CSE252B – Computer Vision II – Final Exam

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`http://www-cse.ucsd.edu/classes/sp10/cse252b`

3:00pm-6:00pm Tue. June 8, 2010.

On this exam you are allowed to use a calculator and two 8.5" by 11" sheets of notes. The total number of points possible is 41. In order to get full credit you must show all your work. Good luck!

1. (1 pt) When estimating the Fundamental matrix from noisy data we set its third singular value to zero. Let F and F' denote the Fundamental matrix before and after this operation. How are the epipolar lines produced by F different from those produced by F'?

2. Consider the two lines $y = x$ and $y = x + 1$.

   (a) (1 pt.) Write down the expression for each line ($\boldsymbol{l}_1$ and $\boldsymbol{l}_2$) in homogeneous coordinates.

   (b) (1 pt.) Solve for their point of intersection.

3. Let $\boldsymbol{l} = (0, 0, 1)^\top$ denote the homogeneous coordinates of a line in $\mathbb{P}^2$ and let $C = \text{diag}\{1, 1, -1\}$ be the coefficient matrix for the conic $\boldsymbol{x}^\top C\boldsymbol{x} = 0$.

   (a) (1 pt.) What is the special name for $\boldsymbol{l}$?

   (b) (1 pt.) What do you get if you intersect $\boldsymbol{l}$ and C?

4. Suppose you capture two images related by a pure translation in the Z direction, e.g., forward motion through a hallway.

   (a) (1 pt.) Where is the epipole in this case?

   (b) (1 pt.) What problem arises if you try to apply standard epipolar rectification to this pair of images?

   (c) (1 pt.) Suggest a high-level approach to address this problem.

5. Consider an image of the chalkboard in Peterson Hall 103 captured by a student sitting in class. Let $\boldsymbol{x}_1 \in \mathbb{P}^2$ denote the homogeneous coordinates of a point on the chalkboard, and let $\boldsymbol{x}_2 \in \mathbb{P}^2$ denote its image.

   (a) (1 pt) What general class of transformation $\mathcal{T}(\cdot)$ maps $\boldsymbol{x}_1$ to $\boldsymbol{x}_2$?

   (b) (2 pts) How many corresponding point pairs are needed to estimate $\mathcal{T}(\cdot)$? What are the conditions on the coordinates of these points for the solution to be valid?

   (c) (1 pt) Suppose the student is seated very far away from the chalkboard. What simplified class of global transformation can be used to approximate $\mathcal{T}(\cdot)$?

   (d) (2 pts) Now suppose the student is seated at an arbitrary location. The professor marks a point $\boldsymbol{x}_1^*$ on the chalkboard. Describe how you would compute a linear approximation $\widetilde{\mathcal{T}}(\cdot)$ to $\mathcal{T}(\cdot)$ that holds in the vicinity of $\boldsymbol{x}_1^*$. What class of transformation is $\widetilde{\mathcal{T}}(\cdot)$?

   (e) (3 bonus pts) Solve for $\widetilde{\mathcal{T}}(\cdot)$ in terms of the coefficients of $\mathcal{T}(\cdot)$.

6. (2 pts.) Referring to the expression for a 3D point imaged by a general camera, i.e., $\lambda\boldsymbol{x} = \Pi\boldsymbol{X}$, with $\Pi = KR[I, \boldsymbol{T}]$, explain why distant points (e.g., on the moon or a mountain) appear stationary when viewed from a translating vehicle.

7. Both the Lucas-Kanade optical flow method and the Förstner operator require the computation of a special 2×2 symmetric matrix in a window around each pixel as an intermediate step.

   (a) (3 pt.) What are the entries of this matrix?

(b) (2 pts.) Prove that this matrix is positive semidefinite.

(c) (3 pts.) How does one interpret this matrix in terms of different types of image neighborhoods?

8. Essential matrix.

   (a) (1 pt.) How many degrees of freedom does E have?

   (b) (3 pts.) Explain where the degrees of freedom come from.

9. Many natural and man-made objects (e.g., airplanes) exhibit bilateral symmetry. Suppose you capture a *single* image $I(x, y)$ of an airplane using a camera with unknown relative pose $(R, \boldsymbol{T})$ with respect to the coordinate frame of the airplane.

   (a) (4 pts) Given only $I(x, y)$ as input, explain how to estimate the 3D structure of the airplane using techniques from this course. This will only be possible up to a certain unknown transformation; name the class of that transformation.

   (b) (2 pts) The quality of the 3D reconstruction will depend on the relative camera pose. What are the worst choices of $(R, \boldsymbol{T})$? What are the best?

10. (2 pt) What kind of transformation in $\mathbb{P}^2$ leaves the line at infinity unchanged? Apply this transformation to $\boldsymbol{l}_\infty$ and show that it is not affected.

11. Suppose you capture two frames by rotating a camera about its optical center.

    (a) (1 pt.) Can you use the four point algorithm to estimate H in this case?

    (b) (1 pt.) If yes, explain a practical use for H. If no, explain how the motion would have to change to make this possible.

12. The orthographic camera model.

    (a) (1 pt.) Describe the conditions under which the orthographic camera model is reasonable.

    (b) (2 pt.) Define the "Hitchcock zoom" effect and explain how to produce it using a video camera with a zoom lens. You can assume you have a tripod with wheels, or a very steady hand.