DVA338 – Fundamentals of Computer Graphics

Date: Jun. 1st, 2022

Time: 8:10 – 12:00

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)

In a rasterizing rendering pipeline, 3D models go through a series of transformations to produce the final 2D rendered image. What are these transformations? Name each of them, explain what they do and name the space (coordinate system) that the model ends up after each transformation.

Task 2 (8p)

Scaling, Translation, and Rotation are three types of transformations that are represented in the 2D case as follows:

$$S(S_x, S_y) = \begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix} \quad T(d_x, d_y) = \begin{bmatrix} d_x \\ d_y \end{bmatrix} \quad R(\theta) = \begin{bmatrix} cos\theta & -sin\theta \\ sin\theta & cos\theta \end{bmatrix}$$

a) Show the three matrices corresponding to $S(S_x, S_y)$, $T(d_x, d_y)$, and $R(\theta)$ in the homogeneous coordinate system (1p)

b) Use the matrices defined in section (a) to compute the final transformation matrix M corresponding to the following sequence of transformations: T(1,3) then S(4,2) and finally R(90°). (2p)

c) Let M be the matrix computed in section (b), calculate M^{-1} without using methods such as the Gauss-Jordan elimination, Gaussian elimination, or LU decomposition (if you don't know what these are, then good!) (2p)

d) Let M be the matrix computed in section (c) and $p' = Mp$, with $p' = [5,7]^T$, calculate p. (3p)

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)

For each of the following topics, name and explain at least one technique that can help to achieve the result using Local and Global Illumination models (1 for local illumination and 1 for global illumination). For example, for part one you should mention one technique for rendering reflections on a mirror using local illumination and one technique using global illumination.

a) Reflections on a mirror
b) Shadows
c) Indirect Lighting
d) Refraction

Task 5 (5p)

The figure below shows four primitives rendered in the following order: Q, R, S, T.

a) Provide the pseudo-code and the explanation of how depth buffering works. (2p)
b) How would you update the figure if the primitives are rendered in this order: S, T, Q, R. (3p)