

# TDA361/DIT220 Computer Graphics, December 20<sup>th</sup> 2012

## EXAM

(Same exam for both CTH- and GU students)

Thursday December 20:th, 2012, 14.00 – 18.00

### Examiner

Ulf Assarsson, tel. 0701-738535

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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 1h 30 min after the start of the exam. If anything is unclear – remember what has been mentioned on the lectures and in the slides and do your best.

### Grades

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

CTH:  $24p \leq \text{grade 3} < 36p \leq \text{grade 4} < 48p \leq \text{grade 5}$

GU:  $24p \leq G < 45p \leq VG$

Max 60p

Grades are announced by the LADOK system ~3 weeks after the exam.

### Solutions

will be put on the course home page on Friday Dec. 21<sup>st</sup>.

### Review

Opportunity to review the correction of your exam is provided on Tuesday January 22<sup>nd</sup> at 12.00, room 4115 (my office room).

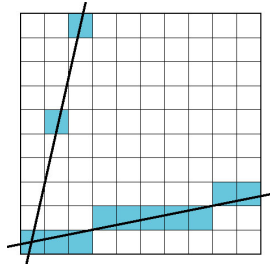
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## Question 1

- a) [1p] Assume you have implemented a DDA algorithm for line drawing that only can draw lines with a low slope correctly, but has problems with steep lines (see image below). How can you in a simple way make it plot steep lines as well?



**Answer:** Swap roles of  $x$  and  $y$ . I.e., loop over  $y$ , instead of  $x$ , to plot the  $(x,y)$ -value.

- b) [1p] What does the geometry shader do?

**Answer:** takes one primitive as input and outputs 0 or more new primitives - possibly other primitives. E.g. triangles, lines, points.

- c) [2p] How does trilinear interpolation work, and how many texture values need to be considered by the hardware for one tri-linearly interpolated texture value?

**Answer:** 8. Do bilinear interpolation at the two surrounding mipmap levels and one linear interpolation between. Draw image. See e.g. slide 10 in texture-lecture.

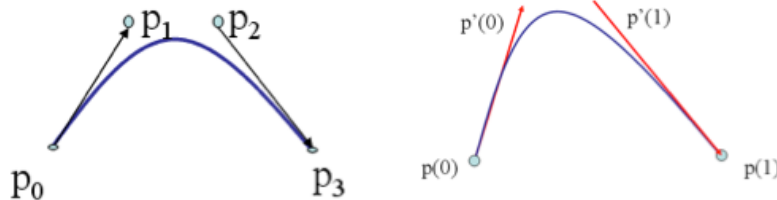
- d) [2p] Explain portal culling.

**Answer:** use scene structure of cells and portals. Recursively use VFC through portals. See slide in spatial-lecture for details.

- e) [4p] What type of curve segments are these two below (left vs right)? What are their strengths and weaknesses?

**Answer:** left: Bezier – don't need to give tangent vectors manually

Right: Hermite – can guarantee continuous 1<sup>st</sup> derivatives between segments.



## Question 2

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- a) **[4p]** What is Constructive Solid Geometry and how does it work?  
**Answer:** Boolean operations between objects. Find overlap for each object and ray. Apply the Boolean operator on each interval and use the closest interval point.
- b) **[2p]** What is the point of using bubblesort in the sweep-and-prune algorithm?  
**Answer:** Frame-to-frame coherency. Expected complexity for resorting nearly sorted lists is linear.
- c) **[2p]** Assume that you are rendering an impostor as a rectangular quad. The impostor's texture represents a tree and contains lots of fully transparent texels. How do you assure that objects that later (for the same frame) are rasterized behind the transparent parts of the impostor will show on the screen?  
**Answer:** alpha test, fragment kill, i.e., kill fragment if alpha = 0 in fragment shader.
- d) **[2p]** Which matrices are involved in the transformation of a vertex from model space to screen space? I.e., give the names for these matrices.  
**Answer:** modelviewmatrix (or model-to-world and world-to-view/camera matrix), projection matrix, (viewport matrix).

### Question 3

- a) **[3p]** How does the shadow map algorithm determine that a point **p** is in shadow?  
**Answer:** Render a z-buffer from the light source. Represents geometry in light space. Render from camera. For every fragment: transform(warp) its 3D-pos (x,y,z) into shadow map (i.e. light space) and compare depth with the stored depth value in the shadow map. If depth greater-> point in shadow. Else -> point in light. (Use a bias at the comparison)
- b) **[2p]** What are the problems with the shadow map, and how can you lower/ameliorate these problems?  
**Answer:** frustum limited ("cubemap"), resolution, filtering, bias-midpoint shadow maps.
- c) **[4p]** Draw a simple scene with a few objects and how to divide it into a kd-tree and an AABB-tree. (Make sure your answer is clear and non-ambiguous.)  
**Answer:**
- d) **[1]** What problem does the z-pass algorithm have that the z-fail algorithm solves elegantly?  
**Answer:** the eye-inside-shadow problem.

### Question 4

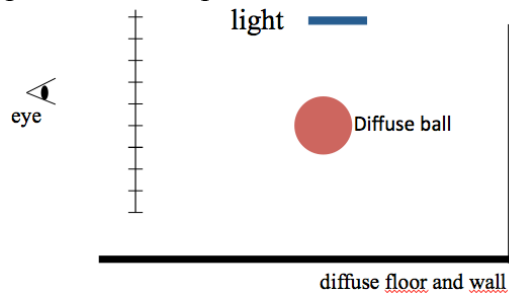


- a) [3p] How do you compute diffuse and specular light at an intersection point when doing ray tracing? Draw an image and show formulas. Assume the standard ambient, diffuse, specular, emission-model that we have used (e.g., for real-time rendering).

**Answer:** see real-time shading model in lecture 3.

- b) [3p] Path tracing: Draw and explain, using the example below, how the color of **one** of the pixels is computed with path tracing. Observe that it is an area light source. Illustrate using at least three ray paths and with words.

**Answer:** see global illumination lecture. Pick one random position on light source, per intersected point. Send one random diffuse ray at each bounce.



- c) [3p] Explain Final Gather and how it is used with the photon maps (caustics map and global map). Also, explain what is good with Final Gather.

**Answer:** Monte Carlo-sample at first bounce. Use caustics map at first intersection and global map at intersections of secondary rays. Good because lowers noise from the global map.

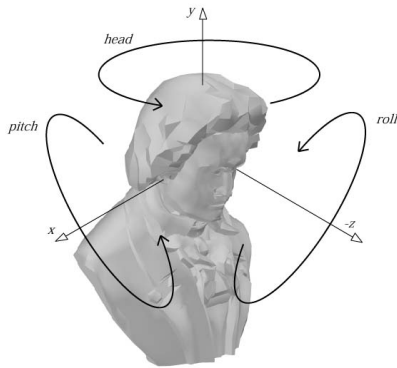
- d) [1p] **Photon mapping:** Why do we use a separate global map and caustics map, instead of just having one combined map?

**Answer:** global map represents correct, but sparsely sampled, light distribution. The caustics map needs very high sampling (high-frequency phenomenon) to be captured correctly.

## Question 5

- a) [1p] Draw the quincunx-filter with the weights per sample.
- b) [3p] Euler rotations can be used to describe the rotation of an object. The rotation is often defined by *head*, *pitch* and *roll*, which each is a rotation around one of the **world space** axes. E.g., the combined rotation is  $\mathbf{M} = R_z(r) R_x(p) R_y(h)$ , where  $R_i$  rotates around the world space axis  $i$ . **Question:** Is  $\mathbf{M}$  dependent on the multiplication order of  $R_x$ ,  $R_y$ , and  $R_z$ ? **Motivate** your answer well.





**Answer:** Yes. E.g., simply use an example with a 90-degree rotation for the first rotation (head) and then it can be seen that the meaning of the pitch and roll are now flipped.

- c) [3p] Assume you have an **incoming** light ray  $\mathbf{l}=(1,2,3)$  at a surface point  $\mathbf{p}$  with the normal  $\mathbf{n}=(2,3,4)$ . Compute the reflection vector  $\mathbf{r}$ . **Also**, normalize the reflection vector! Draw figure.

**Answer:**  $\mathbf{r}=\mathbf{l}-2(\mathbf{n}'\cdot\mathbf{l})\mathbf{n}'$ , where  $\mathbf{n}'$  is  $\mathbf{n}$  normalized. So:

$$\mathbf{r}=(1,2,3)-((80, 120, 160)/29).$$

**Normalized  $\mathbf{r} = \mathbf{r} / \|\mathbf{r}\|$** , which you need to compute.

- d) [3p] Show how to compute the intersection between a ray and an infinite cylinder (all in 3D), centered around the z-axis.

**Answer:** cylinder:  $\|x^2+y^2\| = r$

ray:  $\mathbf{r}(t) = \mathbf{o} + t\mathbf{d}$

gives  $(o_x + td_x)^2 + (o_y + td_y)^2 = r^2$

Solve for  $t$  and consider that there are two solutions. Also, show that solution is point  $\mathbf{o} + t\mathbf{d}$

### Question 6

- a) [4p] Linear interpolation of  $(u,v)$  in screen space does not give perspective correct texturing. Describe how perspective correct texture interpolation can be achieved. (To get points, you must draw an image to explain.)
- b) [1p] Assume  $\mathbf{p}=(1,2,3,4)$ . Perform the homogenization step on  $\mathbf{p}$ .
- c) [2p] Describe how to do a simple intersection test between a tetrahedron and a plane.

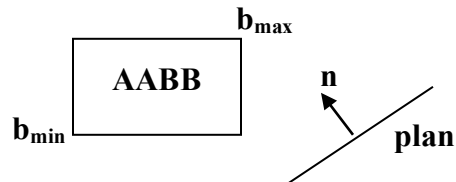
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Answer: test all points against the plane and see if they are on different sides. If



they are, then intersection.

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- d) [3] Show how it is possible to do an AABB vs plane test by only testing 2 of the AABB's vertices against the plane. (Hint: Assume a plane with normal  $\mathbf{n}$  and an AABB defined by  $\mathbf{b}_{\max}$  och  $\mathbf{b}_{\min}$ . Express the two vertices by  $\mathbf{n}$ ,  $\mathbf{b}_{\max}$  and  $\mathbf{b}_{\min}$ .)



Answer:

$$\mathbf{v}_0 = ((\mathbf{n}_x > 0 ? \mathbf{b}_{\max}_x : \mathbf{b}_{\min}_x), (\mathbf{n}_y > 0 ? \mathbf{b}_{\max}_y : \mathbf{b}_{\min}_y), ((\mathbf{n}_z > 0 ? \mathbf{b}_{\max}_z : \mathbf{b}_{\min}_z))$$

$$\mathbf{v}_1 = ((\mathbf{n}_x < 0 ? \mathbf{b}_{\max}_x : \mathbf{b}_{\min}_x), (\mathbf{n}_y < 0 ? \mathbf{b}_{\max}_y : \mathbf{b}_{\min}_y), ((\mathbf{n}_z < 0 ? \mathbf{b}_{\max}_z : \mathbf{b}_{\min}_z))$$

Insert the two vertices into the plane equation. If the signs of all results are equal, then no intersection. Otherwise, intersection. I.e.,  $\text{sign}(\text{dot}(\mathbf{v}_0, \mathbf{n}) + d) == \text{sign}(\text{dot}(\mathbf{v}_1, \mathbf{n}) + d)$

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