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ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

ORGANISATION OF ISLAMIC COOPERATION (OIC)

Department of Computer Science and Engineering (CSE)

SEMESTER FINAL EXAMINATION

DURATION: 3 HOURS

WINTER SEMESTER, 2022-2023

FULL MARKS: 150

CSE 4551: Computer Graphics and Multimedia Systems

Programmable calculators are not allowed. Do not write anything on the question paper.

Answer **all 5 (five)** questions. Figures in the right margin indicate full marks of questions with corresponding COs and POs in parentheses.

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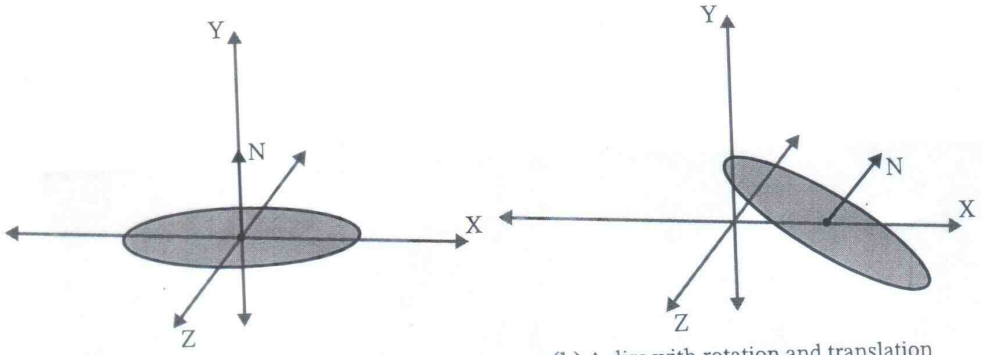
1. You are tasked with the development of a ray tracer that supports rendering of a disc without any tessellation. The user will only mention the radius of the disc. If no transformation is applied, the disc will be rendered centered at the world origin with its normal facing the upward direction (y-axis). The sample diagrams in Figure 1(a) and 1(b) demonstrates a disc without and with transformations respectively. 10 + 10 + 5 + 5 (CO4) (PO3)



(a) A disc without any transformation **(b)** A disc with rotation and translation

Figure 1: Sample diagram of a disc with coordinate system for Question 1

Now, design a system with appropriate mathematical derivations and pseudo-code to perform the rendering of a disc. Highlight how you are going to implement each of the following functionalities:

- Mathematical calculation for ray-disc intersection
- Support for 3D translation, rotation, and uniform scaling of the disc
- Calculation of the normal at the hit point to support shading
- Texture mapping for the disc

2. a) Suppose a game company's engine uses Oren-Nayar and Cook-Torrance reflectance models to calculate diffused and specular reflection components respectively. Though the original engine is targeted towards PCs, now the company wants to port a game developed in the engine to mobile devices. Considering that mobile GPUs cannot process the aforementioned reflectance models in real time, what modification can be done to the engine's material system to port the game to mobile devices while not completely sacrificing either the diffused or the specular reflections? Provide appropriate justification behind your answer. 8 (CO2) (PO2)

   b) Shading realistic hairs or glossy furs in ray tracing is quite complex. A single hair strand can have two, three, or even more different specular highlights based on the direction of the light, the view point, and the place of the hair that is being looked at. Most of the industry grade ray tracers implement special materials to deal with hair shading. For instance, Pixar's 8 (CO2) (PO2)

Renderman uses a variant of the Marschner shading model as depicted in Figure 2, which uses three different specular highlights, Primary (R), Secondary (TT), and Transmit (TRT).

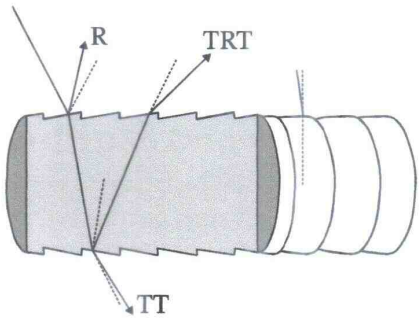
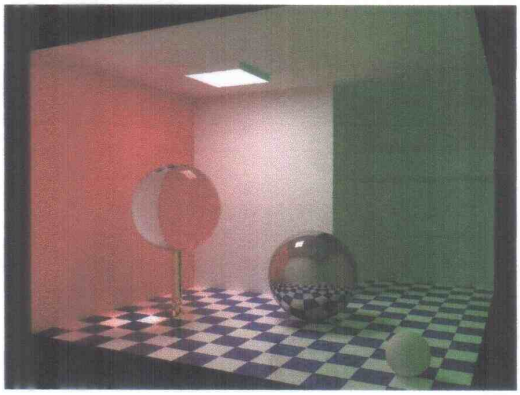


Figure 2: Specular reflections of Marschner hair model for Question 2.b)

Based on Figure 2, explain with proper reasoning and diagram, why simple shading models, like Blinn-Phong or even Cook-Torrance in their default implementation cannot be used for shading the specular component of realistic hairs.

c) Figure 3(a) and 3(b) depict the rendered images of the same scene using a biased and an unbiased ray tracer respectively. 2 + 6 (CO3) (PO2)

(a) Output from the biased ray tracer



(b) Output from the unbiased ray tracer

Figure 3: Outputs from ray tracers for Question 2.c)

i. Identify two phenomena that are being captured in a better way in the unbiased ray tracer than the biased one.

ii. With appropriate reasoning, conceptually explain why the unbiased ray tracer can capture these information better and what is the cost associated with it.

d) With an example, explain why the halfway vector is generally a better choice than reflected direction vector for calculating specular reflections. 6 (CO1) (PO1)

3. a) Briefly explain, among Eulerian and Lagrangian, which kind of system would be more suitable for simulating each of the particle systems below: 4 × 3 (CO3) (PO2)

i. A leaf travelling through a swirling vortex in a water surface

ii. Fireworks exploding in the sky with colorful effects

iii. Sparks coming out of a torn electrical line

iv. A paper airplane travelling through a gusty wind with different wind speed and direction at different places

b) Is it possible to utilize a variation of the Cohen-Sutherland line clipping algorithm in a bounding box based ray tracing optimization algorithm? If yes, explain how you are going to setup and use trivial acceptance, rejection, and clipping conditions in the variation of the Cohen-Sutherland. You do not need to explicitly show the mathematical calculation for finding an intersection point. If no, provide justification behind why it cannot be done. 10 (CO2) (PO2)

c) With a suitable diagram, explain how recursive ray tracing becomes increasingly more costly to achieve higher quality renders. 8 (CO1) (PO1)

4. a) Blender is an open-source 3D rendering software that comes with two renderers by default, EEVEE, a real-time rasterizer that leverages OpenGL, and Cycles, an unbiased ray tracer. Though both of them can be used to produce high quality final renders, EEVEE is used to render the interactive viewport of Blender as well. 5 + 5 (CO1) (PO1)

i. With appropriate reasoning, explain what makes EEVEE suitable as the real-time viewport renderer for Blender.

ii. Briefly describe the advantages and disadvantages of using EEVEE and Cycles as the renderer for final outputs.

b) Old games often used to have very dense *distance fog* to reduce the amount of processing required considering limitations of the contemporary GPUs. Silent Hill, developed in 1999, is a survival horror game that utilized this system to optimize performance. A screenshot from the game is shown in Figure 4. The *distance fog* system is based on the depth from the camera and everything gradually fades into white as the distance increases. Anything beyond the fog boundary (a preset depth) cannot be seen at all.

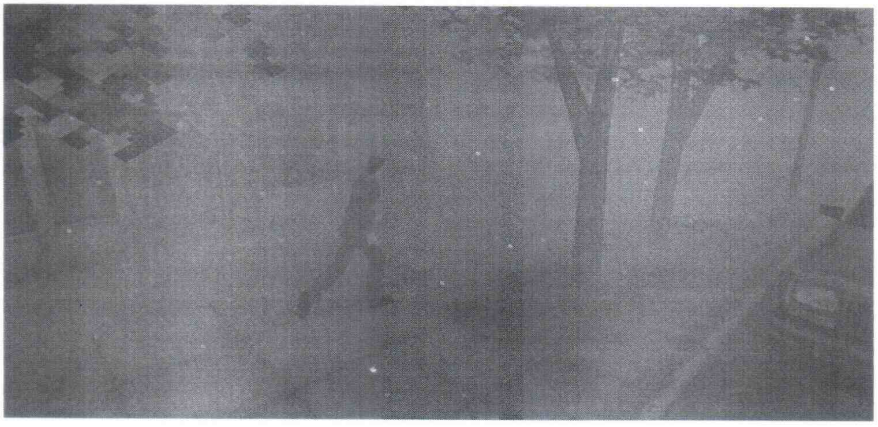


Figure 4: A frame from Silent Hill (1999) for Question 4.b)

Based on Figure 4 and the given information, answer the following questions:

i. How can *distance fog* improve the performance of the game? Give proper reasoning behind your answer by relating it to a known concept. 6 (CO2) (PO2)

ii. Design an algorithm to efficiently render a scene (color of each pixel) with *distance fog* where things gradually fade away to white. Provide mathematical justification behind your answer. 9 (CO4) (PO3)

c) Explain how double buffering helps to prevent visual artifacts in the case of GPU based real-time rendering. 5 (CO1) (PO1)

5. a) With an example and a diagram, describe how hierarchical modeling helps to perform instancing in a graphical system and what are the benefits associated with it. 10 (CO1) (PO1)

b) Briefly explain the necessity of the Model, View, and Projection (MVP) matrices in rendering. 3×2 (CO1) (PO1)

c) With proper justification, explain why zooming in an image taken by your phone makes it pixelated, whereas the same thing does not happen with a text in a PDF file. 6 (CO2) (PO2)

d) With proper reasoning, justify whether it is possible to create a ray tracer that directly renders a scene in grayscale. If it is possible, conceptually explain where the differences would be with respect to a traditional colored ray tracer and whether it would be possible to decrease the overall required calculation. If not, explain the reason why it would not be possible. 8 (CO2) (PO2)