NATIONAL UNIVERSITY OF SINGAPORE

SCHOOL OF COMPUTING
FINAL EXAMINATION FOR
Semester 1, AY2008/2009

CS4243 COMPUTER VISION & PATTERN RECOGNITION

November 2008 Time Allowed: 2 hours

INSTRUCTIONS TO CANDIDATES

1. This examination paper contains **FOUR (4)** questions and comprises **FOURTEEN (14)** printed pages, including this page.
2. Answer **ALL** questions. The maximum mark is 30.
3. Write your answers in the space provided in this booklet.
4. Write legibly. You may use pen or pencil.
5. This is an OPEN BOOK examination.
6. Please write your Matriculation Number below.

Matriculation No.: ____________________________

This portion is for examiner's use only.

Question	Marks	Remarks
Q1		
Q2		
Q3		
Q4		
Total		

Q1: Pattern Recognition [7 marks]

Tom Beh, your classmate, is designing a two-class classifier based on a single feature x and the class-conditional pdfs (likelihoods) shown in Figure 1.

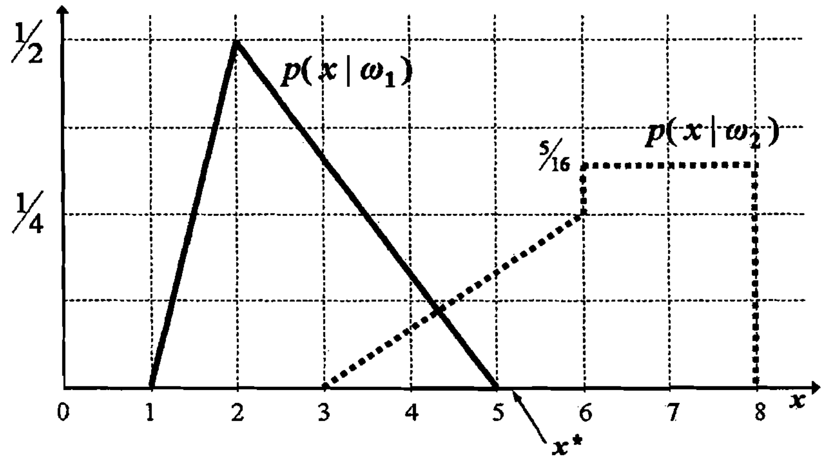

Figure 1: Class-conditional pdfs for a single feature x.

After studying the pdfs very carefully, and noting that both classes are equally likely, Tom sets a threhold $x^* = 5.1$, and writes down the following decision rule:

If $x \geq x^*$ then decide ω_2, else decide ω_1.

Q1(a). Using Beh's classifier (the decision rule above), which class would $x = 4$ be assigned to? [1 mark]

Q1(b). Beh's classifier will always correctly classify (i.e. without error) one of the two classes. Which one? [1 mark]

Q1(c). Calculate the probability of error that Beh's classifier will make for the other class. That is, calculate $P(error \mid \omega)$, where ω is the class with non-zero error. [3 marks]

Q1(d). You, of course, know that the Bayes' classifier will be better than Beh's. Using Figure 1, write down the decision rule for the Bayes' classifier, in a form similar to Beh's decision rule. [2 marks]

Q2: Convolution [8 marks]

Recall from lecture that convolution for 1D images is easy: simply flip the mask, slide it step by step across the image, and at each step, multiply corresponding pixel values and sum them.

Figure 2 shows the convolution for the 1D image $f(x) = \boxed{2}\boxed{1}\boxed{0}\boxed{1}$ with the 1D mask $h_1(x) = \boxed{1}\boxed{-1}$. The resulting image is $z_1(x) = \boxed{2}\boxed{-1}\boxed{-1}\boxed{1}\boxed{-1}$. Note that a length-$N$ image convolves with a length-M mask to give an image of length $M + N - 1$.

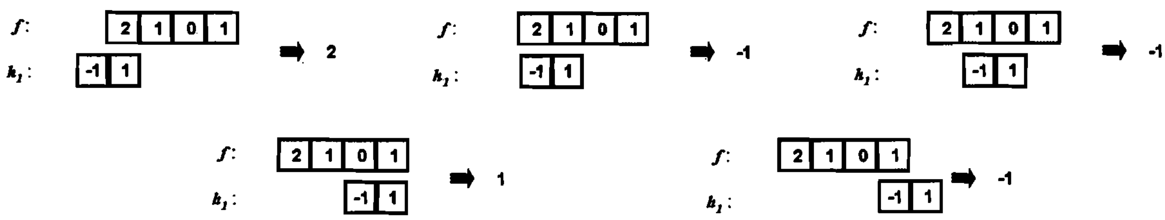

Figure 2: Convolution of 1D image with 1D mask.

Q2(a). Define another mask: $h_2(x) = \boxed{1}\boxed{1}$. Calculate $z_2 = f \star h_2$. That is, convolve $f(x)$ with $h_2(x)$ to get $z_2(x)$. [2 marks]

Figure 3 is a "signal flow" diagram showing how the "signal" (= 1D image) $f(x)$ is convolved separately with $h_1(x)$ and $h_2(x)$, and then recombined. This recombination is achieved by convolving $z_1(x)$ and $z_2(x)$ with new masks $g_1(x)$ and $g_2(x)$ respectively, and then adding their corresponding pixels to get the final signal $e(x)$.

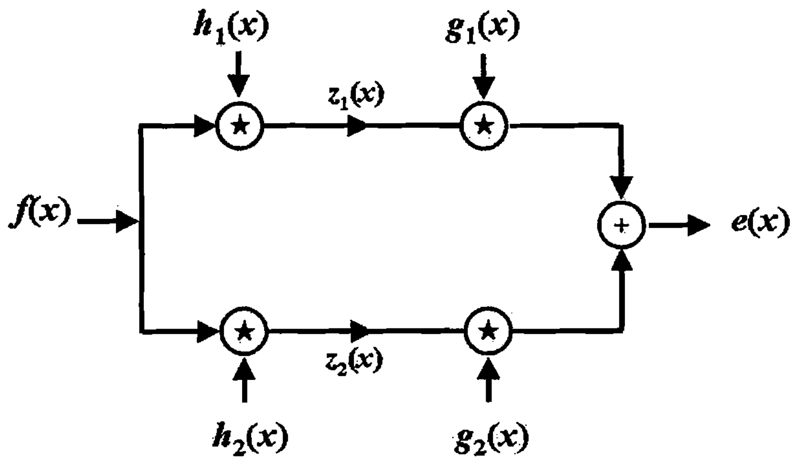

Figure 3: Signal flow diagram.

The new masks $g_1(x)$ and $g_2(x)$ each ~~have~~ has length 1. And the goal is to choose these masks so that $e(x) \cong f(x)$; that is, $e(x)$ is equal to $f(x)$ except for perhaps some leading or trailing zeros.

Q2(b). Determine what these masks $g_1(x)$ and $g_2(x)$ are. Note that their pixel values need not be integers. [2 marks]

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Q2(c). In general, suppose $f(x)$ has length N, and the length-2 masks h_1, h_2 are $h_1(x) = \boxed{\mathrm{A}}\boxed{\mathrm{B}}$ and $h_2(x) = \boxed{\mathrm{C}}\boxed{\mathrm{D}}$. What should the length-1 masks g_1, g_2 be in order for $e(x) \cong f(x)$? [4 marks]

Hint: g_1, g_2 *may be determined based on* A, B, C, D, *and not on* N.

Optional Humor

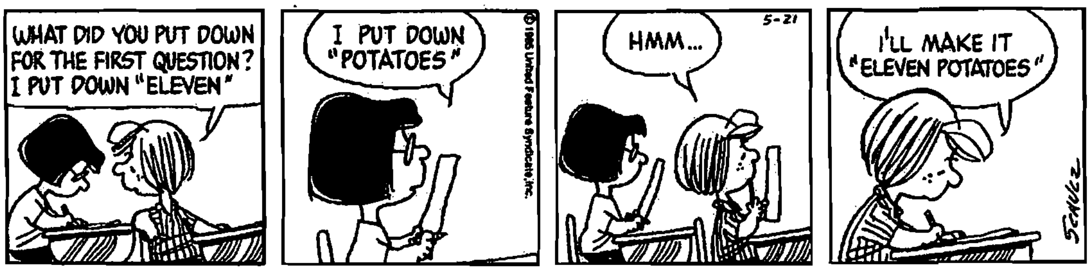
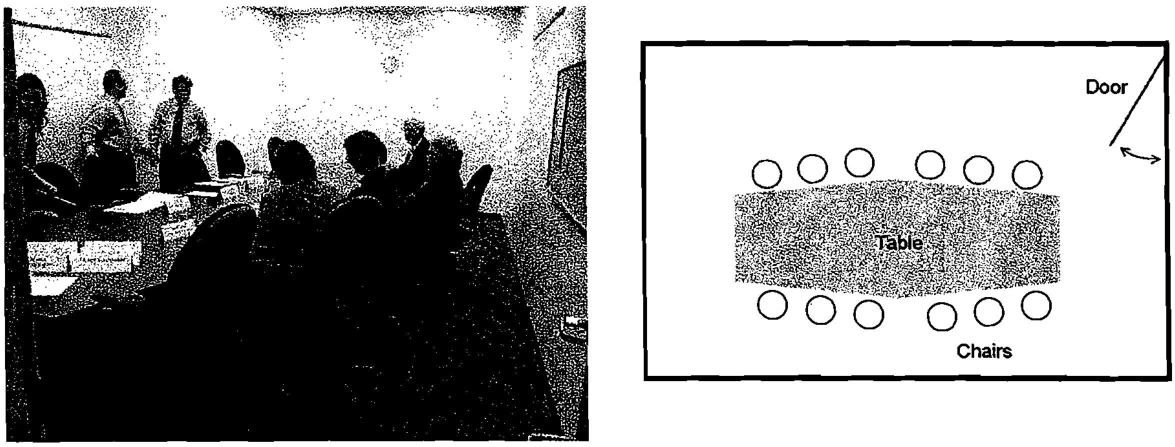


Figure 4: The wrong way to answer exam questions.

Q3: Counting People [9 marks]

You have been approached by a company to design a computer vision system to count the number of people in one of their small meeting rooms. Figure 5 shows two views of the room. The company has the following requirements for your People Counting Vision System (PCVS):



(a) (b)

Figure 5: Two views of the small windowless meeting room: (a) View from the entrance; (b) Plan view (from the top).

- The PCVS should be able to accurately count the number of people in the meeting room as often as once every minute. Accuracy should be $\geq 95\%$.
- The PCVS should be able to see the whole room; there should be no blind spots. You may assume that the users of the room will not do unreasonable things, such as: hide under the table or chair, sit on top of each other, lie on the floor or table, sabotage the cameras, etc. Generally, users in the room will be sitting (on chairs, and occasionally on the table) or standing, and having discussions.
- The PCVS should be fully automatic: it should count people without user interaction. Human interaction is permitted only to start/stop the system, or to calibrate the system if necessary.
- The room has no window, and all lighting is overhead. The walls are mostly bare, except for a wall clock and a small notice board. Users enter and leave the room via the single door at one end of the room. The doorway is large enough for 2 persons to walk through simultaneously. The room can accommodate up to 15 people.

Design a PCVS that satisifes the above requirements. Explain your PCVS by answering the following questions. For each question, please explain briefly in the space provided.

Q3(a). How many cameras are used? Where are they placed? Mark the locations of the cameras in Figure 5(b) above. How would you ensure that there are no blind spots in the room?

Q3(b). If more than 1 camera is used, how would you combine the counts from different cameras? How would you ensure that the same person is not counted multiple times? If only 1 camera is used, how would you deal with occlusion: when one person comes between the camera and another person?

Q3(c). Must the PCVS be calibrated? If so, what is the calibration procedure? How does calibration help your people-counting algorithm?

Q3(d). What feature does your PCVS detect? Heads? Faces? Legs (and divide this number by 2), or other features? If using more than 1 feature, how would you combine the features?

Q4: Principal Components Analysis [6 marks]

You are given three column vectors:

$$\mathbf{x}_1 = \begin{bmatrix} 1 \\ 1 \\ 0 \end{bmatrix}, \quad \mathbf{x}_2 = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}, \quad \mathbf{x}_3 = \begin{bmatrix} -2 \\ -1 \\ -1 \end{bmatrix}.$$

Note that $||\mathbf{x}_1|| = ||\mathbf{x}_2||$ and that $\mathbf{x}_1 + \mathbf{x}_2 + \mathbf{x}_3 = \mathbf{0}$.

Q4(a). Show that the first principal component of the three vectors, $\mathbf{e}_1$, is:

$$\mathbf{e}_1 = \frac{1}{\sqrt{6}} \begin{bmatrix} 2 \\ 1 \\ 1 \end{bmatrix}$$

[3 marks]

Q4(b). A new vector, $\mathbf{x}_4$, is added to the original three, where $\mathbf{x}_4 = 6\,\mathbf{e}_1$.

Calculate the first principal component of all the four vectors $\mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_3$, and $\mathbf{x}_4$.
[3 marks]

(The following formulae are provided for your reference only. You may or may not need to use them.)

$$\det\left(\begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix}\right) = a \times \det\left(\begin{bmatrix} e & f \\ h & i \end{bmatrix}\right) - b \times \det\left(\begin{bmatrix} d & f \\ g & i \end{bmatrix}\right) + c \times \det\left(\begin{bmatrix} d & e \\ g & h \end{bmatrix}\right).$$

and

$$\det\left(\begin{bmatrix} w & x \\ y & z \end{bmatrix}\right) = wz - xy.$$

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— END OF PAPER —