TDA362 / DIT223 Computer Graphics

EXAM

(same exam for both CTH- and GU students)

Examiner

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Permitted Technical Aids

None, except English dictionary

General Information

Numbers within parentheses states the maximum given credit points for the task. Solutions shall be clear and readable. Too complex solutions can cause reductions in the provided number of points

Questions to examiner during exam

will be possible approximately one hour after the start of the exam. If anything is unclear – remember what has been mentioned on the lectures, in the slides and course book and do your best.

Grades

In order to pass the course, passed exam + exercises (or exam + project) are required. The final grade is calculated from the exam grade. The exam is graded as follows

CTH: 24p ≤ **grade 3** < 36p ≤ **grade 4** < 48p ≤ **grade 5**

GU: 24p ≤ **G** < 45p ≤ **VG**

Max 60p

Solutions

provided on homepage.

Grades

are announced within 3 weeks.

Review

Opportunity to review the correction of your exam will be provided.

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Task 1

Pipeline

a) [1p] The real-time graphics **pipeline** consists of three parts. Which?
Anser: Application stage, geometry stage, rasterization stage

b) [1.5p] Explain what is done in each part.
Answer:
Applicaton stage – e.g. VFC, animation, logic,
Geometry stage: transformations + per vertex shading.
Rasterization stage: rasterization, texturing, interpolation of shading or vertex parameters, z-test, fragment shading

c) [1.5p] For each part, describe how you can determine if this step is the performance bottle-neck for the rendering.
Answer:

Applicaton stage:	exchange glVertex with glColor
Geometry stage:	remove all light sources
Rasterization stage:	change window size

Line drawing

d) [1p] What is the advantage of Bresenham's line drawing algorithm?
Answer: only uses integers

Vectors + Transforms

e) [2p] Manually normalize the vector **x=**(1,2,2).

Answer: $\mathbf{x} = \frac{(1,2,2)}{\sqrt{1^2+2^2+2^2}} = \left(\frac{1}{3}, \frac{2}{3}, \frac{2}{3}\right)$

f) [1p] State the 4x4-matrix **M** that performs a **translation t**=(t_x,t_y,t_z) when doing a multiplication **v**=**Mp**. (I.e., state the translation matrix **M**).

Answer: $\mathbf{M}=\begin{bmatrix} 1 & 0 & 0 & tx \\ 0 & 1 & 0 & ty \\ 0 & 0 & 1 & tz \\ 0 & 0 & 0 & 1 \end{bmatrix}$

g) [2p] Will there be a difference in the resulting transformation when doing these commands....

```
glTranslatef(3,2,0);
```

```
glScalef(2,2,2);
```

compared to doing these commands

```
glScalef(2,2,2);
glTranslatef(3,2,0);
```

?

Explain by applying the transformations on a **v**=(0,0,0)

Answer: the first example will effectively do the scaling before the translation, resulting in a translation to (3,2,0). The latter example will effectively do the translation first and then a scaling, resulting in a total translation of (6,4,0).

Task 2

Shading

a) **[5p]** **Emission** is one of the terms in the standard real-time shading model. Which are the 3 other terms? Also, describe how each of the 3 parts are computed (give the formulas and draw picture when needed). State both Blinn's and Phong's model for the corresponding term.

Answer: specular, diffuse, ambient,

spec: = Blinn: $\max\left(0,(n \cdot h)^{4m_{shininess}}\right)\mathbf{m}_{spec} \otimes \mathbf{s}_{spec}$ (also ok without the factor 4)

spec: = Phong: $\max\left(0,(r \cdot v)^{m_{shininess}}\right)\mathbf{m}_{spec} \otimes \mathbf{s}_{spec}$

diff: = $(n \cdot l)\mathbf{m}_{diff} \otimes \mathbf{s}_{diff}$

amb: = $\mathbf{m}_{amb} \otimes \mathbf{s}_{amb}$

Antialiasing and Texturing

b) **[2p]** Describe how bumpmapping works.

c) **[2p]** Draw the pattern for Quincunx and state the sample weights.

d) **[1p]** What is axial billboards?
Answer: Billboards that only can rotate around a fixed axis.

Task 3

Intersection Tests

a) **[3p]** Explain an efficient method for determining intersection between a ray and a box (in 3D).
Answer: Test the ray against the box's 3 slabs. Keep max of tmin and min of tmax. If tmin < tmax there is an intersection.

Speedup Techniques

b) **[3p]** Shortly explain Occlusion Culling, Detail Culling, View Frustum Culling, Portal Culling, Backface Culling and Levels of Detail.

Collision Detection between hundreds of objects

c) **[4p]** Describe an efficient and conservative method for course pruning of non-colliding objects.

Task 4

Spatial Data Structures

a) **[4p]** Give the names of (or draw or describe) 8 common spatial data structures within computer graphics.
Answer: BVH (sphere, AABB, OBB), grids (regular, hierarchical, recursive), octree, quadtree, kd-tree, BSP-tree (axis aliged, polygon aligned)

Ray Tracing

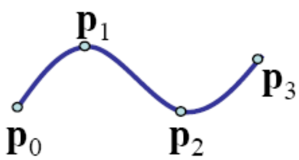
b) **[2p]** Compute the reflection ray, **r**, given **n** and **l**, where **n** is the surface normal and **l** is the incoming ray with **direction towards** the surface.
Answer: $\mathbf{r} = \mathbf{l} - 2(\mathbf{n} \cdot \mathbf{l})\mathbf{n}$

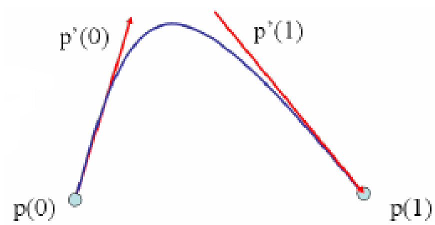
Global Illumination

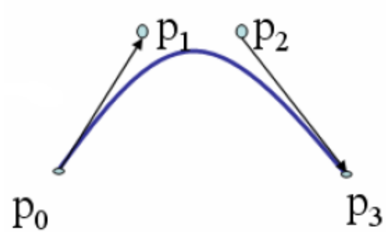
c) **[4p]** Describe the difference between Monte Carlo ray tracing and Path Tracing.
Answer: Monte Carlo ray tracing spawns many rays at each bounce, resulting in a ray tree. Most work is spent on the many rays at the bottom of the tree which have least impact on the pixel. Path tracing only follows one randomly chosen spawned ray per bounce, resulting in a "ray path". Instead, many paths are traced per pixel. The advantage is that an equal amount of rays is traced at each level of bounces. Better balance between spent work and importance.

Task 5
Curves

a) **[5p]** Tell which type of curve each image corresponds to. You can choose between Interpolation-curve, Hermite-curve and Bezier-curve. To get any points, you must also motivate your choice!

I.


II.


III.


Anwer: I. interpolation curve since the curve goes through the control points. II. Hermite-curve since gradients are specified per control point. III. Bezier-curve since 2 intermediate points are used to approximate the gradients in the end points.

b) **[1p]** In which ways are NURBS more general than B-Splines?

Shadows

c) **[4p]** Describe the shadow map algorithm.
Answer:
1. Render a shadow depth map from the light source.
2. Render image from the eye. For each generated pixel, warp the x,y,z—coordinate to light space and compare the depth with the stored depth value in the shadow map (at the pixel position (x,y)).
If greater →point is in shadow
Else →point is not in shadow
Bias/offset is necessary due to disretization and precision problems.

Task 6
Hardware

a) **[2p]** Linear interpolation of (u,v) in screen space does not give perspective correct texturing. Describe how perspective correct texture interpolation can be achieved.
Answer: In screen space, linearly interpolate (u/w, v/w, 1/w) from each vertex. Then, per pixel: $u_i = (u/w)_i / (1/w)_i$, (i=screen space interpolated value)

b) **[3p]** Sketch the architecture for a modern graphics card, e.g. the Geforce 8800. You can use the major functional blocks that we have mentioned in the course.

Miscellaneous math

c) **[1p]** Assume **p**=(1,2,3,4). Perform the homogenization step on **p**.
Answer: **p**=(1/4, 2/4, 3/4, 1).

Reflections

d) **[4]** Explain how you can do planar reflections of an object in a plane. The plane goes through the origin and has the normal **n.**

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