Computer Vision - CSE 344/544
Make up Final Exam - Jun 26, 2023

Maximum score: 70   **Time:** <u>**2 hours**</u>

Instructions:

1. There are six questions with a maximum of 40 extra credit points that can be earned.

2. Please show relevant steps of your calculations to get full credit.

3. For true/false questions : true statements are *always* true; for false statements, there exists at least one example for which the statement does not hold.

4. $\mathcal{P}^n$ is the n-dimensional projective space. $\mathbb{R}^{p \times q}$ denotes the space of $p \times q$ real matrices. $\mathbb{R}^p$ denotes the p-dimensional real vector space.

1. (*20 points*) State whether the following statements are **true** or **false** with appropriate justification.

a) Matrices $\mathbf{A}, \mathbf{B} \in \mathbb{R}^{m \times n}$, both have rank r. $\mathbf{A} + \mathbf{B}$ will always have rank r.

b) In the image formation pipeline, the world to camera coordinate transformation is strictly an affine transformation.

c) Projective transformations guarantee that parallel lines will remain parallel.

d) The effect of radial distortion reduces as you radially move away from the principal point.

e) A line in $\mathcal{P}^2$ is represented by the 3-dimensional vector normal to the plane passing through the origin and the line.

f) An image should be smoothed before computing the gradient.

g) Identifying the line at infinity is sufficient to remove projective distortion from the image of a 3D plane.

h) In a stereo system, both epipoles lie on the an epipolar plane.

i) In the Harris corner detection approach, an edge is detected if the second moment matrix $\mathbf{H}$ is rank-deficient and has large $||\mathbf{H}||_2$

j) For line detection using Hough transforms, a point in the image space corresponds to a circle in the Hough parameter space.

2. (*20 points*) (*Extra Credit*) Let $\mathbf{x}_1, \mathbf{x}_2 \in \mathcal{P}^2$ and $\mathbf{l}$ be a line passing through them such that $\mathbf{l}^\top \mathbf{x}_i = 0$, $i = 1, 2$. If $\mathbf{H} \in \mathbb{R}^{3 \times 3}$ is a 2D projective transformation such that $\mathbf{x}'_i = \mathbf{H}\mathbf{x}_i$, derive the expression for the line $\mathbf{l}'$ passing through the transformed points $\mathbf{x}'_1, \mathbf{x}'_2$, in terms of $\mathbf{H}$ and $\mathbf{l}$.

3. (*20 points*)

a) What are the steps taken in Canny edge detection?

b) Write the pseudo-code for the Hough Transform for identifying lines in an image.

4. (*30 points*) Say you have two uncalibrated images and your goal is to estimate the fundamental matrix $\mathbf{F}$. Write the epipolar constraint in terms of the $\mathbf{F}$. What metric would you use for matching SIFT feature points to obtain point correspondences between two images? What exactly does an element in the 128-dimensional SIFT keypoint descriptor signify? How many point correspondences would you need to estimate $\mathbf{F}$? Since SIFT cannot guarantee correct matches, a usual least squares approach may give you poor estimates. What method can you use for robust estimation of $\mathbf{F}$ using the SIFT matches, some of which may be incorrect?