Name:	**Perm #:**

(Sample) Final Exam

CS/ECE 181B – Intro to Computer Vision

June 10, 2003

8:00 – 11:00 am

Please space yourselves so that students are evenly distributed throughout the room. If possible, there should be no one directly next to you.

This is a **closed-book, closed-notes** test. There are several pages of equations, etc. included for your reference. You may use a calculator for numerical calculations.

Be sure to read each question carefully and provide all the information requested. A good strategy would be to go through the exam once, answering all the questions you are confident about, and then go through and do the rest. Manage your time well.

Exams must be turned in by 11:00am sharp.

Write your answers in the spaces provided and, if necessary, on the back of the page. If you use the back, draw an arrow or write “SEE BACK” to make sure the graders don’t miss it. If you need more space, attach extra sheets of paper (available at the front).

When you’re finished, if you don’t mind *yet another* survey, I’d appreciate it if you would fill out the separate page of questions at the very end. This is to help me improve the course in future years. Please tear it off and place it in a separate pile when you turn in your exam.

Good luck, and have a great summer!

Perspective projection

$$x' = f' \frac{x}{z}$$
$$y' = f' \frac{y}{z}$$
$$z' = f'$$

Orthographic projection

$$x' = x$$
$$y' = y$$
$$z' = f'$$

Weak perspective projection

$$x' = -mx$$
$$y' = -my$$
$$z' = f'$$

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f' & 0 & 0 & 0 \\ 0 & f' & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

Thin lens equation:

$$\frac{1}{z'} - \frac{1}{z} = \frac{1}{f}$$

Snell's Law for refraction:

$n_1 \sin (q_i) = n_2 \sin (q_r)$

Rigid coordinate transformation from world coord. frame to camera coord. frame in homogeneous coordinates:

$$^{C}P = \begin{bmatrix} {}^{C}_{W}R & {}^{C}O_W \\ 0^T & 1 \end{bmatrix} {}^{W}P = M_e \; {}^{W}P$$

Camera calibration matrices (intrinsic and extrinsic):

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = M_i M_e \, P = M \; P$$

$$= \begin{bmatrix} kf & -kf \cot q & u_0 & 0 \\ 0 & lf \csc q & v_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} {}^{C}_{W}R & {}^{C}O_W \\ 0^T & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

Polynomial function to model radial distortion:

$$\begin{bmatrix} u_d \\ v_d \end{bmatrix} = l(d) \begin{bmatrix} u \\ v \end{bmatrix} \qquad \lambda(d) = 1 + \kappa_1 d^2 + \kappa_2 d^4 + \kappa_3 d^6$$

The solid angle subtended by a patch of area *dA*:

$$dw = \frac{dA \cos q}{r^2}$$

The solid angle subtended by a patch of angular size (*dq*, *df*):

$$dw = \sin q \; dq \; df$$

A surface experiencing radiance *L(q,f)* coming in from solid angle *dw* experiences irradiance:

$$dE = L(q, f) \cos q \; dw$$

Radiant energy	Q_e		Energy	J
Radiant flux	F_e	$\Phi_e = \frac{\Delta Q_e}{\Delta t}$	Energy per unit time (power)	J/s or W
Irradiance	E_e	$E_e = \frac{\Delta \Phi_e}{\Delta A}$	Power falling on unit area of target	W/m^2
Radiant intensity	I_e	$I_e = \frac{\Delta \Phi_e}{\Delta w}$	Source power radiated per unit solid angle	W/sr
Radiance	L_e	$L_e = \frac{\Delta I_e}{\Delta A}$	Source power radiated per unit area per unit solid angle	W/m^2-sr

Rotation about the *X* axis:

$$X_q = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos q & -\sin q \\ 0 & \sin q & \cos q \end{pmatrix}$$

Rotation about the *Y* axis:

$$Y_f = \begin{pmatrix} \cos f & 0 & \sin f \\ 0 & 1 & 0 \\ -\sin f & 0 & \cos f \end{pmatrix}$$

Rotation about the *Z* axis:

$$Z_y = \begin{pmatrix} \cos y & -\sin y & 0 \\ \sin y & \cos y & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Total irradiance:

$$E = \int_0^{2p} \int_0^{\frac{p}{2}} L(q, f) \cos q \sin q \, dq \, df$$

$$BRDF : r = f(q_i, f_i, q_o, f_o)$$

$$= \frac{L_o(q_o, f_o)}{L_i(q_i, f_i) \cos q_i dw}$$

$$0 \leq r \leq \infty$$

Chromaticity values from tristimulus values:

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

$$z = \frac{Z}{X+Y+Z}$$

$$x + y + z = 1$$

Image irradiance on the image plane as a function of the object radiance (L):

$$E = \left[\frac{p}{4} \left(\frac{d}{z'} \right)^2 \cos^4 a \right] L$$

Sensor responses:

$$p_1 = \int E(l) s_1(l) dl \quad = \int S(l) r(l) s_1(l) dl$$

$$p_2 = \int E(l) s_2(l) dl \quad = \int S(l) r(l) s_2(l) dl$$

$$p_3 = \int E(l) s_3(l) dl \quad = \int S(l) r(l) s_3(l) dl$$

$$p_1 = \sum e(k) s_1(k) = e \cdot r_1 = e^T r_1$$

$$p_2 = \sum e(k) s_2(k) = e \cdot r_2 = e^T r_2$$

$$p_3 = \sum e(k) s_3(k) = e \cdot r_3 = e^T r_3$$

RGB/YIQ conversions:

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.0 & 0.956 & 0.621 \\ 1.0 & -0.272 & -0.647 \\ 1.0 & -1.106 & -1.703 \end{bmatrix} \begin{bmatrix} Y \\ I \\ Q \end{bmatrix}$$

RGB-to-HSV conversion algorithm:

max=largest RGB component
min=smallest RGB component

H = 60*(G-B)/(max-min) if red is largest
180*(B-R)/(max-min) if green is largest
300*(R-G)/(max-min) if blue is largest
S = (max-min)/max
V = max

Convolution:

$$R_i = \sum_{u,v} H_{i-u,j-v} F_{uv}$$

or

$$R_{ij} = \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} H_{mn} F_{i-m,j-n}$$

Gaussian:

$$G_s(x,y) = \frac{1}{2ps^2} e^{\frac{-(x^2+y^2)}{2s^2}}$$

Normalized correlation:

$$R = \cos\theta = \frac{H \cdot F}{\|H\| \, \|F\|}$$

Sum of Squared Differences (SSD):

$$SSD(u,v) = \sum_{\substack{\text{area}\\\text{around}\\(u,v)}} \left(I_{left}(i,j) - I_{right}(i,j)\right)^2$$

Magnitude: $|F(u,v)| = [(F_R(u,v))^2 + (F_I(u,v))^2]^{1/2}$

Phase: $\phi(F(u,v)) = \tan^{-1}(F_I(u,v) / F_R(u,v))$

Magnitude and angle of gradient filter output:

$$|G| = G_x^2 + G_y^2$$

$$\angle G = atan\ G_y/G_x$$

The Essential Matrix

$$p^T E p' = 0$$

The Fundamental Matrix

$$p^T F p' = 0$$

Mahalanobis distance:

$$d^2 = (x - x_m)^T C_x^{-1} (x - x_m)$$

Total classification risk:

Total risk = Σ_i P(error$_i$) Loss(error$_i$)

Sample Final Exam Questions

1. [N points] What is a fundamental difference between the fields of (a) computer vision and (b) pattern recognition?

2. [N points] Which will cause a higher response in an infrared image: white Styrofoam or black skin?

3. [N points] The RGB value of (128, 100, 42) corresponds to what YIQ value?

4. [N points] Is a histogram operation a point operation, local area operation, or global operation?

5. [N points] Does the following kernel represent a low-pass or high-pass operator? Explain your answer.

1	-1

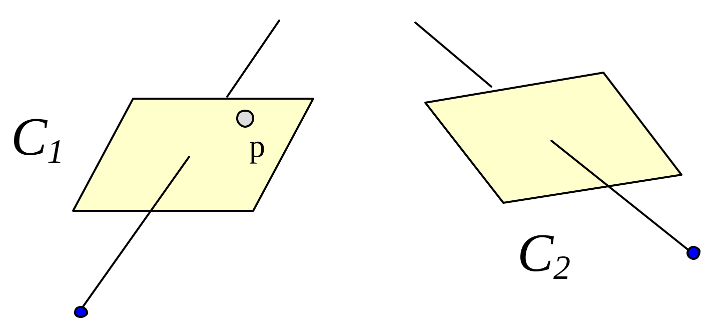
6. [N points] If you convolve an image with filter H_1 and then convolve the result with filter H_2, does it give you the same result as when you first convolve with H_2 and then with H_1?

7. [N points] If you plan on subsampling an image after capturing it, why might it be a good idea to first slightly defocus the camera lens?

8. [N points] How many levels of a Gaussian pyramid can be created from a 256x256 image?

9. [N points] Why is image noise a bad problem for edge detection?

10. [N points] On the diagram below, draw and label the epipolar line corresponding to point p.



11. [N points] Describe the fundamental matrix.

12. [N points] What are the advantages and disadvantages of a small baseline in stereo vision?

13. [N points] In general, what does segmentation try to achieve?

14. [N points] Outline an algorithm to segment wheatfields from ocean from city areas in satellite imagery.

15. [N points] What sort of binary features will a "Dilate then erode" morphological operator get rid of?

16. [N points] Explain how the *k*-means algorithm works. What is it used for?

17. [N points] What is a dynamic model used for in tracking?

18. [N points] You are using template matching (via regular correlation) to find an object in an image. The template is *5* x *5* and the image is *256* x *256*. How large will the output image be, if you don't deal with the borders at all (i.e., only do correlation where image and the template completely overlap)?

19. [N points] Your job is to build a computer vision system to recognize a news anchor's face – it's either Dan Rather, Peter Jennings, or Tom Brokaw. Given an image of a face, describe a complete approach to accomplish this task, including any preparation, training, or testing that would be necessary before running the program.