**Written exam, December 14, 2016**

Course name: Image analysis  
Course number: 02502  
Aids allowed: All aids allowed. Laptop computer with Matlab required  
Duration: 4 hours  
Weighting: All questions are equally weighted  

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Possible answers to each question are numbered from 1 to 6. The chosen number of the answer must be entered in the table above. In case you enter an incorrect number in the table this may be corrected by "inking out" the wrong number and instead placing the correct number below. Should there be any doubts in connection with a correction, the question will be considered as not answered. **ONLY THE FRONT PAGE IS TO BE HANDED-IN.**

If you decide to make a blank hand-in or leave the examination prematurely the front page must in all circumstances be handed-in. Rough drafts, calculations and comments will not be included in the evaluation. Only numbers included in the above table will be registered.

A correct answer will be equivalent to 5 points. An incorrect answer will be equivalent to -1 points. Questions unanswered as well as answer number six (equivalent to "do not know") will not produce points. The number of points required for a satisfactorily answered exam is finally determined by teacher during evaluation.

Please don't forget to state your name, signature and desk number on the paper.
QUESTION 16.1

When you fit a second-order polynomial

\[ p_2(x, y) = a \cdot x^2 + b \cdot y^2 + c \cdot x \cdot y + d \cdot x + e \cdot y + f \]

to pixel values in a 3x3 neighborhood with equal weighting then you get the following LSI filters for the 6 parameters

What is the value of the polynomial in the marked pixel below when the above fit is used?

1. 2.33
2. 2.5
3. 2.25
4. 2
5. 2.17
6. Do not know
In an image we apply a first-order polynomial transform that maps the point (-2,2) to (0,0), the point (4,1) to (2,3), and the point (1,5) to (0,7). Which point is mapped to (2,2)?

1. (2.39, 3.06)
2. (3.54, 3.33)
3. (2.01, 4.45)
4. (2.92, 0.81)
5. (3.57, 0.57)
6. Do not know
On the set $X$ of black pixels in the above image we apply the morphological operation

$$(X \otimes A) \cup (X \otimes B) \cup (X \otimes C),$$

where

A=

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B=

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C=

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Boundary conditions are white pixels around the image. How many black pixels are there in the output image?

1. 15
2. 17
3. 19
4. 21
5. 23
6. Do not know
On the 6x6 image above we apply the following sequence of operations:

1. A linear mapping with positive gain such that minimum is 0 and maximum is 1 in the output image.
2. A hyperbolic paramg with k=3.
3. A histogram covering the interval [0;1] is made with 5 equidistant bins with the following intervals: [0;0.2], [0.2;0.4], [0.4;0.6], [0.6;0.8], [0.8;1].

What is the pixel count in the bin with the second-largest number of pixels?

1. 10
2. 12
3. 14
4. 15
5. 16
6. Do not know
QUESTION 16.5

In a classification problem with 2 populations we measure a twodimensional feature vector. Feature distributions are given by

1. \[ N \left( \begin{pmatrix} 1 \\ 2 \\ 1 \\ 4 \end{pmatrix} \right) \]

2. \[ N \left( \begin{pmatrix} 3 \\ 1 \\ 2 \\ 1 \\ 4 \end{pmatrix} \right) \]

The loss function is symmetric and prior probabilities are equal. How many of the following 5 observations are classified as belonging to population 1 by a Bayesian classifier?

\[ \begin{pmatrix} 3 \\ -1 \\ 2 \\ 0 \\ 3 \\ 3 \\ 3 \\ 4 \\ 1 \\ -3 \end{pmatrix} \]

1. 1
2. 2
3. 3
4. 4
5. 5
6. Do not know
What is the value of the marked pixel after filtering the above image with a black tophat filter using a 5-cross structuring element?

1. 1
2. 2
3. 3
4. 4
5. 5
6. Do not know
QUESTION 16.7

A camera has the following specifications:

CMOS-chip

- Resolution: 4096 pixels horizontally * 3000 pixels vertically
- Pixel size: 3.45 μm * 3.45 μm
- Pixel distance: 3.45 μm (center to center)

The camera is mounted with a working distance of 450 mm above a horizontal table. The camera is pointed at the table with an optical axis perpendicular to the table surface. The focal length of the lens is 50 mm. What is the vertical field-of-view?

1. 69.11 mm
2. 75.00 mm
3. 88.77 mm
4. 93.15 mm
5. 105.67 mm
6. Do not know
QUESTION 16.8

After filtering of the above input image we obtain the output image below. Pixels outside the image is set to zero.

Which of the following filters has been used?

1. 3x3 median filter
2. 5x5 median filter
3. 3x3 range filter
4. 5x5 mean filter
5. 3x3 local max filter
6. Do not know
QUESTION 16.9

Which of the following statements is wrong?

1. Morfological thickening is idempotent

2. LSI filter are linear operations

3. A n x n mean filter is separable

4. A morphological opening is independent of the location of the origo of the structuring element

5. Row sums of the image may be used to detect horizontal stripes

6. Do not know
QUESTION 16.10

What is the gray level skewness of the 4x4 gray level image below? (Hint: use the definition of gray level variance in the texture note when you calculate skewness.)

```
1 1 1 2
1 0 0 2
2 3 3 3
2 3 3 0
```

1. -0.34
2. -0.20
3. -0.11
4. 0
5. 0.12
6. Do not know
QUESTION 16.11

What is Eccentricity for the above black object, when it is calculated by Matlab?

1. 0.65
2. 0.76
3. 0.81
4. 0.87
5. 0.90
6. Do not know
QUESTION 16.12

In the image below X is the set of black pixels. Pixels outside the image field are assumed white.

![Image](image.png)

We apply an opening on X with the following structuring element:

![Structuring Element](image.png)

How many connected components (4-connectivity) are there in the output image?

1. 1
2. 2
3. 3
4. 4
5. 5
6. Do not know
QUESTION 16.13

How many of these 10 RGB værdier has a saturation of 1.0?

(0, 0, 1)
(1, 1, 1)
(0, 1, 0)
(0, 1, 1)
(1, 0, 0, 1)
(1, 1, 0)
(0, 0, 0)
(1, 0.5, 0)
(0.5, 0.5, 1)
(0.1, 0, 1)

1. 1
2. 2
3. 3
4. 4
5. 5
6. Do not know
QUESTION 16.14

We want to send a light beam from air into a planar diamant. Which angle of incidence should we use to obtain a refracted beam with an angle of 24 degrees?

1. 55.55 degrees
2. 67.15 degrees
3. 79.83 degrees
4. 85.58 degrees
5. 88.10 degrees
6. Do not know
The above image is transformed with a geometric transformation. The 'Input-to-output' transformation is first-order and given by:

\[
\begin{align*}
x' &= x + 2.2 \\
y' &= y - 1.5
\end{align*}
\]

What is the value of pixel position \((x', y') = (5.7, 1.3)\) in the transformed image, when bilinear resampling is used in the input image?

1. 1.5
2. 1.8
3. 1.9
4. 2.0
5. 2.25
6. Do not know
**QUESTION 16.16**

What is result in the marked pixel above when performing a 3x3 rank filter with the following RLC vector?

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

1. 12
2. 10
3. 9
4. 7.5
5. 6
6. Do not know
QUESTION 16.17

We perform a chamfer-1-1.3 distance transformation on the white pixels in the image above. What is the output value of the pixel marked with a "?"?

1. 3.9
2. 4
3. 4.2
4. 4.3
5. 4.6
6. Do not know
QUESTION 16.18

Which of the following Matlab scripts calculates the focal length from the sensor dimensions (SW,SH) and the diagonal angle-of-view AD?

1. 
   ```matlab
   function f=myfunction(SW,SH,AD)
   f=0.5*cos(AD)*(SW/SH);
   return
   ```

2. 
   ```matlab
   function f=myfunction(SW,SH,AD)
   f=tan(SW^2+SH^2)/tan(AD/2);
   return
   ```

3. 
   ```matlab
   function f=myfunction(SW,SH,AD)
   f=sqrt(SW^2+SH^2)/(2*tan(AD/2));
   return
   ```

4. 
   ```matlab
   function f=myfunction(SW,SH,AD)
   f=(tan(AD)*sqrt(SW^2+SH^2))/cos(AD);
   return
   ```

5. 
   ```matlab
   function f=myfunction(SW,SH,AD)
   f=SW*acos(sqrt(SW^2+SH^2)/SH);
   return
   ```

6. Do not know
QUESTION 16.19

Which output `out` is calculated by the following Matlab script on the input image `im`, that is a binary image with pixel values 0 (background) or 1 (foreground)?

```matlab
function out=myfunction(im)
    L=bwlabel(im);
    stats=regionprops(L, 'Area','MajorAxisLength','Eccentricity');
    statlist = [cat(1, stats.Area) cat(1,stats.MajorAxisLength)];
    [Y,I] = max(statlist(:,1));
    [Y,J] = max(statlist(:,2));
    out=(L==I) | (L==J);

    return
```

1. An output image with only the connected component of `im` that has largest eccentricity
2. An output image, where both the longest and the largest by area connected component in `im` has been removed
3. An output image, with only the longest and the largest by area connected components in `im`
4. A histogram of connected component lengths and areas in `im`
5. Length, area, and eccentricity of the largest connected component in `im`
6. Do not know
QUESTION 16.20

Which of the following statements is wrong?

1. An optical filter made by putting two filters with absorption A in sequence has the resulting absorption of 2*A.

2. The built-in flash in a camera normally gives an illumination of type brightfield frontlight

3. Blue light has a higher frequency than red light

4. The angle of refracted light is smaller than the angle of incidence, when light is sent from air to a material with a refractive index above 1

5. Brightfield backlight is used to see surface texture in a sample

6. Do not know
The above image is segmented with a watershed using 4-connectivity for watershed regions (aka catchment areas). How many catchment areas are there in the result?

1. 9
2. 7
3. 0
4. 3
5. 5
6. Do not know
QUESTION 16.22

We have 5 normally distributed populations:

1. \( N \left( \begin{pmatrix} 2 \\ 0 \end{pmatrix}, \begin{pmatrix} 4 & 2 \\ 2 & 3 \end{pmatrix} \right) \)
2. \( N \left( \begin{pmatrix} 3 \\ 1 \end{pmatrix}, \begin{pmatrix} 4 & 2 \\ 2 & 3 \end{pmatrix} \right) \)
3. \( N \left( \begin{pmatrix} 1 \\ 3 \end{pmatrix}, \begin{pmatrix} 4 & 2 \\ 2 & 3 \end{pmatrix} \right) \)
4. \( N \left( \begin{pmatrix} 3 \\ 2 \end{pmatrix}, \begin{pmatrix} 4 & 2 \\ 2 & 3 \end{pmatrix} \right) \)
5. \( N \left( \begin{pmatrix} 1 \\ 1 \end{pmatrix}, \begin{pmatrix} 4 & 2 \\ 2 & 3 \end{pmatrix} \right) \)

Prior probabilities for population 1 to 5 are respectively 0.1, 0.2, 0.2, 0.2, and 0.3. Equal losses are assumed. To which of the 5 classes is the point \( \begin{pmatrix} 2 \\ 1.7 \end{pmatrix} \) classified by a Bayes classifier? (Hint: use Matlab)

1. 1
2. 2
3. 3
4. 4
5. 5
6. Do not know
QUESTION 16.23

Which of the following statements is wrong?

1. Emitted light during fluorescence has a lower frequency than the light absorbed

2. A watershed transformation together with the Matlab function imimposemin can implement a marker-based watershed transformation

3. The spatial dispersion matrix has eigenvalues larger than or equal to 0

4. A Bayes classifier is defined by minimization of the maximal loss

5. Morphological erosion is not commutative

6. Do not know
QUESTION 16.24

By filtering the above image with the 3x3 LSI filter:

\[
\begin{bmatrix}
-1 & 2 & -1 \\
2 & 3 & 2 \\
-1 & 2 & -1 \\
\end{bmatrix}
\]

using 0 pixels as boundary condition we obtain the following output image:

\[
\begin{array}{cccccc}
-1 & 0 & 1 & 1 & 0 & -1 \\
0 & 9 & 11 & 14 & 8 & 0 \\
0 & 11 & 23 & 12 & 17 & 0 \\
3 & 18 & 26 & 22 & 15 & 0 \\
-1 & 14 & 33 & 27 & 27 & 5 \\
-1 & -3 & 4 & 1 & 3 & -4 \\
\end{array}
\]

Find the value of the pixel marked with "?" in the input image. The value is

1. 1
2. 2
3. 3
4. 4
5. 5
6. Do not know
QUESTION 16.25

For the texture below we calculate a cooccurrence matrix for the displacement \( \mathbf{h}=(3,0) \).

\[
\begin{array}{cccc}
3 & 2 & 1 & 1 \\
2 & 3 & 2 & 1 \\
1 & 2 & 2 & 2 \\
2 & 2 & 1 & 1 \\
3 & 2 & 2 & 3 \\
3 & 3 & 2 & 2 \\
\end{array}
\]

The cooccurrence matrix is:

1. 
\[
\begin{array}{ccc}
1 & 2 & 3 \\
1 & 2 & 1 \\
2 & 0 & 5 \\
3 & 1 & 2 \\
\end{array}
\]

2. 
\[
\begin{array}{ccc}
1 & 2 & 3 \\
1 & 2 & 2 \\
2 & 1 & 4 \\
3 & 2 & 1 \\
\end{array}
\]

3. 
\[
\begin{array}{ccc}
1 & 2 & 3 \\
1 & 2 & 4 \\
2 & 2 & 2 \\
3 & 1 & 1 \\
\end{array}
\]

4. 
\[
\begin{array}{ccc}
1 & 2 & 3 \\
1 & 2 & 1 \\
2 & 2 & 4 \\
3 & 2 & 2 \\
\end{array}
\]

5. 
\[
\begin{array}{ccc}
1 & 2 & 3 \\
1 & 2 & 3 \\
2 & 1 & 4 \\
3 & 2 & 2 \\
\end{array}
\]

6. Do not know