EXAM COMPUTER VISION

April 8, 2008, 14:00-17:00 hrs

During the exam you may use the book, lab manual, copies of sheets and your own notes.

Put your name on all pages which you hand in, and number them. Write the total number of pages you hand in on the first page. Write clearly and not with pencil or red pen. ***Always motivate your answers.*** *Good luck!*

Problem 1. (2.5 pt) Let X be a binary image X and A a structuring element as in Fig. 1.

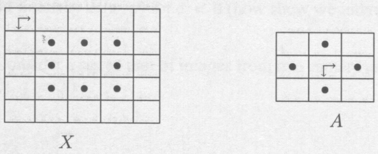

Figure 1: *Binary image X and structuring element A.*

a. (1 pt) In a similar way to Fig. 1 draw: the dilation $\delta_A(X) = X \oplus A$, the erosion $\varepsilon_A(X) = X \ominus A$, the opening $\gamma_A(X) = X \circ A$ and the closing $\phi_A(X) = X \bullet A$.

b. (0.5 pt) Furthermore, draw $\delta_A\, \varepsilon_A\, \delta_A(X)$ and $\varepsilon_A\, \delta_A\, \varepsilon_A(X)$.

c. (1 pt) Prove that for any X, A: $\delta_A\, \varepsilon_A\, \delta_A(X) = \delta_A(X)$.
Hint: Prove that $\delta_A\, \varepsilon_A\, \delta_A(X) \subseteq \delta_A(X)$ *and* that $\delta_A\, \varepsilon_A\, \delta_A(X) \supseteq \delta_A(X)$.

Problem 2. (2 pt) Consider a grey-value image f.

a. Sobel gradients in the image in horizontal (easterly) direction can be detected by linear filtering using the filter kernel (or mask) in Fig. 2 (left). Give Sobel kernels to detect gradients in northerly, north-westerly, and north-easterly direction.

b. A discrete second derivative filter in the x-direction $\frac{\partial^2}{\partial x^2}$ is defined by convolution with the kernel in Fig. 2(right). If image f is constant, the result of this filter will be zero in every pixel. Show by calculation that the result for an image $f(x, y) = ax^2 + bx + c$, is $-2a$ for each pixel with a, b, c constants.

-1	0	1
-2	0	2
-1	0	1

0	0	0
-1	2	-1
0	0	0

Figure 2: *Convolution masks for the Sobel x-gradient filter (left) and the second-order x-derivative filter (right).*

Problem 4. (2.5 pt) Consider a parabolic surface centred at the origin with equation

$$z = d - x^2 - y^2$$

The surface is Lambertian with constant albedo $\rho_S = 1$, and is illuminated by a light source at a very large distance, from a direction defined by the unit vector $\vec{s} = (a, b, c)^T$, with c negative. The camera is on the negative z-axis.

a. (1.5pt) Show that the image intensity under orthographic projection is given by

$$E(x, y) = \frac{2ax + 2by - c}{4(x^2 + y^2) + 1} \tag{1}$$

b. (1pt) Suppose $\vec{s} = (1, 0, 0)^T$, i.e., the light source is in the direction of the positive x-axis. What is the observed light intensity $E(x, y)$ for $x < 0$ (how show we interpret (1))?

Problem 4. (2 pt) Consider a stereo pair of images from two camera as shown below with $O_L = (-10, 0, 0)$ and $O_R = (10, 0, 0)$, $f = 20$

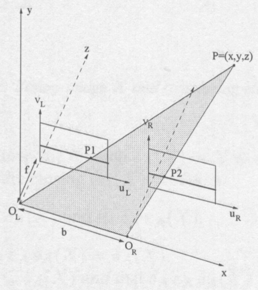

Figure 3: *Standard stereo set-up.*

a. (1 pt) Suppose a feature is detected in the left camera image at $(u_L, v_L) = (0, 0)$ and the right camera image at $(u_R, v_R) = (-2, 0)$. What is the (x, y, z)-position of the object?

b. (1pt) Which variables determine the accuracy with which we can determine the z-position, and in what way do they affect the accuracy (i.e. does the accuracy increase or decrease as you increase or decrease each variables).