Computer Vision

All documents are allowed. The different sections below are independent. Answers should be explained and should be concise.

1 Part I

1.1 Epipolar geometry (3 points)

Consider a camera that acquires two images – between the two image acquisitions the camera moves by a pure translation, i.e. the camera's orientation/rotation does not change during the motion. Let K be the camera's calibration matrix; it does not change either during the motion.

Hint: as often done during the lecture, one may simplify equations by choosing an appropriate coordinate system.

(a) Which is the general form of the essential matrix between two images, for the type of camera motion described above? Give the mathematical expression and describe the characteristics of it (which special type of matrix one obtains).

(b) Suppose we have to estimate the essential matrix in the considered case of a camera motion, from point matches. How does the knowledge that the camera motion is of the type described above, help in this estimation?

1.2 Point matching for 3 Images (4 points)

During the lecture, two key concepts for matching **pairs** of images have been explained: use of a geometric constraint given by the epipolar geometry and comparison of image windows in order to detect matching points (by computing e.g. a correlation score).

One of the problems when using only 2 images for matching is the possibility of obtaining a wrong solution: for a point in the first image, there may exist several points on the epipolar line in the second image which look similar to it.

This problem may be avoided by using more than 2 images. Here, we consider the case of 3 images. We suppose to know the epipolar geometry for each of the 3 pairs of images that may be formed. The goal is to find, for a point $\mathbf{q_1}$ in the first image, the matching points $\mathbf{q_2}$ and $\mathbf{q_3}$ in the other two images.

Sketch a method for doing this. The method should benefit from the fact that 3 images are used, in order to avoid the above mentioned problem existing for the 2-image case.

Hint: It is not required to develop formulas; it is enough to describe the method using words, and if applicable, to refer to the course notes for details which they already contain.

1.3 Pose estimation (3 points)

Consider a special case of pose estimation: suppose we know the camera's calibration matrix K, a set of 3D points $\mathbf{Q}_i$ and their projections $\mathbf{q}_i$ in the camera image. We also suppose to know the orientation of the camera relative to these 3D points, i.e. its matrix R.

The goal of this question is to compute the position $\mathbf{t}$ of the camera.

(a) Develop a method for computing $\mathbf{t}$.
Hint: show how to obtain linear equations in $\mathbf{t}$ from the usual projection equation: $\mathbf{q}_i \sim \mathsf{K}\mathsf{R}\left(\mathsf{I}_{3\times 3}| - \mathbf{t}\right)\mathbf{Q}_i$.

(b) How many points are needed to compute $\mathbf{t}$ (i.e. how many couples of 3D points and corresponding image points)?

2 Part II

2.1 3D Modeling (3 points)

- What shape approximation can we obtain using image silhouettes and given the camera calibration ?
- What is photoconsistency and how can we use it when building models from images ?
- What is a time consistent model and what is the benefit with respect to (time-)inconsistent models ?

2.2 Kinect (4 points)

The Microsoft kinect device allows to perceive human motion and enables therefore body interactions in virtual reality applications such as games.

- How is human motion represented with the kinect ?
- What image based feature is used and how is it extracted ?
- Which strategy, generative or discriminative, is used to determine motion ? why ?
- What are the limitations of the approach ?

2.3 Projective Geometry (3 points)

- Can two lines be parallel in a purely projective space ?
- Show that the intersection of two lines is preserved under projective transformations.
- Can we represent the transformation between a square and a general (non self-intersecting) quadrilateral with a homography of P^2 ?