in the sequence).

Timetable

Planned starting date is 09/10/2014.

1. **Slot 0: 9th Oct - 24th Oct**

- Read relevant literature and plan the project.

Milestone: Submit proposal

2. **Slot 1: 25th Oct - 14th Nov**

- Further research: gain a deeper understanding of the techniques involved in edge detection and 3D modelling

Milestone: Have a clear understanding of the techniques needed to complete the project

3. **Slot 2: 15th Nov - 28th Nov**

- Start implementation: implement the digital renderer
- Use the renderer to design a few basic unit tests for the edge detector, dense set generator and wireframe generator.

Milestone: finish implementing the digital renderer and the test harness

4. **Slot 3: 28th Nov - 5th Dec**

- Implement the wireframe generator. This should be implemented first because it is the riskiest module of the project.

Milestone: Pass the unit tests for the wireframe generator

5. **Slot 4: 6th Dec - 26th Dec**

- Implement dense set generator

Milestone: Pass the unit tests for the dense set generation module

6. **Slot 5: 27th Dec - 16th Jan**

- Implement the edge-detector

Milestone: Finish implementation, Pass the unit tests for the edge-detection module

7. **Slot 6: 17th Jan - 30th Jan**

- Buffer time: catch up or start doing the extensions
- Write progress report

Milestone: Submit progress report

8. Slot 7: 31st Jan - 13th Feb

- Further tests

Milestone: Finish writing integration tests and more in-depth unit tests

9. Slot 8: 13st Feb - 27th Feb

- Debug

Milestone: Pass all of the tests

10. Slot 9: 27st Feb - 13th Mar

- Catch-up time or extensions

Milestone: Pass all of the tests

11. Slot 10: 14th Mar - 3rd Apr

- Analysis

Milestone: Finish doing the evaluation graphs

12. Slot 11: 4th Apr - 17th Apr

- Plan and start writing the dissertation

Milestone: Write the main parts of the dissertation

13. Slot 12: 18th Apr - 8th May

- Write the dissertation

Milestone: Finish writing dissertation

14. Slot 13: 9th May - 15th May

- Safety slot

Milestone: Submit dissertation