Midterm Exam
CS 4495/7495 Computer Vision

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Solutions due at my office or in email by 5pm, Tuesday October 28, 2008

You are not permitted to discuss the exam questions or your answers with anyone else. Your answers to these questions must be entirely your own work.

The questions are organized into 6 topics, one per page. Students enrolled in CS 7495 must answer all questions. Students enrolled in CS 4495 may omit one topic of their choice (i.e. skip one page of questions); please indicate your choice clearly. (If you answer all questions, please indicate which topic is for extra credit).

This exam is open book, open notes. You do not need to typeset your answers, legible hand-written responses are fine. Clearly indicate your final answer for each problem.
1 Projective Geometry

1. What are the homogeneous coordinates of the 3D plane where all vanishing points lie?

2. Can the process of casting a shadow be modeled as a projective transform? What kind of transform is needed? Be precise in your explanation.
2 Single View Metrology

The cross-ratio of 4 points $a, b, c, d$ is defined as

$$\frac{|a, c| \times |b, d|}{|a, d| \times |b, c|}$$

1. What does this become if the point $d$ is the vanishing point of all 3D vertical lines?

2. How can we use this fact to estimate the height of an object in the scene, as seen by an upright camera (i.e. with its Y-axis aligned with the vertical?)
3 Camera Models

The matrix representation of a general projective camera is a $3 \times 4$ matrix

$$P = \begin{bmatrix} a & b & c & d \\ e & f & g & h \\ i & j & k & l \end{bmatrix}.$$

1. What is the 2D coordinate of the 3D origin?

2. How can we find the homogeneous coordinates of the pinhole itself? (Hint, use SVD)
4 Multi-View Geometry

In the factorization algorithm for SFM by Tomasi and Kanade, one matrix is factored into a product of two matrices.

1. The factorized matrix contains tracks. What are tracks? What are the dimensions of this matrix? What are the requirements for the tracker?

2. Factorization produces two matrices as the output. What do these matrices contain? What are their dimensions?

3. Suppose the scene contains a cube. During the SVD stage of the factorization method, what class of scene shapes are consistent with the measurements? Sketch an equivalent shape.
5 Color

1. Under what conditions do yellow and blue make green?

2. Give a definition of the color constancy problem.

3. Why are the color spaces RGB, HSV, etc. all three dimensional?

4. Euclidean distance in color space is a popular metric for color-based segmentation. How accurately does this metric reflect human perception of color similarity? Explain. Can you suggest a more accurate metric?
6 Photometric Stereo

1. What is the minimum number of light sources that are needed for photometric stereo? (Show the result mathematically)

2. What would be the effect of a cast shadow on the height map produced by photometric stereo?

3. Suppose I had access to a special high dynamic-range camera. Instead of the usual 8 bits of gray scale precision, this camera has 16. Would this improve my photometric stereo results? Explain (mathematically, if possible).