DVA338 – Fundamentals of Computer Graphics

Date: Feb. 21st 2020

Time: 8:10 – 12:30

Help: Small calculator is allowed in the exam

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The exam has 34 points. The grades will be awarded as follows:

- 3 : 17 Points
- 4 : 22 Points
- 5 : 28 Points

Important Notes:

- Give as full an answer as possible to obtain full marks. All calculations, approximations, assumptions and justifications must be reported for full credit unless stated otherwise. Please use figures and examples to clarify.
- If you do not understand a question clearly, make an assumption, write down the assumption and solve the problem based on that.
- Write the question and part number on each page clearly.
- Answer each question on a separate page.
- Do NOT use pencil. No pencil. Papers written with pencil will not be corrected.

May the force be with you.

Some Useful Information

$S(S_x, S_y) = \begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix}$

$T(d_x, d_y) = \begin{bmatrix} d_x \\ d_y \end{bmatrix}$

$R(\theta) = \begin{bmatrix} cos\theta & -sin\theta \\ sin\theta & cos\theta \end{bmatrix}$

$Shear(m_x) = \begin{bmatrix} 1 & m_x \\ 0 & 1 \end{bmatrix}$ this means that $(x', y') = (x + m_x \times y, y)$

$Shear(m_y) = \begin{bmatrix} 1 & 0 \\ m_y & 1 \end{bmatrix}$ this means that $(x', y') = (x, y + m_y \times x)$

$\sin 30° = \frac{1}{2}, \cos 30° = \frac{\sqrt{3}}{2}$

$\sin 45° = \frac{\sqrt{2}}{2}, \cos 45° = \frac{\sqrt{2}}{2}$

$\sin 60° = \frac{\sqrt{3}}{2}, \cos 60° = \frac{1}{2}$

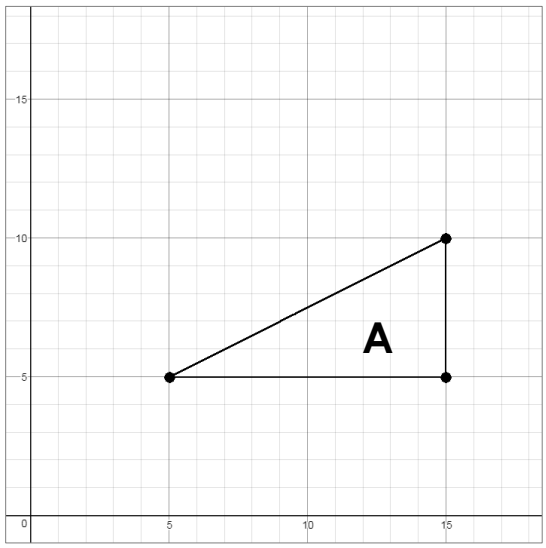
$\sin 90° = 1, \cos 90° = 0$

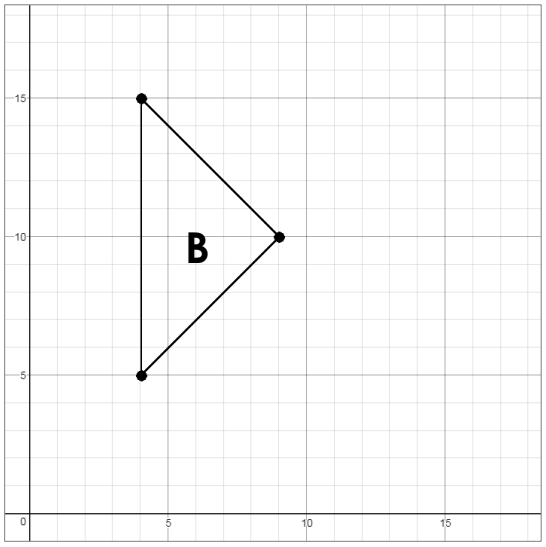
Task 1 (6p)

a) Find a composite transformation matrix **M** that can be used to transform A to B in the illustration below (2p)

b) Find a composite transformation matrix **N** that can be used to transform B to A in the illustration below (2p)

c) Is there any relationship between these two matrices? Explain (2p)





Task 2 (6p)

The vertices of a regular icosahedron can be defined as

$$P = \{(0,1,a),(0,-1,-a),(0,1,-a),(0,-1,a),(1,a,0),(-1,-a,0),$$
$$(1,-a,0),(-1,a,0),(a,0,1),(-a,0,-1),(a,0,-1),(-a,0,1)\}$$

Where

$$a = \frac{\sqrt{5}-1}{2}$$

a) Find the minimum axis-aligned bounding box (AABB) of P (2p).

b) Find the minimum bounding sphere of P (2p).

c) Which of the two bounding objects is the smallest? Compare their volumes (2p).

Task 3 (7p)

Consider the light that falls on a flat ground plane $y = 0$ according to the Phong illumination model. A point light source is positioned at $q = (2,4,1)$, and the viewer is located at $e = (8,8,1)$.

a) What are the coordinates of the brightest position the viewer sees on the ground given that it consists of a purely diffuse material? (3p)
b) What is the brightest position in the ground plane as perceived by the viewer assuming that the ground material only gives a specular reflection? (4p)

Task 4 (8p)

To determine the colour of a pixel during texture mapping some kind of texture filtering is needed.

a) What do we mean by texture filtering in this context? Explain (2p)

There are different texture filtering approaches, define and discuss the following texture filtering approaches: (2p each)

b) Nearest-neighbour
c) Bilinear filtering
d) Mipmapping

Task 5 (7p)

Ray tracing is a backwards rendering algorithm that can easily produce shadows, reflections and refractions.

a) How does this technique work? Explain (1p)
b) Ray tracing is known to be a very computationally expensive algorithm. Why is that? (2p)
c) Name and discuss 4 different ways that we use to improve the performance of ray tracing technique (4p)