NATIONAL UNIVERSITY OF SINGAPORE

RI3001 UNDERSTANDING BIOMETRICS

(Summer 2017)

Time Allowed: 90 minutes

INSTRUCTIONS TO CANDIDATES

1. This assessment paper contains **SIXTEEN (16)** questions in **TWO (2)** parts and comprises **TEN (10)** printed pages, including this page.
2. Answer **ALL** questions.
3. This is an **OPEN BOOK** assessment.
4. You are allowed to use **NUS APPROVED CALCULATORS**.
5. **Write** your **IVLE ID** below. **Do not write your name.**
6. You may use pen or pencil to write your answers, but please erase cleanly, and write legibly. Marks may be deducted for illegible handwriting.

IVLE ID. (gstCNxxx): SOLUTIONS

This portion is for examiner's use only.

Question	Marks	Remarks
Part A		
Part B		
Total		

Part A: (30 marks) Multiple Choice Questions.

For each multiple choice question, choose the best answer and **circle** it. Each multiple choice question is worth 2 marks. No mark is deducted for wrong answers.

Q1. Average filtering is a type of

A. Point processing.

B. Neighborhood processing.

C. Derivative processing.

D. Global processing.

E. None of the above.

Q2. Convolve the mask $\begin{array}{|c|c|}\hline -1 & 0 \\ \hline \boxed{1} & 1 \\ \hline \end{array}$ with the image $\begin{array}{|c|c|c|}\hline 0 & 1 & 1 \\ \hline \boxed{-1} & 2 & 0 \\ \hline \end{array}$. The boxed number is at the origin. Zero-pad the image as necessary.

A.

0	**-1**	**-1**	**0**
1	**-1**	**2**	**1**
$\boxed{-1}$	**1**	**2**	**0**

B.

0	1	2	1
-1	1	1	-1
$\boxed{0}$	1	-2	0

C.

-1	2	1
$\boxed{1}$	2	0

D.

1	1	-1
$\boxed{1}$	-2	0

E. None of the above.

Q3. Aiken is taking this exam paper and does not know the answers to three multiple-choice questions (MCQs). All MCQs have five choices for the answer.

Aiken can eliminate two answer choices as incorrect for one of the three questions, and eliminate one answer choice as incorrect for the second question, but has no clue about the correct answer at all for the third question.

Assuming that whether Aiken chooses the correct answer on one of the questions does not affect whether she chooses the correct answer on the other questions, what is the probability that Aiken will answer at least one of the three questions correctly?

A. 2/5

B. 13/30

C. 3/5

D. 2/3

E. None of the above.

Q4. Mr. Lee says: "I have two children. One is a boy born on a Tuesday. What is the probability that I have two boys?"

A. 1/3

B. 13/27

C. 1/2

D. 14/27

E. None of the above.

The next three questions (Q5 to Q7) refer to Figure 1, which shows a 9×9 grayscale image with a bit-depth of 5-bits (= 32 gray levels). It contains a 3×3 white (pixel value = 31) square in the center of the image. All other pixels are black (pixel value = 0). The origin of the image is at the center pixel.

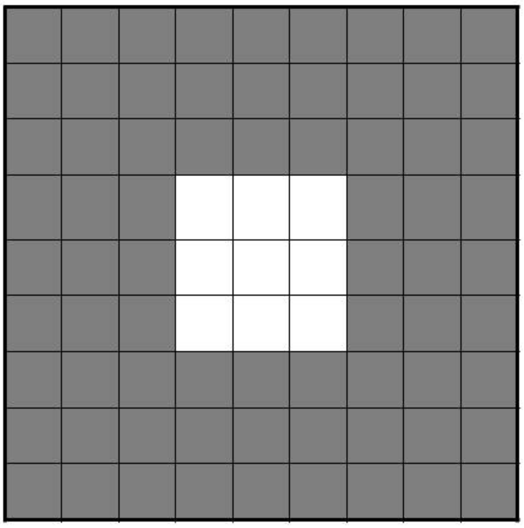
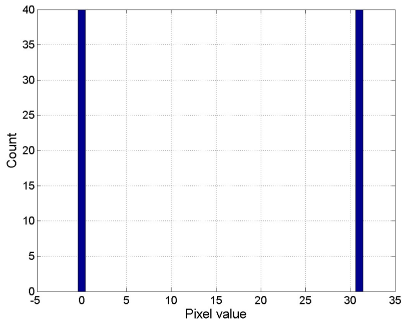
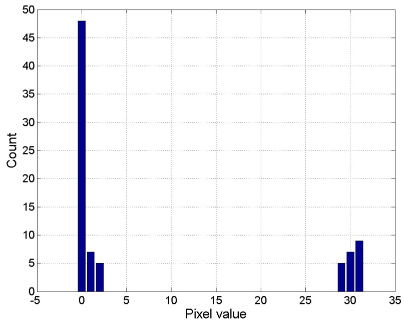


Figure 1: White square in a black image.

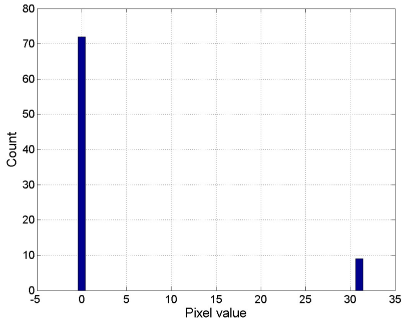
Q5. The histogram of the above image is:



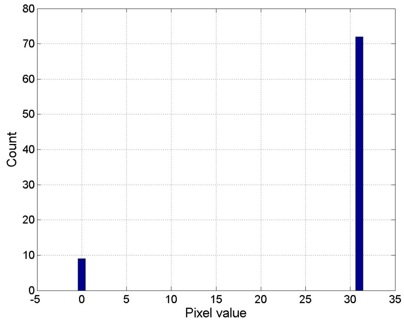
A.



B.



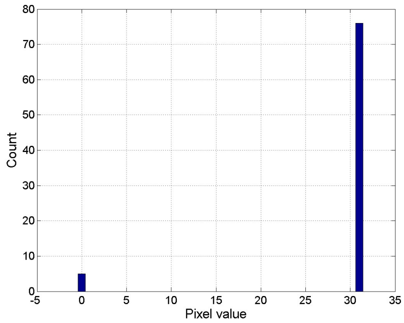
C.



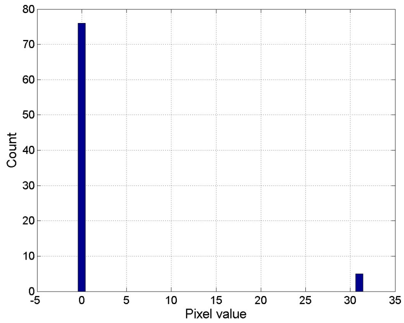
D.

E. None of the above.

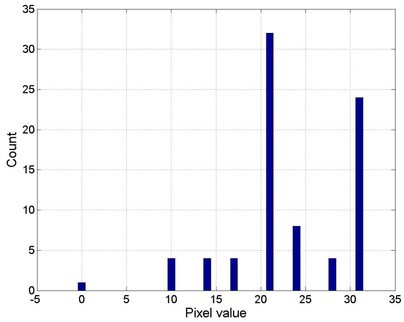
Q6. A 3×3 **median** filter is now applied to the zero-padded image in Figure 1. The resulting histogram is:



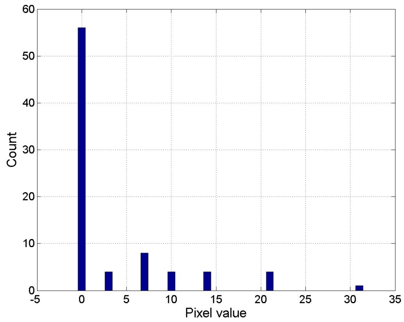
A.



B.



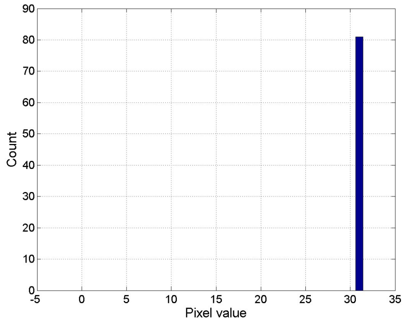
C.



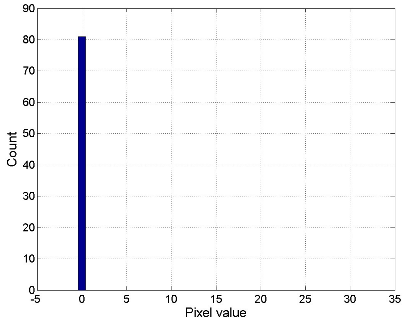
D.

E. None of the above.

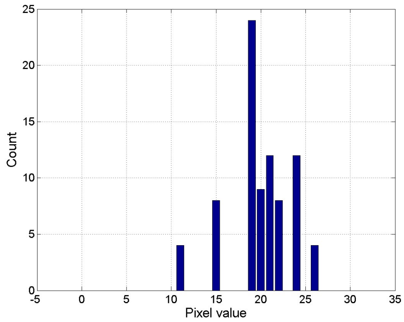
Q7. A 5×5 **median** filter is now applied to the zero-padded image in Figure 1. The resulting histogram is:



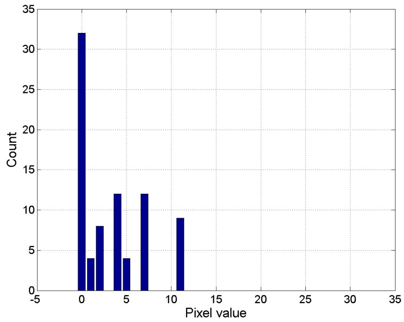
A.



B.



C.



D.

E. None of the above.

Q8. In pattern recognition,

A. PCA is always more accurate than LDA.

B. LDA is always more accurate than PCA.

C. PCA is more accurate than LDA when class means are equal.

D. LDA is more accurate than PCA when class means are equal.

E. None of the above.

Q9. Given the same features and the same training set,

A. the KNN classifier does not scale up as well as the Bayes' classifier.

B. the KNN classifier is better than the Bayes' classifier because it can handle multi-dimensional feature vectors.

C. the Bayes' classifier is always more accurate than the KNN classifier.

D. the Bayes' classifier and the KNN classifier will yield the same decision boundaries for 2-class problems.

E. All of the above.

Q10. A 2D transformation matrix is defined as $\mathbf{T} = \begin{bmatrix} 5\cos 60° & -5\sin 60° & 100 \\ 5\sin 60° & 5\cos 60° & 50 \\ 0 & 0 & 1 \end{bmatrix}$.

All the following statements are true, EXCEPT

A. $\mathbf{T}$ performs a 2D rotation.

B. $\mathbf{T}$ is an affine transformation matrix.

C. After applying $\mathbf{T}$ to a square, its area is unchanged.

D. After applying $\mathbf{T}$ to a square, its angles are unchanged.

E. All of the above.

Q11. The statement, "An $n \times n$ matrix $\mathbf{B}$ is invertible", is equivalent to the following statements, EXCEPT

A. $\det(\mathbf{B}) \neq 0$

B. $rank(\mathbf{B}) = n$

C. $Null(\mathbf{B}) = \{\mathbf{0}\}$

D. $\mathbf{B}$ is positive semi-definite

E. None of the above.

Q12. Consider the 2D transformation matrix $\mathbf{T} = \left[\begin{array}{cc|c} \multicolumn{2}{c|}{\mathbf{A}} & \mathbf{b} \\ \hline 0 & 0 & 1 \end{array}\right]$ where $\mathbf{A}$ is a 2×2 matrix, and $\mathbf{b}$ is a 2×1 column vector. Let $\mathbf{v}$ be an eigenvector of $\mathbf{A}$ with eigenvalue λ. A *fixed point* of $\mathbf{T}$ is a 2D point $\mathbf{x}$ such that applying $\mathbf{T}$ to $\mathbf{x}$ leaves it unchanged.

Select the TRUE statement from the following.

A. If $\mathbf{A} - \mathbf{I}$ is singular, then $\mathbf{T}$ has no fixed point.

B. The origin $\mathbf{0}$ is a fixed point of $\mathbf{T}$ if and only if $\mathbf{b} = \mathbf{0}$.

C. If $\mathbf{b} = (1 - \lambda)\mathbf{v}$, then $\mathbf{v}$ is a fixed point of $\mathbf{T}$.

D. All of the above.

E. None of the above.

Q13. A covariance matrix must be:
(I) symmetric (II) positive semi-definite (III) invertible (IV) orthogonal

A. (I) only.

B. (III) only.

C. (I) and (II) only.

D. (II), (III) and (IV) only.

E. None of A, B, C, or D.

Q14. Which of the following *could be* a covariance matrix?

A. $\begin{bmatrix} 5 & -1 & 0 \\ -1 & 2 & 1 \\ 0 & 1 & 3 \end{bmatrix}$

B. $\begin{bmatrix} 5 & -1 & 0 \\ 0 & 1 & 3 \end{bmatrix}$

C. $\begin{bmatrix} -1 & 0 \\ 0 & 0.1 \end{bmatrix}$

D. $\begin{bmatrix} 3 & 4 & 1 \\ -1 & 0 & 2 \\ 0 & 1 & 1 \end{bmatrix}$

E. None of the above.

Q15. Consider a general $m \times n$ matrix $\mathbf{A}$. The column space of $\mathbf{A}$

A. is a subset of its row space.

B. is orthogonal to its left null space.

C. is orthogonal to its null space.

D. may not exist.

E. is a subset of $Col(\mathbf{AB})$, where $\mathbf{B}$ is an $n \times r$ matrix.

Part B (10 marks): Structured Question.

Q16. Klas E. Fyer is hired by the Jurong Bird Park after graduating from pattern recognition school. He first job is to recognize 3 types of birds from photographs taken of them during flight. Klas decides to use a single feature, x, and the Bayes' Classifier for recognition. Using training data, he estimates the posterior pdfs for each of the 3 classes $(\omega_1, \omega_2, \omega_3)$ and plots them as shown in Figure 2.

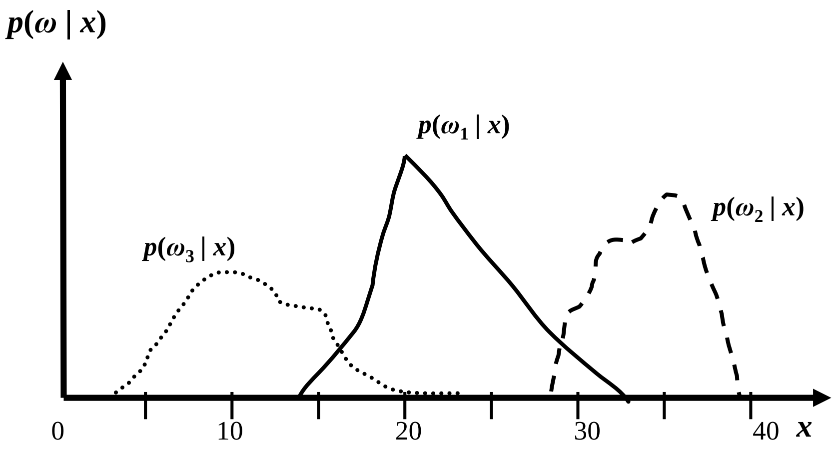


Figure 2: Posterior pdfs for the 3 classes using a single feature x.

(a) (1 mark) An unknown bird is photographed, and its feature is measured to be $x = 15$. What will this bird be classified as?

Classified as w3

Using a separate set of testing data, Klas measures the performance of his classifier and obtains the following confusion matrix:

Actual \ Predicted	ω_1	ω_2	ω_3
ω_1	32	2	5
ω_2		10	7
ω_3		20	24

(b) (1 mark) Calculate the accuracy of the classifier.

Accuracy = trace / (matrix sum)
= (32 + 10 + 24)/100
= 66%

(c) (3 marks) Explain (in one or two sentences) why the confusion matrix is not consistent with the posterior pdfs shown in Figure 2.

The Confusion Matrix says 20 images of w3 are misclassified as w2. This is not possible since their pdfs do not overlap.

(d) (3 marks) Klas decides to use a different feature, y, for classification. This time, however, he is only able to estimate the class-conditional pdfs: $p(y \mid \omega_i)$, $i = 1, 2, 3$. To use the Bayes' Classifier, Klas needs to know the prior probabilities $p(\omega_i)$, $i = 1, 2, 3$. Help him to calculate these from the confusion matrix.

p(w1) = 0.39
p(w2) = 0.17
p(w3) = 0.44

(e) (2 marks) With more experience, Klas now decides to capture 2 images (in quick succession) of a bird, so as to improve classification accuracy. As before, Klas computes one feature x from each image, giving him two features: x_1, x_2. But his pdfs remain unchanged: they are still single-feature pdfs, $P(x \mid \omega_i)$, $i = 1, 2, 3$, estimated from training data.

How should Klas combine both features? According to Bayes' theory, Klas should (circle the best answer):

A. compute $\arg\max_{\omega_i} P(\omega_i) \prod_{j=1}^{2} P(x_j \mid \omega_i)$**.**

B. compute $\arg\max_{\omega_i} P(\omega_i) \sum_{j=1}^{2} P(x_j \mid \omega_i)$.

C. compute $\arg\max_{\omega_i} P(\omega_i \mid \frac{x_1+x_2}{2})$.

D. compute $\arg\max_{\omega_i} P(\frac{x_1+x_2}{2} \mid \omega_i)$.

E. None of the above.

END OF PAPER