School of Computer Science, University of Bristol

COMS30087: Image Processing and Computer Vision, AY: 2024/25

Assignment Part 2: 3-D from Stereo

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This part of the assignment assumes that you have completed the two Stereo Lab Sheets. The assignment involves determining corresponding spheres in two views of a scene consisting of spheres on a plane and using the correspondences to reconstruct the spheres and their centre points. You are required to submit your code and a report that describes and explains the tasks completed, your experiments and the results obtained. Both the code and the report are required to obtain marks.

Important: There are a number of ways in which the assignment can be tackled. However, **you must use the methods described in the lectures**. If you use alternative methods, then **zero marks** will be given.

1. Download and run the assignment version of the 3-D simulator used in lab sessions. Refer to Lab Sheet I for details.
2. You should see 6 spheres of different sizes located on a plane. You will find two images in your current directory corresponding to the images captured by two virtual cameras (VCs). Each time you run the code you will see a different arrangement of the spheres and images captured from different viewpoints. You can change the number, separation and size of the spheres and show the sphere centres via command line arguments. Experiment with the different parameters to see the impact on the VC images.
3. Use the openCV function cv2.HoughCircles() to detect circles in each VC image. Check and document the results, noting any dependencies on any parameter settings.
4. Select one of the VCs as the reference view and for each detected circle centre in its image, compute the corresponding epipolar line for the other image. Draw the line and check that it is correct.
5. Use the epipolar line for each detected circle centre in the reference view to find the corresponding circle in the other view.
6. For each circle correspondence, compute the 3-D location of the associated sphere centre using the 3-D reconstruction algorithm described in the lectures.
7. Display the estimated sphere centres alongside the ground-truth centres in the visualisation. Compute the errors in the sphere centre estimates. Note: think carefully about how you should compute the errors.
8. Using the circle detections in the reference and viewing images, estimate the radius of each sphere.

9. Display the estimated spheres alongside the ground truth spheres and compute the error in the radius estimates. Think carefully about how you display the estimated and ground truth spheres so as to allow comparison, since comparison may be difficult if you display the estimates as solid spheres.

10. Evaluate the performance of your implementation using different sphere sizes and separations. Note when it does work and when it fails, and find out why in the latter case.

11. Investigate what happens if you use noisy relative pose between the cameras (position and orientation), rather than the ground-truth.

Submission

1. **Code** that is clearly commented, explaining the key components and the functionality, with clear reference to relevant parts of your report. Note: the code will be tested and so please make sure that any required inputs and outputs are clearly explained at the top of the code.

2. **Report**, that describes, explains, discusses and analyses the tasks completed and the results obtained, including example visualisations and showing quantitive and qualitative results of the estimation and any failure cases. The report should have the following sections:

   (a) **Introduction** Provide a brief overview of the assignment, the tasks involved and what you discovered. (*0.5 pages*)

   (b) **Method** Describe and explain the theory you used for each task. You should aim to be concise, precise and complete, including equations and diagrams where relevant. You need only concentrate on those elements that are directly related to stereo. For example, you do need to explain epipolar lines and how you implemented task **??**, but you do not need to explain how the Hough circle detector works, only what it provides and how the parameters impact on its performance. (*2 pages*)

   (c) **Experiments and Results** Describe and explain your experiments, including the motivation for the methods used. Describe and discuss the results that you obtained, and whether they are as you expected or otherwise. Pay particular attention to any failure cases and aim to explain why they have occurred. Again, you should be aiming for conciseness, precision and completeness. (*2 or 3 pages*)

   (d) **Conclusion** - Conclude with a brief discussion of what you have discovered and the overall performance and provide any thoughts you have about how your implementation might be improved. (*0.5 pages*)

   You can use the equations and figures from the lecture slides in your report if you wish, but you must include clear descriptions and explanations alongside to demonstrate that you understand them. The page lengths given are a guide. They assume that you make good use of each page, using appropriate sizes for fonts, figures and images. You may need slightly more or less, depending on your implementation, which is fine.

Marking Scheme

This part is worth 50% of the CW mark for the unit. Marks will be awarded based on the code and report **in combination**. Marks will be allocated according to the parts given below. To gain full marks for each part, you need to have completed all of the tasks relevant to the part, provided code that works, and given descriptions of the method, experiments and results in the report that provides strong evidence that you have fully understood the tasks and results.

1. Epipolar lines (tasks **??**) - 10%
2. Sphere correspondence (task **??**) - 10%
3. Centre reconstruction (tasks **??** and **??**) - 10%
4. Sphere reconstruction (tasks **??** and **??**) - 10%
5. Failure modes and noise analysis (tasks **??** and **??**) - 10%