Features: Interest Points, Descriptors and Structure from Motion

As seen in the lectures, it is possible to obtain the 3D structure of objects and the camera pose in 3D space given a collection of images. This project includes image acquisition, feature extraction and matching and 3D point cloud generation.

1 Basic - Interest Points

Detection of interest points is an important in many computer vision applications. In particular for Structure from Motion. Interest points are points in an image that are salient and identify the object(s) depicted in the image. In SfM, keypoint or interest point detection is the first step towards 3D reconstruction.

Perform the following tasks:

1. Implement an Harris interest-point detector for the detector of salient points.
2. Test your detector on 'corners.jpg' and evaluate the influence of window size and the sensitivity parameter k.
3. Now that you can find interest points, we need to calculate a descriptor, so that we can try to track the point in a new frame with a (slightly) different viewpoint of the same scene. So, build an IP descriptor. (Hint: For example, you can build a simple histogram of gradients in the neighborhood of the IP.)
4. Acquire some real world images with slight differences in viewpoint (for example of your desk).
5. Implement an IP matcher that finds the best match for an IP to an IP in a new frame, based on your descriptor. For example, find the descriptor with the smallest Euclidean distance.
6. Repeat this exercise using a different descriptor (SIFT or SURF). Report on the differences.

2 Advanced - Structure from Motion

The previous exercises deal with the fundamental tasks required for SfM. In this advanced version you will implement a full Structure from Motion pipeline using Matlab's computer vision toolbox.

Perform the following tasks:

1. Using the available drone, acquire a short video of an area within university grounds. Make sure that feature rich and relevant objects are present in your video (avoid flat areas or greatly textured objects like trees). Additionally, acquire some images of a (printed) checkerboard pattern and generate the calibration object using Matlab's camera calibration app.
2. Select a pair of images with a relatively small viewpoint variation and extract features for each image. Find correspondences between both images (Hint: check the 'matchFeatures' function).
3. Estimate the essential matrix using the matching points and then compute the camera pose.
4. Once you have the essential matrix you can estimate the extrinsic parameters of the camera. Use these parameters and triangulate the location of the 3D points. (Hint: use matlab's traingulate function).
5. Finally, repeat this using frames with larger viewpoint differences. What do you observe? What do you conclude about your results? How could they be improved.
6. Optional: As an optional task you may use your entire sequence (or a fraction of it if it is too long) together with PMVS and compare it against your previous results.

3 Evaluation

For this project you must write a short report (6 pages single column maximum) preferably in LaTeX or in other word processing software such as Microsoft Word addressing at least the following points:

3.1 Basic

- How did you implement each step?
- Describe your findings on the Harris parameters. Which settings did you use for the matching?
- Comment on your interest point descriptor. What did you observe during matching? How could it be improved?
- Provide the source code. This can be delivered electronically.

3.2 Advanced

- Why is it necessary to calibrate the camera before reconstruction?
- Comment on the results of the SfM pipeline using just two images. Are they what you expected? Argument your answer. What happens when the viewpoint difference increases?
- Provide the source code (This can be delivered electronically to r.imbriaco@tue.nl).

Additionally, a brief demonstration of your code is necessary for evaluation. During this demonstration you will run your code live while showing some intermediate results and explaining them.