**CSE252 – Computer Vision – Assignment #2**

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`http://www-cse.ucsd.edu/classes/sp03/cse252`

Target Due Date: Tue. Apr. 29, 2003.

1. Let $\boldsymbol{\pi} = (\mathbf{n}^\top, d)^\top$ denote the homogeneous coordinates of a plane with surface normal $\mathbf{n}$ and offset $d$, so that $\mathbf{n}^\top \mathbf{X} + d = 0$ for points on the plane. Let $M$ and $M'$ denote the $3 \times 4$ perspective projection matrices

$$M = K[I \mid \mathbf{0}] \quad \text{and} \quad M' = K'[R \mid \mathbf{t}]$$

for a calibrated stereo rig with the world origin at the first camera center, instrinsic calibration matrices $K$ and $K'$, relative rotation $R$, and relative translation $\mathbf{t}$. Show that the homography induced by $\boldsymbol{\pi}$ can be expressed as

$$H = K' \left( R - \mathbf{t}\mathbf{n}^\top / d \right) K^{-1}$$

2. Prove that images acquired by a camera rotating about its center are related to each other by a planar homography $H$. Assume that the camera is centered at the origin with calibration matrix $K$ and that the relative rotation is specified by the matrix $R$.

3. Hartley Normalization.
   (a) Derive the entries of the $3 \times 3$ Hartley normalization matrix $T$.
   (b) Demonstrate Hartley normalization on a set of 100 2D coordinates randomly distributed on $[1, 128] \times [1, 192]$.

4. 2D Projective Transformations.
   (a) Implement the Direct Linear Transform (DLT) method for 2D homography estimation with the option of Hartley normalization.
   (b) Use it to remove the projective distortion from three images: `fig1.4a.gif`, `fig1.6c.gif`, and one image of your own choice.
   (c) Discuss the effects of normalization on the quality of the result.

5. Epipolar Geometry.
   (a) Implement the Eight Point Algorithm for estimating the Fundamental matrix $F$ with Hartley Normalization.
   (b) Run your code on the stereo pair of `fig7.6b.gif` and `fig7.6c.gif` with $n \geq 8$ hand-clicked correspondences. Plot the epipolar lines for at least three points in the first view, and verify that they pass through the corresponding points in the second view.
   (c) Solve for the coordinates of the epipoles $\mathbf{e}$ and $\mathbf{e}'$.
   (d) Repeat the above two steps for another stereo pair of your own choosing.

6. Reconstruction from Two Calibrated Views.
   (a) Run the script `make_scene.m` to produce two views of the synthetic scene shown in class. Use your code from Problem 5 to estimate the essential matrix $E$.
   (b) Use Longuet-Higgins's algorithm to estimate $R$ and $\mathbf{T}$ from $E$ (up to a scale factor).
   (c) Use $R$ and $\mathbf{T}$ to reconstruct the depths of the points. Plot the estimated 3D coordinates of the pointset relative to each camera.