Berlin University of Technology

Computer Vision & Remote Sensing

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Final Examination

Digital Image Processing

Winter term 2018/19

Name:.. **Student ID number:**...............

Auxiliary resources: None

A Februar 11th, 2019

DO NOT OPEN THIS EXAMINATION SHEET UNTIL YOU ARE TOLD TO DO SO!

Write your **name** and **student ID** in the corresponding places at the top of this page **now**. Books, notes, dictionaries, own empty sheets of paper, and pocket calculators are **not allowed**. **Use only a pen**. Everything written with a pencil will not be taken into account.

If you do not understand a question, **please ask**. It will be to your advantage to read the entire examination before beginning to work.

The exam is a **multiple choice** test. For each question there is at least **one and at most four** correct answers. The number of points p for a single correct answer are stated next to the question. Please note, that there is a **penalty of -p/2 points** for a wrong answer, while by giving no answer points are neither gained nor lost (i.e. no penalty for not giving an answer). The minimal number of points for each question is 0 (i.e. no negative points for whole questions).

Example:

	Which of the following numbers is even?				**2 P**
	i) 2	**ii) 3**	**iii) 4**	**iv) 5**	
Example 1			**X** (correct +2P)		Result: 2P
Example 2		**X** (incorrect -1P)	**X** (correct +2P)		Result: 1P
Example 3	**X** (correct +2P)		**X** (correct +2P)		Result: 4P
Example 4		**X** (incorrect -1P)			Result: 0P

Notation:

Angles are defined counter clock-wise.

Black = Gray level of 0; White = Gray level of 255 (or 1 for binary images)

Lots of luck and do your best!

Please use this table to denote your answers by making a cross ("X") in the column corresponding to your answer. If you want to correct a falsely given answer, strike the entire line through and use the empty rows at the end of the table.

Question	i)	ii)	iii)	iv)
1.				
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Total:
76 points

Block 1

Question 1: (1 P)

Oversegmentation means that ...

i) ... segment boundaries are likely to be a subset of object boundaries.
ii) ... a subsequent segment splitting might be beneficial.
iii) ... object boundaries are likely to lie within segments.
iv) ... object boundaries are likely to be a subset of segment boundaries.

Question 2: (2 P)

The following image **f** shall be segmented by **Optimal Thresholding** (as introduced in the lecture). The initial background pixels are marked in bold.
Which is the threshold T_0 defined by Optimal Thresholding in the very first iteration?

$$\mathbf{f} = \begin{bmatrix} \mathbf{10} & 12 & 10 & 11 & \mathbf{10} \\ 11 & 9 & 109 & 9 & 12 \\ 10 & 9 & 115 & 9 & 10 \\ \mathbf{12} & 11 & 10 & 11 & \mathbf{12} \end{bmatrix}$$

i) 112	ii) 17	iii) 11	iv) 23

Question 3: (1 P)

The clustering method **kMeans** (as defined in the lecture) ...

i) ... provides an estimate for the optimal number of clusters.
ii) ... minimizes the Euclidean distance between the center of each cluster and the samples assigned to it.
iii) ... does always find the same solution if the same data is provided.
iv) ... does always converge.

Question 4: (1 P)

Given a grayscale image **f**, its gradient $\nabla\mathbf{f}$, and a parametrized curve $\mathbf{v}(s), s \in [0,1]$ defined over the image coordinates, which of the following is an example term for the internal energy of the **active contour v**?

i) $\left\lvert \frac{d\mathbf{v}}{ds} \right\rvert^2$	ii) $-\lvert \nabla f(x,y) \rvert^2$	iii) $\left\lvert \frac{d^2\mathbf{v}}{ds^2} \right\rvert^2$	iv) $f(x,y)$

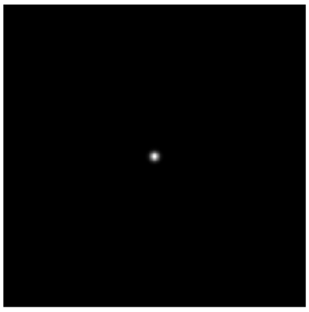
Block 2

Question 5: (1 P)

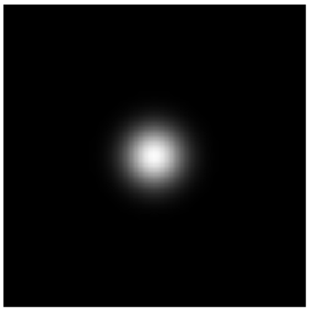
In the context of the **discrete Fourier transformation** (as introduced in the lecture), a discrete spectrum implies a . . .

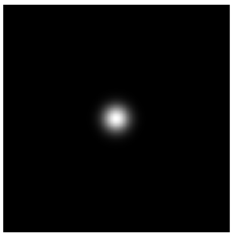
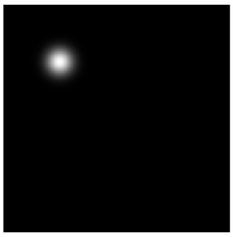
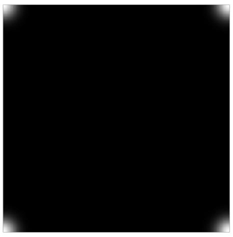
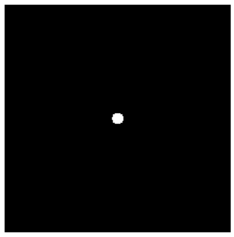
i) . . . a symmetric signal.	ii) . . . a discrete signal.
iii) . . . a periodic spectrum.	iv) . . . periodic signal.

Question 6: (1 P)

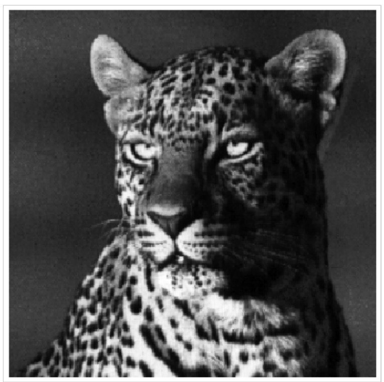


The image on the left shows the **amplitude spectrum** of which of the following images? Note: The image on the right shows a zoom-in to the $(0, 0)$-position of the given spectrum.



i) 	ii) 	iii) 	iv) 

Question 7: (1 P)



The image on the right is the result of applying which of the following **filters** to the image on the left?

i) . . . Gaussian filter.	ii) . . . ideal lowpass filter.
iii) . . . Butterworth highpass filter.	iv) . . . ideal highpass filter.

Block 3

In the following, let f, g be input and output images (i.e. binary images if not stated otherwise) and h a structuring element. The operations $\hat{()}$, $()_p$, and $()^c$ correspond to reflection, shift, and complement as defined in the lecture. Dilation and erosion operations are denoted by $\oplus$ and $\ominus$, respectively.

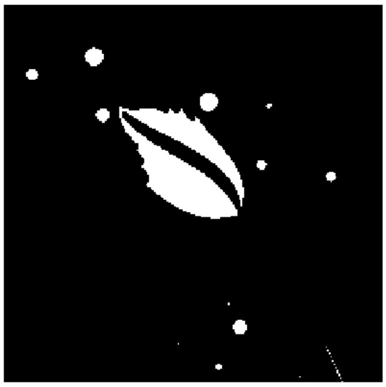
Question 8: (1 P)

The **top-hat transform** of a grayscale image f is defined as:

i)	ii)	iii)	iv)
$((f \oplus h) \ominus h) - f$	$f - ((f \ominus h) \oplus h)$	$f - (f \ominus h)$	$(f \oplus h) - f$

Question 9: (1 P)

The image on the right is the result of applying which of the following transformations to the image on the left?



i) A morphological closing.	ii) A morphological opening.
iii) A morphological dilation.	iv) A morphological erosion.

Question 10: (1 P)

The output of **Ultimate Erosion** ...

i) ... is the inner boundary of the foreground objects.	ii) ... is the outer boundary of the foreground objects.
iii) ... are regional maxima of the distance transform.	iv) ... are regional minima of the distance transform.

Question 11: (1 P)

Grayscale erosion of a grayscale image f is defined as

i) $(f \ominus h)(x,y) = \max_{(i,j)\in h_{x,y}} (f(i,j))$	ii) $f \ominus h = f - (f \otimes h)$
iii) $f \ominus h = (f \otimes h) - f$	iv) $(f \ominus h)(x,y) = \min_{(i,j)\in h_{x,y}} (f(i,j))$

Question 12: (1 P)

Dilation is defined as ...

i)	ii)
$g = \{p \mid \hat{h}_p \cap f \neq \emptyset\}$	$g(x,y) = \wedge_{i,j \in \mathbf{h}_{x,y}} (h(i,j) \wedge f(x-i, y-j))$
iii)	**iv)**
$g = \{p \mid h_p \subset f\}$	$g(x,y) = \vee_{i,j \in \mathbf{h}_{x,y}} (h(i,j) \wedge f(x-i, y-j))$

Question 13: (1 P)

If the structuring element h is **symmetric**, which of the following statements is correct?

i)	ii)	iii)	iv)
$(f \oplus h)^c = f^c \oplus h$	$(f \ominus h)^c = f^c \ominus h$	$(f \ominus h)^c = f^c \oplus \hat{h}$	$(f \oplus h)^c = f^c \ominus h$

Question 14: (1 P)

Morphological **opening** is defined as:

i)	ii)	iii)	iv)
$(f \oplus h) \setminus f$	$f \setminus (f \ominus h)$	$(f \oplus h) \ominus h$	$(f \ominus h) \oplus h$

Question 15: (1 P)

Which case does most likely denote a **keypoint**?

i) Both eigenvalues of the structure tensor are close to 0.
ii) One eigenvalue of the structure tensor is close to 0.
iii) The product of the eigenvalues is much larger than their sum.
iv) No eigenvalue of the structure tensor is close to 0.

Question 16: (1 P)

Given the structure tensor A (and a scalar k), the isotropy of the **Förstner point detector** is computed as:

i) $\frac{4det(A)}{tr^2(A)}$	ii) $\frac{det(A)}{tr(A)}$	iii) $\frac{tr(A)}{det(A)}$	iv) $det(A) - k \cdot tr^2(A)$

Question 17: (1 P)

Given a grayscale image $\mathbf{f}$, its 1st derivative in x- and y-direction $\mathbf{g}_x$, $\mathbf{g}_y$, as well as its 2nd derivatives $\mathbf{g}_{xx}$, $\mathbf{g}_{xy}$, $\mathbf{g}_{yx}$, and $\mathbf{g}_{yy}$, which of the following is the **structure tensor** $A(x,y)$ at point (x,y)?
Note: $W(x,y)$ is a local window around (x,y).

i)

$$A(x,y) = \sum_{i,j \in W(x,y)} \begin{bmatrix} g_{xx}(i,j)g_{xx}(i,j) & g_{xy}(i,j)g_{yx}(i,j) \\ g_{yx}(i,j)g_{xy}(i,j) & g_{yy}(i,j)g_{yy}(i,j) \end{bmatrix}$$

ii)

$$A(x,y) = \sum_{i,j \in W(x,y)} \begin{bmatrix} g_x(i,j) & g_y(i,j) \\ g_y(i,j) & g_x(i,j) \end{bmatrix}$$

iii)

$$A(x,y) = \sum_{i,j \in W(x,y)} \begin{bmatrix} g_{xx}(i,j) & g_{xy}(i,j) \\ g_{yx}(i,j) & g_{yy}(i,j) \end{bmatrix}$$

iv)

$$A(x,y) = \sum_{i,j \in W(x,y)} \begin{bmatrix} g_x(i,j)g_x(i,j) & g_x(i,j)g_y(i,j) \\ g_y(i,j)g_x(i,j) & g_y(i,j)g_y(i,j) \end{bmatrix}$$

Block 5

Question 18: (1 P)

Average filters ...

i) ... introduce zero shift.	ii) ... have filter kernels that integrate to one.
iii) ... preserve the mean value.	iv) ... are isotropic.

Question 19: (1 P)

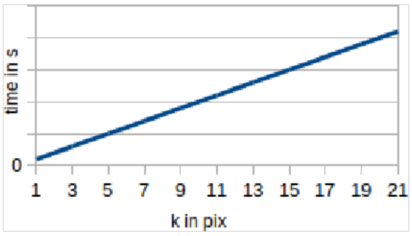
The application of which of the following filters can be carried out by applying the **convolution theorem**?

i) Median filter.	ii) A filter with kernel $\mathbf{k} = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$
iii) A box filter of size 3×7.	iv) A Gaussian filter of size 5×5.

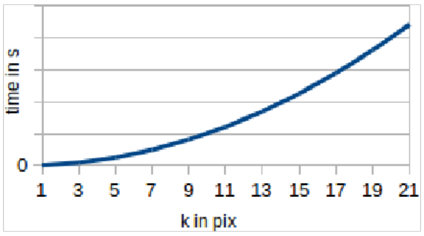
Question 20: (1 P)

Given different filter kernels of size $k \times k$, which of the following graphs corresponds to the time complexity of applying the concept of **separable filters** during the convolution of two signals in spatial domain?

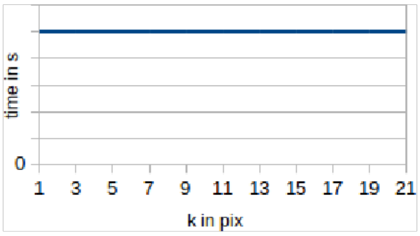
i)



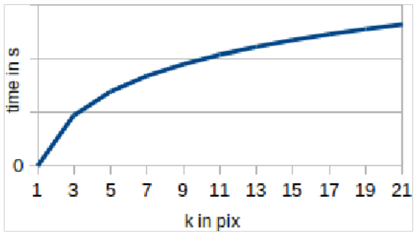
ii)



iii)



iv)



Question 21: (1 P)

The application of which of the following filters can be carried out by applying the concept of **separable filters**?

i) A filter with kernel $\mathbf{k} = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$	ii) A Gaussian filter of size 5×5.
iii) A box filter of size 3×7.	iv) Median filter.

Question 22: (1 P)

Let $\mathbf{f}, \mathbf{g}$ be two signals (of equal size) with the corresponding frequency spectra $\mathbf{F}, \mathbf{G}$. Convolution is denoted by $\otimes$, point-wise multiplication is denoted by $\cdot$, and complex conjugation by $()^*$. Which of the following is the **reverse convolution theorem**?

i) $\mathbf{f} \otimes \mathbf{g} \Leftrightarrow \mathbf{F} \cdot \mathbf{G}^*$	ii) $\mathbf{f} \cdot \mathbf{g} \Leftrightarrow \mathbf{F} \otimes \mathbf{G}$	iii) $\mathbf{f} \cdot \mathbf{g} \Leftrightarrow \mathbf{F} \otimes \mathbf{G}^*$	iv) $\mathbf{f} \otimes \mathbf{g} \Leftrightarrow \mathbf{F} \cdot \mathbf{G}$

Question 23: (1 P)

The application of which of the following filters can be carried out by applying the concept of **integral images**?

i) Median filter.	ii) A box filter of size 3×7.
iii) A Gaussian filter of size 5×5.	iv) A filter with kernel $\mathbf{k} = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$

Question 24: (1 P)

Let **g** be the measured image, **f** the undistorted image, **h** the kernel of the degredation, and **n** a noise term. Which of the following signal models would cause the **inverse filter** to completely fail (if no proper countermeasures are applied)? Note: $\otimes$ denotes convolution and $\cdot$ point-wise multiplication.

i) $g = (h \otimes f) \cdot n$	ii) $g = h \otimes f + n$	iii) $g = h \otimes (f + n)$	iv) $g = h \otimes f$

Question 25: (1 P)

The **Wiener filter** assumes that ...

i) ... the image degradation is an isotropic blur.	ii) ... there is no noise in the image.
iii) ... the image degradation can be modelled as a convolution.	iv) ... image and noise are uncorrelated.

Question 26: (1 P)

Given a measured image **g** and a degredation **h** (with their respective Fourier spectra **G** and **H**) as well as a real-valued scalar T, the **clipped inverse filter** computes the spectra **E** of the restored image **e** as ...
Note: $()^*$ denotes complex conjugation.

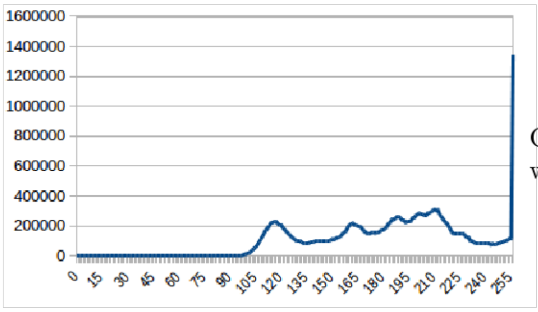
i) $E(u,v) = \frac{G(u,v)}{H(u,v)}$	ii) $E(u,v) = \frac{G(u,v)H^*(u,v)}{H(u,v)H^*(u,v) + T}$
iii) $E(u,v) = \begin{cases} \frac{G(u,v)}{H(u,v)} & \text{, if } \lvert H(u,v) \rvert > 0 \\ 0 & \text{, otherwise.} \end{cases}$	iv) $E(u,v) = \begin{cases} \frac{G(u,v)}{H(u,v)} & \text{, if } \lvert H(u,v) \rvert > T \\ \frac{G(u,v)}{T} & \text{, otherwise.} \end{cases}$

Question 27: (1 P)

Which of the following **homographies H** performs a translation followed by a rotation followed by a scaling (denoted by transformation matrices **T**, **R**, and **S**, respectively) when multiplied to a column vector **x**?

i) $\mathbf{H} = \mathbf{T} \cdot \mathbf{S} \cdot \mathbf{R}$	ii) $\mathbf{H} = \mathbf{S} \cdot \mathbf{T} \cdot \mathbf{R}$	iii) $\mathbf{H} = \mathbf{T} \cdot \mathbf{R} \cdot \mathbf{S}$	iv) $\mathbf{H} = \mathbf{S} \cdot \mathbf{R} \cdot \mathbf{T}$

Question 28: (1 P)



Given the **absolute grayscale histogram** of an image on the left, which of the following statements is correct?

i) The image is large, i.e. has more than 10 mega-pixel.	ii) The image has a rather high contrast.
iii) The image is oversaturated.	iv) The image is rather dark.

Question 29: (1 P)

Assume matrix **M** is used to **transform** a set of 2D image coordinates **x** into another set of coordinates **x′** by $\mathbf{x}' = \mathbf{M} \cdot \mathbf{x}$. Which of the following matrices performs a shearing transformation?

i) $M = \begin{bmatrix} 1 & 0 & 2 \\ 0 & 1 & 2 \\ 0 & 0 & 1 \end{bmatrix}$	ii) $M = \begin{bmatrix} 1 & 2 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	iii) $M = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	iv) $M = \begin{bmatrix} 2 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

Question 30: (1 P)

Applying a **log-function** to an image performs a ...

i) ... contrast enhancement of dark regions.	ii) ... contrast enhancement of bright regions.
iii) ... contrast compression of dark regions.	iv) ... contrast compression of bright regions.

Question 31: (2 P)

Convolving the image **s** given below (with $s(i,j) \in [0,255], 0 \le i,j < 3$) with the Scharr operator (kernel **k** given below) produces the output image **o**. Which value has the center pixel $o(1,1)$ of this output image? Note: As border handling mirroring should be applied.

$$\mathbf{s} = \begin{bmatrix} 10 & 40 & 100 \\ 10 & 40 & 100 \\ 10 & 40 & 100 \end{bmatrix} \quad , \quad \mathbf{k} = \begin{bmatrix} -3 & 0 & 3 \\ -10 & 0 & 10 \\ -3 & 0 & 3 \end{bmatrix} \tag{1}$$

i) $o(1,1) = -1440$	ii) $o(1,1) = 1760$	iii) $o(1,1) = 1440$	iv) $o(1,1) = 0$

Question 32: (1 P)

Which of the following is a possible kernel for the **Laplace operator**?

i) $\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$	ii) $\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$	iii) $\begin{bmatrix} 1 & 1 & 1 \\ -1 & -1 & -1 \\ 1 & 1 & 1 \end{bmatrix}$	iv) $\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$

Question 33: (2 P)

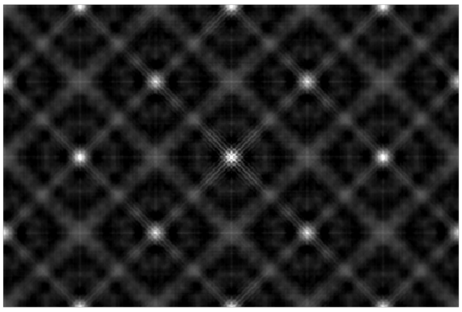
Given the following two images, **f** and **g**, as well as an operator T that can be modelled as **convolution** with kernel **k**, which of the following is the result **s** of $\mathbf{s} = 3 \cdot T[\mathbf{f}] + 2 \cdot T[\mathbf{g}]$? Note: Assume zeros outside of the image borders.

$$\mathbf{f} = \begin{bmatrix} 2 & 4 & -2 \\ -2 & 4 & 2 \\ 2 & 4 & -2 \end{bmatrix} \quad , \quad \mathbf{g} = \begin{bmatrix} -3 & -6 & 3 \\ 3 & -6 & -3 \\ -3 & -6 & 3 \end{bmatrix} \quad , \quad \mathbf{k} = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$$

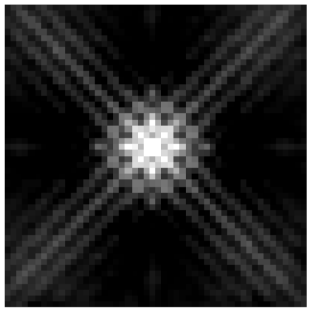
i) $\mathbf{s} = \begin{bmatrix} -72 & 24 & 72 \\ -96 & 0 & 96 \\ -72 & 24 & 72 \end{bmatrix}$	ii) $\mathbf{s} = \begin{bmatrix} 36 & -12 & -36 \\ 48 & 0 & -48 \\ 36 & -12 & -36 \end{bmatrix}$	iii) $\mathbf{s} = \begin{bmatrix} 72 & 24 & 72 \\ 96 & 0 & 72 \\ 72 & 24 & 96 \end{bmatrix}$	iv) $\mathbf{s} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$

Block 8

Question 34: (1 P)



The figure on the left shows the **autocorrelation function** of an image I (the figure on the right shows the central region in more detail). Based on this autocorrelation function, the texture in image I is ...



i) ... fine.	ii) ... random.
iii) ... coarse.	iv) ... regular.

Question 35: (1 P)

A common filterbank within the **texton** framework is the MR8 filterbank which involves the application of ...

i) ... 13 filters.	ii) ... 8 filters.	iii) ... 48 filters.	iv) ... 38 filters.

Question 36: (1 P)

GLCM are a texture analysis method that ...

i) ... applies a filterbank to a set of images and clusters the filter responses.
ii) ... counts how often two pixels with a predefined spatial offset show a certain combination of gray values.
iii) ... takes the spatial layout of pixel intensities into account.
iv) ... is based on local, one-dimensional gray-value histograms.

Block 9

Question 37: (1 P)

The **principal plane** in the **pinhole camera model** ...

i) ... is parallel to the image plane.	ii) ... contains principal point and camera center.
iii) ... contains the principal point.	iv) ... contains the projection center.

Question 38: (1 P)

What is the **principal distance** in the **pinhole camera model**?

i) The distance between camera projection center and principal plane.
ii) The distance between camera projection center and principal point.
iii) The distance between camera projection center and image plane.
iv) The distance between principal point and image plane.

Question 39: (1 P)

What is the **principal point** in the **pinhole camera model**?

i) The intersection of the principal ray with the principal plane.
ii) The center of the image.
iii) The origin of the image coordinate system.
iv) The intersection of the principal ray with the image plane.

Question 40: (1 P)

Image noise is often assumed to be **homogeneous**. This means ...

i) ... it follows the Gaussian distribution.	ii) ... it is modelled as being added to the signal.
iii) ... its statistics do not depend on the image position.	iv) ... its expected value is 0.

Question 41: (1 P)

The **projection matrix** maps a 3D point in world coordinates into a 2D point in image coordinates. It is a ...

i) ... 3×4 matrix.	ii) ... 3×3 matrix.	iii) ... 2×3 matrix.	iv) ... 3×2 matrix.

Question 42: (1 P)

A **standard digital** camera contains ...

i) ... an array of filters for colored light.	ii) ... an array of color-blind light sensors.
iii) ... a filter for white light.	iv) ... a filter for infra-red light.

Question 43: (1 P)

Which parameters belong to the **interior orientation** of the **pinhole camera model**?

i) The orientation angles of the camera.
ii) The rotation matrix between world and camera coordinate system.
iii) The position of the camera.
iv) The focal length of the camera.

Question 44: (1 P)

What is meant by **camera calibration**?

i) Estimating the intrinsic camera parameters of the camera.
ii) Using an image-based 3D reconstruction to measure the geometry of an object.
iii) Finding the optimal setting to acquire sharp and well exposed images.
iv) Setting the internal camera parameters so that image acquisition satisfies the needs of a 3D reconstruction.

Block 10

Question 45: (1 P)

A **wavelet** can be a ...

i) a sine wave.	ii) a cosine wave.
iii) a well localized oscilation.	iv) a sinc function.

Question 46: (1 P)

The **DCT-II** ...

i) ... uses both, sine and cosine waves, as basis functions.	ii) ... is often used for image compression.
iii) ... is a linear integral transform.	iv) ... leads to a complex-valued spectrum.

Question 47: (1 P)

Assume a given feature extraction methods computes 10 different feature values per pixel for a given image. The corresponding $10D$ feature vectors shall be further processed by applying **PCA** which computes a variance-covariance matrix with the following set of Eigenvalues $\lambda_i, 0 \leq i < 10$:

$$\{\lambda_0, \lambda_1, \lambda_2, \ldots, \lambda_9\} = \{1, 0, 10, 100, 220, 4, 90, 20, 2, 3\}$$

If the number of features shall be reduced from 10 to 3, which of the Eigenvectors $\mathbf{v}_i$ will be used?

i) $\mathbf{v}_4, \mathbf{v}_3, \mathbf{v}_6$	ii) $\mathbf{v}_1, \mathbf{v}_0, \mathbf{v}_8$	iii) $\mathbf{v}_7, \mathbf{v}_8, \mathbf{v}_9$	iv) $\mathbf{v}_0, \mathbf{v}_1, \mathbf{v}_2$

Use for your own notes, calculations, ...

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