NTNU
Institutt for datateknikk
og informasjonsvitenskap

EXAMINATION IN
TDT4195 IMAGE TECHNIQUES
WEDNESDAY JUNE 3, 2009
TIME 09:00 – 13:00

Exam paper prepared by: Richard Blake
Jo Skjermo

Quality control: Torbjørn Hallgren

Contact persons during exam:

Richard Blake	phone 93683/926 20 905
Jørn Hokland	phone 91844/995 06 322
Jo Skjermo	phone 91447/922 36 618

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

Examination results to be announced on: June 24

Answer all the five themes. Total maximum score is 600 points.

- Read all of the examination paper before starting answering. Thus you may improve your chances for efficient time utilisation 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.

THEME 1 Graphics – miscellaneous questions (120 points)

a) What is meant by primitives and by attributes respectively? Give some examples. Present two methods for incorporating attributes.
(15 points)

b) Explain briefly two of the methods available for determining if a polygon is concave or convex.
(30 points)

c) A convex polygon is defined by the points P1, P2 and P2 in view-space. Present an approach that can be used to decide if the polygon is oriented towards the camera. Any assumptions you make about orientations and directions should be specified.
(30 points)

d) Explain briefly the difference between the "toe-in" and "off-axis" approaches for stereo projection. Use sketches.
(30 points)

e) Give two reasons for using quaternions instead of rotational matrices with Euler or similar angles.
(15 points)

THEME 2 Graphics – projection, reflection model and raster converting (180 points)

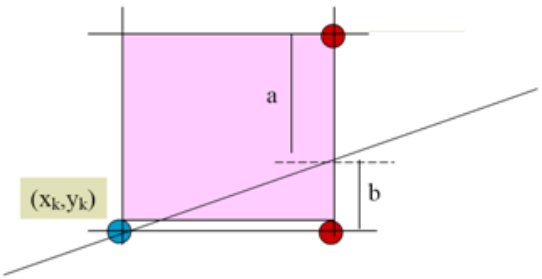
a) Derive the perspective projection matrix for a projection onto the plane z = d with the projection centre at the origin.
(45 points)

b) Explain the significance of the different parts of the Phong reflection model (see the figure).
(30 points)

$$I_\lambda = \sum_i \left\{ \frac{S_i}{a + bd_i + cd_i^2} \left[k_{\lambda d} L_{i\lambda d} (l_i \cdot n) + k_{\lambda s} L_{i\lambda s} (r_i \cdot v)^\alpha \right] + k_{\lambda a} L_{i\lambda a} \right\} + k_{\lambda a} L_{\lambda a}$$

c) How are the elimination codes in Cohen-Sutherland's algorithm for 2D line clipping built? How may the codes be extended for use in 3D?
(45 points)

d) Give the **first part** of Bresenham's algorithm for line drawing. Use d = a – b as the decision variable (see the figure).
(60 points)



THEME 3 Image processing – Fourier transforms and frequency domain filtering (100 points)

Consider the definition of the Fourier transform, $F(u,v)$, of an image, $f(x,y)$, for an $N \times N$ image:

$$F(u,v) = \frac{1}{N}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}\exp(-2\pi jux/N)\exp(-2\pi jvy/N)\mathrm{f}\left(x,y\right)$$

a) Use the definition to prove that $F(u+N,v) = F(u,v)$.
(25 points)

b) For the image function,

$$f(x,y) = 100\sin(12\pi x/N)\sin(16\pi y/N)$$

deduce the coordinates of the spectral peaks in *u*, *v* space.

(Hint: it can be done quickly. Relate $2\pi ux/N$ to the variation in *x* and $2\pi vy/N$ to the variation in *y*.)
(25 points)

c) What is the radius of a band stop filter that would suppress the signal in part question b) above?
(25 points)

d) What effect will be visible in the output of the band stop filter if it does not have a smooth profile?
(25 points)

THEME 4 Image processing fundamentals and filtering (100 points)

a) How would you set up a camera to capture images that are silhouettes of shapes without using reflected light?
(20 points)

b) Consider a CCD chip that supports a grid of pixels with side h. Draw a diagram of a region imaged onto the chip that lets you deduce the width of the narrowest region that will certainly be 4-connected.
(20 points)

c) Give a statement of a design criterion for an image processing system that gives adequate sampling.
(20 points)

d) Give a mathematical definition of a linear transformation.
(20 points)

e) What effects does median filtering have on an image?
(20 points)

THEME 5 Image processing – segmentation, description and recognition (100 points)

a) What is meant by 'region based segmentation'?
(20 points)

b) Consider the choice of threshold to segment an image. The table below lists the number of pixels associated with an object, and the background, indexed by the pixel intensity. By observing the tables, sketching the histogram, or otherwise, choose a threshold that is a good approximation to the optimum for this problem.
(20 points)

Pixel brightness	Background pixel count	Object pixel count
5	8	0
25	22	0
45	47	0
65	76	0
85	97	0
105	96	0
125	74	0
145	44	2
165	20	21
185	7	75
205	2	96
225	0	45
245	0	7

c) The choice of threshold becomes difficult when the background and the object have very different numbers of pixels. How can the difficulty be reduced?
(20 points)

d) What is the Euler number of a shape?
(20 points)

e) What is meant by the term "cluster in feature space"?
(20 points)