Graphics 2007/2008

Second Exam

Thu, Jan 31, 2008, 16:30–18:30

- **Do not open this exam until instructed to do so. Read the instructions on this page first.**
- You may write your answers in English, Dutch, or German.
- You may not use books, notes, or any electronic equipment (including your cellphone, even if you just want to use it as a clock).
- Please put your student ID on the table so we can walk around and check it during the exam.
- Write down your name and student number on every paper you want to turn in. Additional paper is provided by us. You are not allowed to use your own paper.
- When you hand in your work, have your student ID ready to be checked by the instructor.
- You have 2 hours for this exam. If you finish early, you may hand in your work and leave, except for the first half hour of the exam.
- The test consists of seven problems. The maximum number of points you can score is 20. You need 18 points to get the best possible grade.

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Problem 1: Perspective projection

[1 pt] Subproblem 1.1 (Camera transformation)
Given a camera position and a scene containing an object: What does the *gaze vector* specify in this context? Assume the center of the object is located at point (1,2,3) and we have the camera placed at position (3,2,1). Calculate the gaze vector for the given situation if we want the object to be placed directly in the center of the image.

[1 pt] Subproblem 1.2 (Perspective transformation)
After multiplication with the perspective transformation matrix M_p and the following homogenization, the point $\begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix}$ contains the values $\begin{pmatrix} nx/z \\ ny/z \\ n+f-\frac{fn}{z} \\ 1 \end{pmatrix}$.

Show that all points on the near clipping plane n have been projected onto themselves by these operations.

[2 pt] Subproblem 1.3 (Windowing transformation)
In the lecture, the orthographic projection matrix M_o was introduced as the matrix resulting from the multiplication of the following three matrices:

$$M_o = \begin{pmatrix} \frac{m}{2} & 0 & 0 & \frac{m}{2}-\frac{1}{2} \\ 0 & \frac{n}{2} & 0 & \frac{n}{2}-\frac{1}{2} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \frac{2}{r-l} & 0 & 0 & 0 \\ 0 & \frac{2}{t-b} & 0 & 0 \\ 0 & 0 & \frac{2}{n-f} & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 & -\frac{l+r}{2} \\ 0 & 1 & 0 & -\frac{b+t}{2} \\ 0 & 0 & 1 & -\frac{n+f}{2} \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Describe what each of these matrices does. (Note: l,r,t,b,n,f specify the left, right, top, bottom, near, and far plane of the orthographic view volume, respectively, and mxn is the size of the projected image.)

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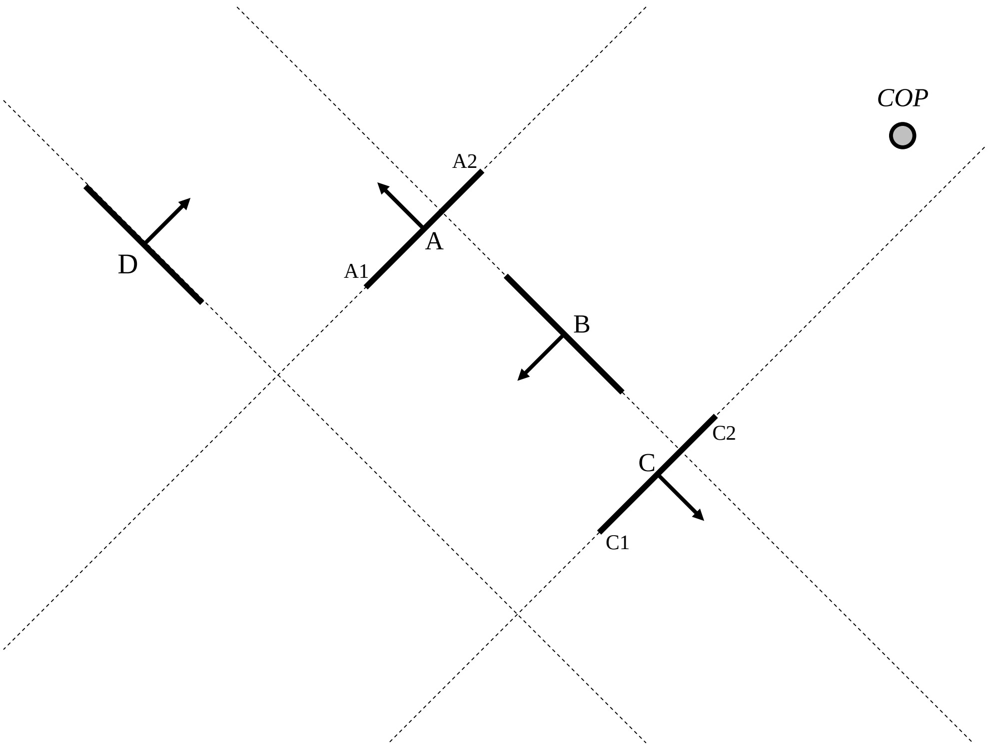
Problem 2: Hidden surface elimination

[1 pt] Subproblem 2.1
The scene below consists of 4 line segments and a camera view point (i.e. the center of projection *COP*). The normal vectors of the segments point to the visible side. The dashed lines are not part of the input, but indicate where the supporting lines of the segments intersect the other segments.

Illustrate the construction of a BSP tree for the situation shown in the image. **Important**: Illustrate how you build this tree by drawing a new tree for each new node that is added. Use the notation given in the image, i.e. specify the segments using the letters A, B, C, and D. If you have to split up a segment, use the notation A1, A2, C1, and C2, respectively, as indicated in the image.



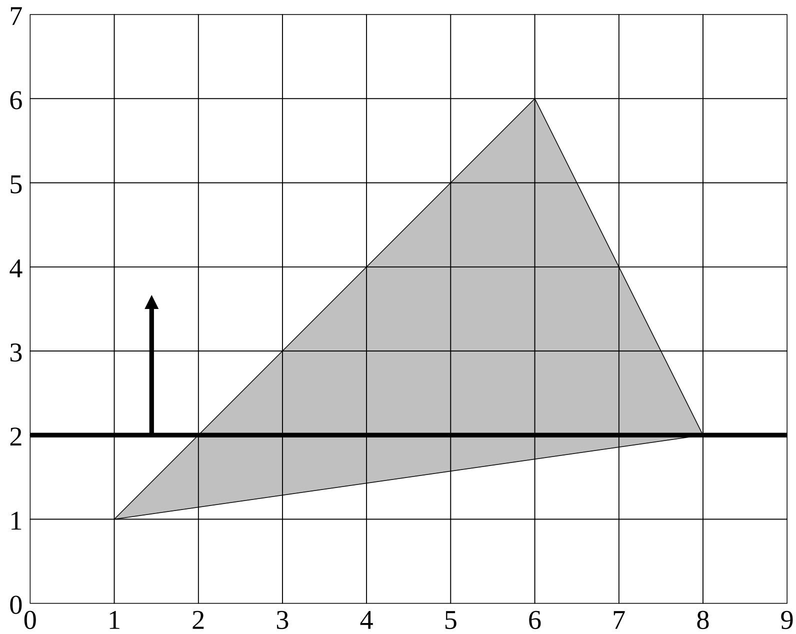
[2 pt] Subproblem 2.2
Give a short explanation about how to get the projection order for a given BSP tree and camera view point *COP* using the situation in the image and the tree you constructed in the previous subproblem. Give the order in which the segments are drawn based on your tree.

[1 pt] Subproblem 2.3
How do your results from subproblem 2.1 and 2.2 change if the *COP* is in the center of the far left side of the image?

Problem 3: Triangle rasterization

[1 pt] Subproblem 3.1
In the lecture, we used two data structures in the algorithm for triangle rasterization via scan-line conversion: The *edge table* and the *active edge table*. What does each of these tables contain?

[1 pt] Subproblem 3.2
Look at the image below (note: assume that the scan-line is horizontal and moves vertically from the bottom of the image to the top as illustrated by the black line and the associated arrow). Give the values for the edge table that are stored for scan-line number 2. Give the values for the active edge table that are stored for scan-line number 3.

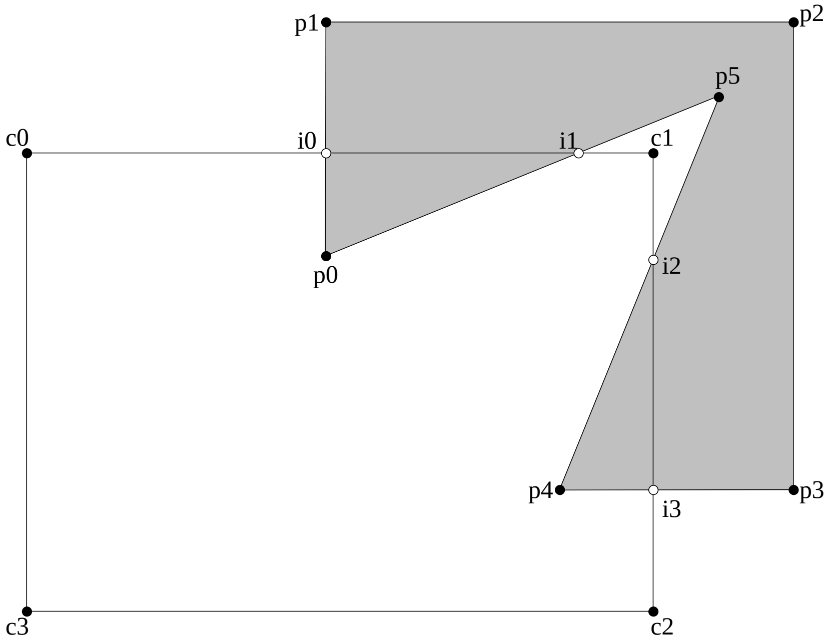


[1 pt] Subproblem 3.3
Explain how Gouraud shading can be incorporated in the scan-line conversion algorithm.

Problem 4: Clipping

[1 pt] Subproblem 4.1
Explain how the graph used in the Weiler-Atherton algorithm is constructed.

[1 pt] Subproblem 4.2
Construct this graph for the example given below.



[1 pt] Subproblem 4.3
Explain how the graph is used to determine the resulting polygons.

Problem 5: Texture mapping

[2 pt] Give a short description of the following techniques:

- Bump mapping
- Environment mapping

Problem 6: Radiosity

[2 pt] Explain the meaning of the following formula, which is used to calculate the radiosity B_i of a patch A_i:

$$B_i = E_i + \rho_i \sum_j B_j F_{ij}$$

Problem 7: Shadows

[2 pt] What is a stencil buffer and what kind of operations does it support?