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Due: 01 November 2026, 23:59

Computer Graphics
Theoretical Assignment 1

Submission instructions

Your solution must be uploaded to the CMS as a PDF.

Remember: While assignments are ungraded, during the colloquium, you must be able to demonstrate that you engaged with the task.

Asking questions

General questions regarding the assignment should be asked on Discourse (`Forum` tab in CMS)

1.1 Ray-Sphere Intersection

This is the theoretical counterpart to the ray sphere intersection of the practical assignment.

Given a ray R parameterized by its origin o and (non-normalized) direction d and a sphere with radius $r = 1$ and its center c at point $(0, 0, 0)$. Your task is to derive the distances t along the ray at which the ray intersects the sphere. Simplify as far as possible. How do you ensure that you only get one solution for t?

- Ray equation: $R(t) = o + t \cdot d$
- Sphere equation: $\|x - c\| = r$ (c is center, r radius)

1.2 Types of Transformation Matrices

Match the below matrix types to the corresponding matrix.

Non-uniform scale: ☐ Rotation around y: ☐ Translation: ☐

$$A = \begin{pmatrix} 3 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 \\ 0 & 0 & 3 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad B = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0.5 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad C = \begin{pmatrix} 3 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 3 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$D = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta & 0 \\ 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad E = \begin{pmatrix} \cos\theta & 0 & \sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

1.3 Acceleration Structures

1.3.1 Basic Properties

For each statement below, indicate for which acceleration structure type it is true:

	kD-tree	BVH	Octree	Grid

Subdivides the 3D space into non-overlapping regions				
Construction can benefit from the surface area heuristic				
Can terminate traversal on first hit				

1.3.2 Number of intersections

Given a scene containing $1,048,576$ spheres. We want to find the closest intersection of a ray with this scene.

a) How many sphere intersection tests do you need to find the closest hit by brute force (i.e. without an acceleration structure)?

b) Given a balanced binary BVH. In the best case, a ray can descend the BVH with a single root to leaf path. How many bounding box intersection tests do you need?

c) Why is the best case number you computed in b) not regularly achievable in practice?

1.4 Colloquium Preparation

These questions can refer to the practical, theoretical, or lecture content. As they are designed for you to reflect on this block's content, there is no right or wrong answer.

a) What was the biggest difficulty you faced this block?

b) What was the most interesting thing you have learned?

c) What part of your code do you want to discuss in detail?

d) Which theoretical concept do you want to discuss in detail?

e) Do you have any questions?