Examination in
TDT4195 Visual Computing Fundamentals
Wednesday December 12, 2012
Time 09:00 – 13:00

THE EXAMINATION IS GIVEN IN ENGLISH ONLY!

Exam paper prepared by:
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Permitted facilities – code D:
No printed nor hand written material permitted.
Specified simple calculator permitted.

Examination results to be announced by: January 14

Answer all the **7** themes. Total maximum score is **100 points**.
Total Pages: **9**

- **Read all of the examination paper before starting answering**. Thus you may improve your chances for efficient time utilization and at the same time you may have more questions for the professors when they come on their rounds.
- **Give short and precise answers.**
- The questions of the part problems may most often be answered independently of each other.
- If you think the problem is insufficiently explained it may be wise to make assumptions. Possible assumptions have to be explained.

Image Processing (50%):

Theme 1 (Total 14 points): Short questions (Fundamentals)

1.1 **[1 point]** What is the blind spot in our eyes?

1.2 **[2 points]** Which discretizations take place when an image is captured by a digital image recording device (e.g camera)?

1.3 **[2 points]** Provide a binomial approximation of a 1D Gaussian filter with 4 (four) elements **and** give the appropriate normalization factor. How do the elements sum up after normalization?

1.4 **[2 point]** What is the main consequence from the fact that a 2D Gaussian filter (mask) is separable?

1.5 **[2 points]** What is padding used for in image processing? Name (or describe) four different options for the padding.

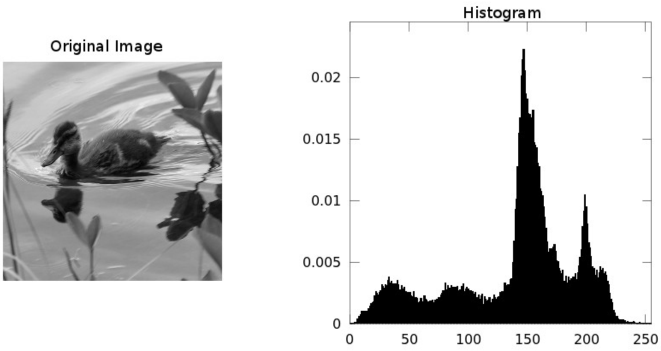
1.6 **[2 point]** What kind of image operation is performed by “unharp masking” ?

1.6 **[1 point]** If you compute the sum of elements of a derivative filter, what do you typically get as result?

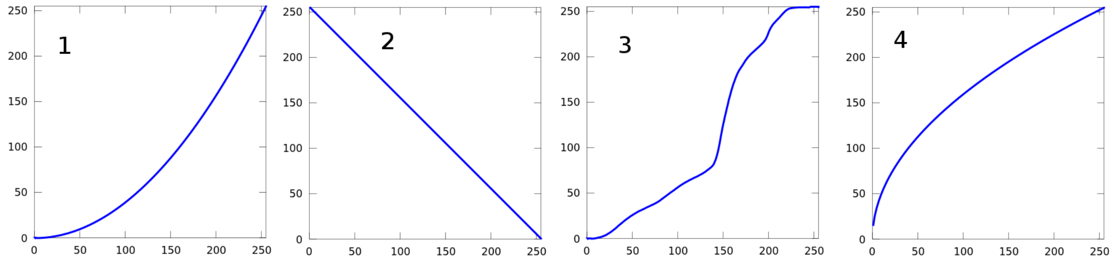
1.7 **[2 point]** Draw a typical histogram that corresponds to an underexposed histogram and one for an overexposed image.

Theme 2 (Total 12 points): Intensity Transformations

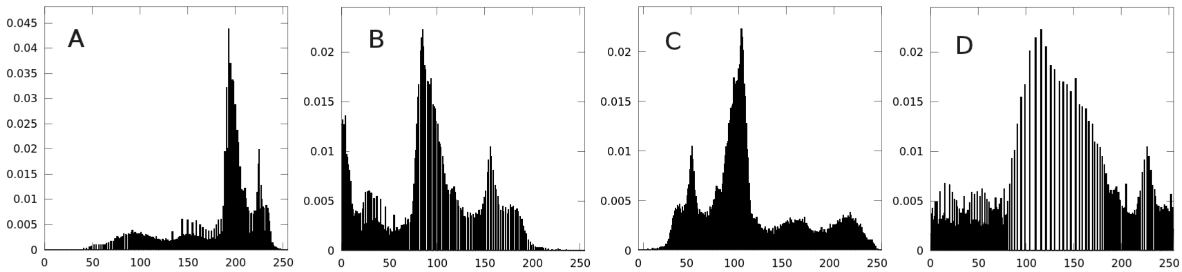
The following figure shows a gray-value image and its corresponding histogram



The following four (1 to 4) different intensity transformations have been applied to the image



2.1 **[2 points]** : Assign the histograms (A to D) that are shown below to the transformations (e.g. give the matching pairs 5E,6F ...).



2.2 **[3 points]** : Shortly indicate what these transformations do and how the resulting images look like in comparison to the original image.

2.3 **[2 points]** Sketch/Draw an intensity transformation that performs a thresholding (binarization) of a gray-value image at threshold T.

2.4 **[5 points]** : Give an algorithm (and/or formulas) that performs a histogram equalization on gray-value images of size N*N. (This can be done in a few lines!)

Theme 3 (Total 12 points): Morphology

3.1 **[2 points]** Determine the **erosion** $f \ominus s$ of the shown (6x6 pixels) binary image f (foreground pixels = 1) using the structuring element s drawn below the image. The reference pixel is indicated by a circle. (You can answer into the empty array)

0	0	0	0	0	0
0	0	0	1	1	0
0	0	0	1	0	0
0	1	1	1	0	0
0	1	1	1	0	0
0	0	0	0	0	0

Structuring Element

1	(1)	1

3.2 **[2 points]** Determine the **dilation** $f \oplus s$ of the shown binary image f (foreground pixels = 1) using the structuring element s below. The reference pixel is indicated by a circle. (You can answer into the empty array)

0	0	0	0	0	0
0	0	0	1	0	0
0	0	1	0	0	0
0	1	0	0	1	0
0	0	0	0	1	0
0	0	0	0	0	0

Structuring Element

	1	
1	(1)	1
	1	

3.3 **[2 points]** Define the morphological operations **opening and closing.**

3.4 **[1 point]** Determine the **opening** of the shown image. (you can answer into the empty array)

0	0	0	0	0	0
0	0	0	1	1	0
0	0	0	1	0	0
0	1	1	1	0	0
0	1	1	1	0	0
0	0	0	0	0	0

Structuring Element			
	1	(1)	1

3.5 **[3 points]** Describe or give a formula for a morphological method to obtain the boundary of binary objects.

3.6 **[2 points]** The operations opening and closing are **idempotent**. What is meant by that ?

Theme 4 (Total 12 points): Spatial Filtering

4.1 **[2 point]** Give an example for a 3x3 filter-mask that will smooth your image.

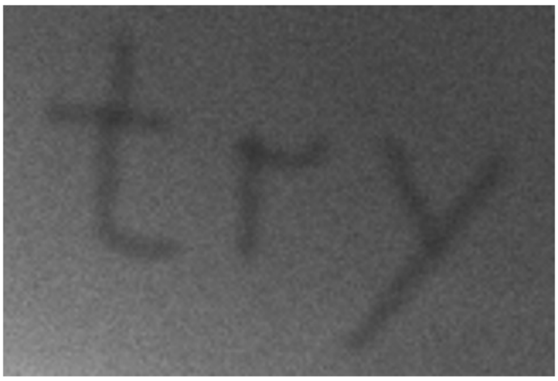
4.2 **[2 point]** When are convolution and correlation the same?

4.3 **[3 points]** Describe how you can compute the gradient and the gradient image $|\nabla|$ of an image. (Give also the filter masks.)

Recall: $\nabla = \begin{pmatrix} \frac{\partial}{\partial x} \\ \frac{\partial}{\partial y} \end{pmatrix}$

4.4 **[4 points]** You try to recognize handwritten characters and your first task is to compute binarized images from noisy source images as shown below. The background is not uniform and might show a gray-value gradient (e.g. bright in one part of the image and darker in other areas). Enumerate a few image processing steps that you think are necessary to obtain a binary image similar to the one shown on the right side below. Very briefly explain what you expect to obtain from each selected method (just one or two sentences per method).

Source Image



Aim Image

4.5 **[1 point]** Sketch how you think the histogram of the above shown low contrast “Source Image” looks like.

Graphics (50%):

Theme 5 (Total 30 points): Transformations

5.1 **[6 points, 7 points , 7 points]** Derive the 3D affine transformations necessary in order to transform object K :

$$K = [A\,B\,C\,D] = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

into each of the following objects (homogeneous coordinates, right-handed system):

$$\Sigma_1 = \begin{bmatrix} 0 & 0 & 0 & 3 \\ 0 & 0 & 2 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 \end{bmatrix} \quad \Sigma_2 = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 \end{bmatrix} \quad \Sigma_3 = \begin{bmatrix} 0 & 0 & 0 & 3 \\ 2 & 2 & 4 & 2 \\ 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

Briefly explain your answers. Drawing the objects could help you. The order of the vertices A-D in the above matrices **is** important.

5.2 **[10 points]** Suppose that we want to rotate by 45° object *K* (given above) about the axis specified by point **p** = (2,2,2) and vector $\vec{v}$ = (0,0,1). Determine the 3D homogeneous transformation matrix which expresses this transformation and give the coordinates of the transformed object.

Theme 6 (Total 10 points): Clipping

[10 points] The line segment defined by the endpoints **P_1**=(-1,7) and **P_2**=(4,2) is clipped against the clipping window defined by (x_{min},y_{min})=(0,0) and (x_{max},y_{max})=(6,6) using the Liang-Barsky algorithm. Spot the errors in the shaded part of the following execution of the algorithm.

$\Delta x = 5$, $\Delta y = -5$

$p_1 = -5$, $q_1 = -1$
$p_2 = 5$, $q_2 = 7$
$p_3 = 5$, $q_3 = 7$
$p_4 = -5$, $q_4 = -1$

$$t_{in} = max\left\{\frac{-1}{-5}, \frac{-1}{-5}, -1\right\} = \frac{1}{5}$$

$$t_{out} = max\left\{\frac{5}{7}, \frac{5}{7}, 1\right\} = 1$$

$P_{1\_CLIPPED}$ = $\frac{4}{5}$ (-1,7) + $\frac{1}{5}$ (4,2) = (0,6)

$P_{2\_CLIPPED}$ = 0 * (-1,7) + 1 *(4,2) = (4,2)

Theme 7 (Total 10 points): Antialiasing

A) **[3 points]** Give two possible appearances of aliasing in computer graphics.

B) **[3 points]** What is the theoretical reason behind aliasing?

C) **[4 points]** How much is the cost of creating a synthetic image increased by, if the post-filtering antialiasing method is applied? (Give a rough estimate, stating any assumptions. You may ignore the cost of averaging).