CPS 843 (CP 8307) Problem Set 4

(25 points)

Purpose

- Familiar with the algorithm in computer vision
- Understand the basic concepts of imaging process and single view geometry

Requirements

- The assignment is due on Friday, November 26th @ 11:59 pm. Late submissions will not be accepted.
- Submit all your work in one PDF file through D2L, including the source code (multiple submission is allowed, but only the last submission will be kept and evaluated).
- Highly recommend using IEEE double-column format. The Word and LaTeX template can be found at http://www.ieee.org/conferences_events/conferences/publishing/templates.html
- Please resize all images properly in line with the text of your report.
- Submit the source code, if any, along with the report of each part in one PDF file.
- You can directly use available functions or software packages of Matlab in your work.
- Complete the report by yourself. We will use Turnitin® for similarity check.

Part 1:

Problem 1. (1) Give the canonical form of the plane at infinity; (2) Verify that the plane at infinity is a fixed plane under a 3D affine transformation; (3) Given the 3D points transformation $\mathbf{X}' = \mathtt{H}\mathbf{X}$, verify that a 3D plane is transformed as $\boldsymbol{\pi}' = \mathtt{H}^{-\mathsf{T}}\boldsymbol{\pi}$. (4 points)

Problem 2. (1) Give the general form of a finite projective camera's intrinsic parameter matrix **K** and the meaning of each parameter in K; (2) Given the projection matrix $\mathtt{P} = [\mathtt{M} \mid \mathbf{p}_4]$, show how to recover the internal and external parameters from the projection matrix; (3) Verify that the image of a point at infinity is only affected by the sub-matrix **M**. (4 points)

Problem 3. (1) Given the projection matrix **P**, show how to compute the optical center of the camera; (2) Verify that the first three columns of the projection matrix correspond to the vanishing points of the X, Y, and Z axes of the world system; (3) Verify that the last row of the projection matrix corresponds to the principal plane of the camera. (4 points)

Problem 4. (1) Verify that coplanar 3D points and their images are related by a 2D homography given by $\mathtt{H} = \mathtt{K}[\mathbf{r}_1, \mathbf{r}_2, \mathbf{t}]$; (2) Verify that the back-projection of an image line is a 3D plane given by $\Pi = \mathtt{P}^{\mathsf{T}}\mathrm{l}$; (3) Verify that the images captured by a zooming camera are related by a 2D homography given by $\mathtt{H} = \mathtt{K}'\mathtt{K}^{-1}$. (4 points)

Problem 5. (1) Verify that the image of the absolute conic is given by $\boldsymbol{\omega} = (\mathtt{KK}^{\mathsf{T}})^{-1}$. (2) Verify that two image points correspond to orthogonal directions satisfy $\mathbf{x}_1^{\mathsf{T}}\boldsymbol{\omega}\mathbf{x}_2 = 0$; (3) Verify that two constraints on the image of the absolute conic can be obtained from a homography between a 3D plane and its image $\mathtt{H} = [\mathbf{h}_1, \mathbf{h}_2, \mathbf{h}_3]$. (4) Show the constraints on the image of the absolute conic obtained under the square pixel assumption. (4 points)

Part 2: (4 points)

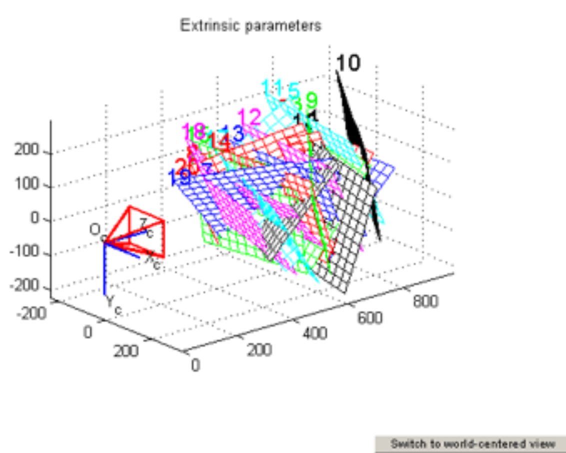
Software:
The Camera Calibration Toolbox for Matlab, which can be downloaded from
http://www.vision.caltech.edu/bouguetj/calib_doc/

Work to do:

- Download the calibration pattern from http://www.vision.caltech.edu/bouguetj/calib_doc/htmls/pattern.pdf; print it in its original size, and stick the pattern to a flat board; You can share the template with other students.
- Put the board at a proper position in front of your camera, take 12 images of the calibration pattern with different camera poses (rotate, pan, and tilt your camera). Note: you should try to keep the same focal length during the process (maintain the same distance from the camera to the object).
- Using the given software, calibrate the camera parameters.

Report:

- A brief technical overview (within 1 page, in your own words) of the camera calibration paper. "Flexible Camera Calibration by Viewing a Plane from Unknown Orientations - Zhang, ICCV'99" (the toolbox is based on this paper). You may find the download link here http://www.vision.caltech.edu/bouguetj/calib_doc/htmls/ref.html.
- In your report, please include the images you took, the camera-centered view figure (the figure below), and the calibration results.



Available resources

- Software homepage: http://www.vision.caltech.edu/bouguetj/calib_doc/
- Calibration example: http://www.vision.caltech.edu/bouguetj/calib_doc/htmls/example.html
- Description of the calibration parameters: http://www.vision.caltech.edu/bouguetj/calib_doc/htmls/parameters.html
- Description of the used functions: http://www.vision.caltech.edu/bouguetj/calib_doc/htmls/functions.html
- Step by step guide: http://www.vision.caltech.edu/bouguetj/calib_doc/htmls/own_calib.html

Part 3: (1 point)

Please tell me the progress of your final project (in one very short paragraph).