NTNU
Det skapende universitet

Examination in
TDT4195 Visual Computing Fundamentals
Monday May 21, 2012
Time 09:00 – 13:00

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: June 11

Answer all the 8 themes. Total maximum score is 100 points.

- 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 – Image Processing – Intensity Transformations (10%)

Explain the discrete form of histogram equalization and perform the transformation on the 64x64 image with 8 intensity levels (3-bit) and the intensity distribution given in table 1.

r_k	n_k
$r_0 = 0$	790
$r_1 = 1$	1023
$r_2 = 2$	850
$r_3 = 3$	656
$r_4 = 4$	329
$r_5 = 5$	245
$r_6 = 6$	122
$r_7 = 7$	81

Table 1: Intensity distribution

THEME 2 – Image Processing – Frequency Domain Filtering (10%)

Explain how filtering is performed in the frequency domain (basic steps), the most common filter types and one form of noise that easily can be removed using this method.

THEME 3 – Image Processing – Morphological Image Processing (10%)

1. Let A denote the set shown in figure 1. Refer to the structuring elements shown (the black dots denote the origin). Sketch the results of the following morphological operations:
   a. $(A \ominus B^4) \oplus B^2$ (Dilate (Erode A by B^4) by B^2)
   b. $(A \ominus B^1) \oplus B^3$ (Dilate (Erode A by B^1) by B^3)
   c. $(A \oplus B^1) \oplus B^3$ (Dilate (Dilate A by B^1) by B^3)
   d. $(A \oplus B^3) \ominus B^2$ (Erode (Dilate A by B^3) by B^2)
2. What do we mean by opening and closing?

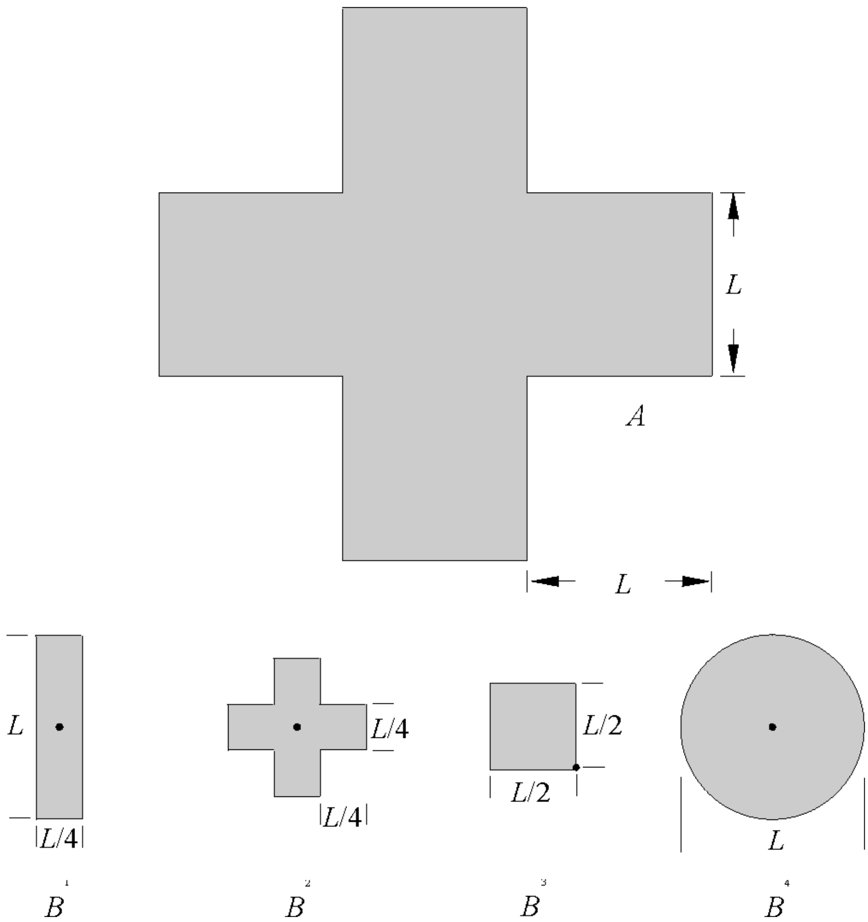

Figure 1: Object A and different structuring elements B1-B4 (from left to right).

THEME 4 – Image Processing – Image Segmentation (10%)

1. Given the edge models shown in figure 2. Sketch the gradient and Laplacian of each profile.
2. Explain the Hough transform and develop a general procedure for obtaining the normal representation of a line from its slope-intercept form y = ax + b.

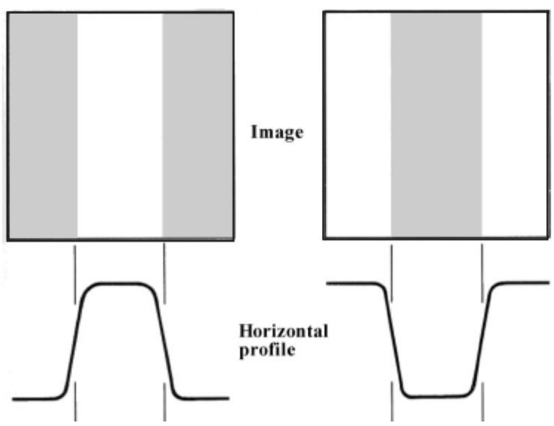

Figure 2: Edge models

THEME 5 – Image Processing - Surveillance system (10%)

An automatic system for pier monitoring is to be implemented. The system should be able to detect intruders (tips: change/motion) after everybody has gone home for the day (surveillance) and discriminate between a vehicle and a human. List all the high level steps (pseudo-code) that are necessary for achieving such a system, e.g. digital_image_t = AcquireSampleAndQuantitate (camera), together with a small description of it's content. Figure 3 shows the fundamental steps in digital image processing (DIP); most steps would be necessary to realize such a system.

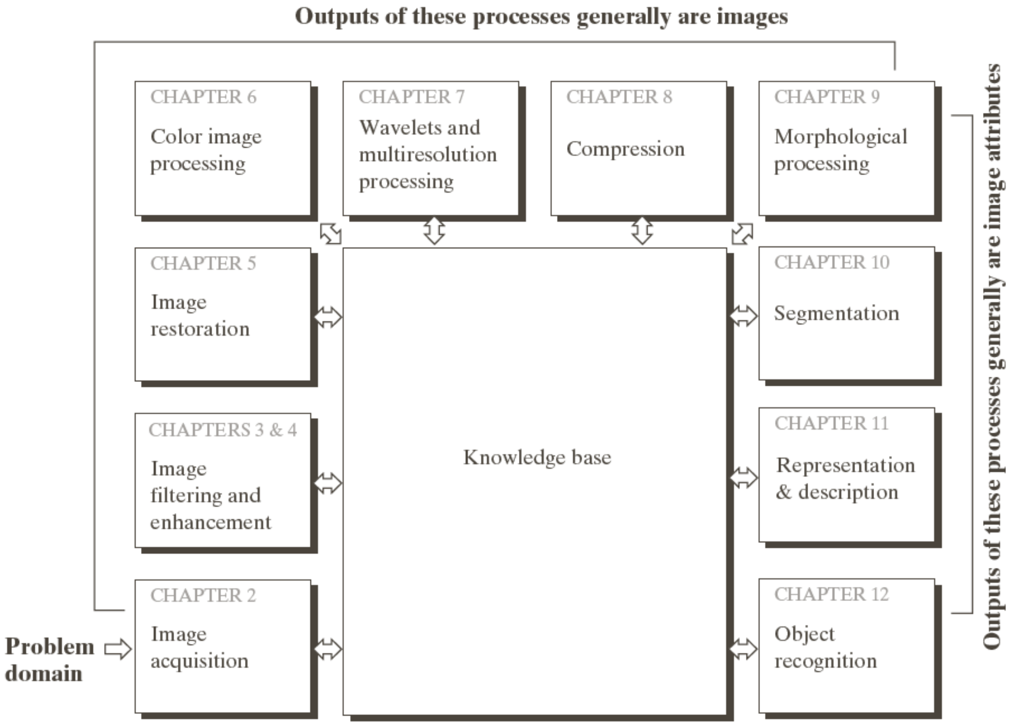

Figure 3: Fundamental steps in DIP

Graphics (50%):

THEME 6 – Graphics – Transformations (30 %)

A) Derive the 3D affine transformations necessary in order to transform object K:

$$K = [ABCD] = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

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

$$\Sigma_1 = \begin{bmatrix} 1 & 1 & 1 & 2 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 \end{bmatrix} \qquad \Sigma_2 = \begin{bmatrix} 1 & 1 & 1 & 2 \\ 1 & 1 & 2 & 1 \\ 1 & 2 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix} \qquad \Sigma_3 = \begin{bmatrix} 1 & 1 & 1 & 2 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

Briefly explain your answers. Drawing the objects could help you. The order of the vertices **is** important.

B) Determine the 3D homogeneous transformation matrix which expresses symmetry about the plane specified by the point $\overline{P}$ (1,1,1) and normal vector $\vec{v} = (1,1,0)$ (see Figure 4). Give all steps in the transformation and the calculation of the final matrix.

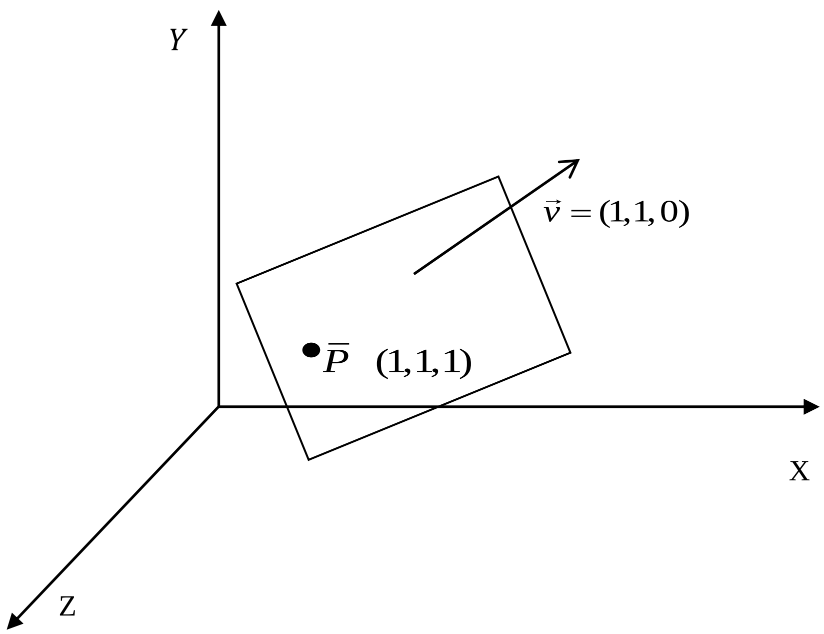

Figure 4: Symmetry plane

THEME 7 – Graphics – Rasterization (10 %)

Show how the following code for the rasterization of triangles can be adapted for the rasterization of quadrilaterals. Is your answer suitable for arbitrary quadrilaterals?

```
triangle1 ( vertex v0, v1, v2, color c ); {
	line l0, l1, l2;
	float e0, e1, e2, e0t, e1t, e2t;

	mkline(v0, v1, &l0);
	mkline(v1, v2, &l1);
	mkline(v2, v0, &l2);

	bb_xmin = min(v0.x, v1.x, v2.x);
	bb_xmax = max(v0.x, v1.x, v2.x);
	bb_ymin = min(v0.y, v1.y, v2.y);
	bb_ymax = max(v0.y, v1.y, v2.y);

	e0 = l0.a * bb_xmin + l0.b * bb_ymin + l0.c;
	e1 = l1.a * bb_xmin + l1.b * bb_ymin + l1.c;
	e2 = l2.a * bb_xmin + l2.b * bb_ymin + l2.c;
	for (y=bb_ymin; y<=bb_ymax; y++) {
		e0t = e0; e1t = e1; e2t = e2;
		for (x=bb_xmin; x<=bb_xmax; x++) {
			if (sign(e0)==sign(e1)==sign(e2)) setpixel(x,y,c);
			e0 = e0 + l0.a;
			e1 = e1 + l1.a;
			e2 = e2 + l2.a;
		}
		e0 = e0t + l0.b;
		e1 = e1t + l1.b;
		e2 = e2t + l2.b;
	}
}
```

THEME 8 – Graphics – Color (10 %)

A) Give the CMY equivalents of RGB colors: $[0.2, 0.3, 0.5]^T$ and $[0.0, 0.0, 0.0]^T$.
B) What is an *alpha* color $[r,g,b,\alpha]^T$?
C) Show how the *over* operator works with *alpha* colors.