Module: **M6. 3D Vision** **Final exam**
Date: May 4, 2017
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- Books, lecture notes, calculators, phones, etc. are not allowed.
- All sheets of paper should have your name.
- Answer each problem in a separate sheet of paper.
- All results should be demonstrated or justified.

Problem 1 *1.25 Points*

(a) *(0.5 points)* What is the general form of a matrix that represents a similarity transformation in the 2D projective space? How many degrees of freedom does it have?

(b) *(0.5 points)* Show how a similarity transformation acts on conics.

(c) *(0.25 points)* Which are the geometric invariants for a similarity transformation?

Problem 2 *0.75 Points*

Consider an image representing a plane in the 3D world. Assume that the image has been affinely rectified so that the line at infinity in the image is given by $\ell_\infty = (0, 0, 1)$. Explain the method of metric rectification via orthogonal lines.

Problem 3 *0.25 Points*

Consider the problem of computing (with the DLT algorithm, for instance) a 2D homography H between two image views of a plane objet. Let $\mathbf{x}_i \in \mathbb{P}^2$ and $\mathbf{x}'_i \in \mathbb{P}^2$, $i = 1, \ldots, n$, be a set of points on the first image and the second image, respectively, such as, in pairs, they correspond: $\mathbf{x}_i \longleftrightarrow \mathbf{x}'_i$, $\forall i = 1, \ldots, n$.

What is the minimum value of n?

Problem 4 *0.75 Points*

What is the general form of a finite projective camera matrix P? Describe its internal and external parameters.

Problem 5 *0.75 Points*

Explain (briefly) the camera calibration method (of Zhang) using a planar pattern and several images of it.

Problem 6 *2 points*

Consider two images I and I' of 80×80 pixels capturing the same scene with the same camera from diferent viewpoints and two epipolar lines in image I such as: $\ell_1 \equiv 2x-4y = 0$ and $\ell_2 \equiv x+10y-400 = 0$ Consider the coordinates origin on the bottom right of the images (positive going up and right). Answer the following questions:

a) What are the pixel coordinates of the epipole in image I?

b) Justify if the epipole is inside or outside of the image I.

c) Are the two images I and I' rectified? Why?

d) Compute the last row of the fundamental matrix F if the epipolar line ℓ_1 corresponds to the point $x' = (0, 0)^T$ in image I'.

Let's assume now that the fundamental matrix F between the two images I and I' is known.

e) Would you be able to reconstruct the structure of the camera configuration (rotation, translation and scale)? Why?

f) If the answer to the previous is negative, What extra information would you need to obtain the structure of the camera configuration? If positive, what steps would you do to obtain the structure?

Problem 7 *1 Point*

Depth and disparity estimation.

(a) *(0.5 points)* Describe how the disparity is estimated by the local and global methods and what is the main difference between them.

(b) *(0.5 points)* Describe the main steps of the plane sweep method.

Problem 8 *1 Point*

Factorization method.

(a) *(0.25 points)* Describe what are the unknowns and the available data in the factorization method.

(b) *(0.5 points)* What is the algebraic system of equations we form in the factorization method? Describe the different elements involved and the size of the matrices.

(c) *(0.25 points)* How do we use the prvious system of equations in order to find an estimate of the solution?

Problem 9 *0.75 Points*

In the metric reconstruction step of a stratified structure from motion approach the essence is to find an estimate of the image of the absolute conic.

(a) *(0.25 points)* How does the image of the absolute conic relates to the matrix of i nternal parameters of the camera?

(b) *(0.5 points)* What are the different constraints on the image of the absolute conic we use to estimate it with the method studied in the course? How many constraints do we need? Why?

Problem 10 *0.5 Points*

Depth sensors

(a) State the advantage of active depth sensors over depth measurement with passive stereo sensors. What are the main features of commercial depth sensors regarding range, noise, and resolution compared to pre-existing industrial grade scanners (such as FARO)? What are the advantages and disadvantages of both?
Why have commercial depth sensors experienced such a success since 2010?

(b) RGBD data is usually captured as color+depth, but it can also be represented in terms of point clouds (RGBXYZ).

Explicit the operation performed for the conversion from RGBD to RGBXYZ. Which parameters are required for the conversion? State advantages and disadvantages of each format.

Problem 11 *0.5 Points*

3D data and Point clouds

(a) Point clouds can be "unorganized", what does this mean? What is the disadvantage of unorganized point clouds for processing purposes? Can an unorganized point cloud be converted into RGBD?

(b) Explain the main problem for processing unorganized point clouds for local feature extraction or smoothing (i.e. filtering based on spatial or temporal coherence)

Problem 12 *0.5 Points*

Depth scans and meshing

(a) What are the principles of a good point feature representation for point cloud data according to R.B. Rusu?

(b) How can we compute a tangent plane on a local neighborhood of the point cloud?