Interactive Computer Graphics: Midterm Exam

2022.04(Thu), 09:30 ~ 12:20

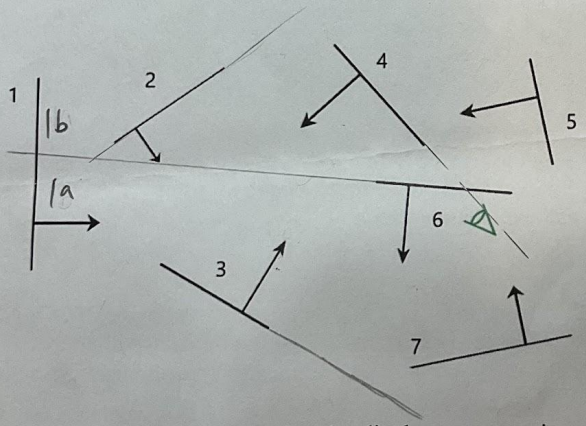
Note: Need signature from everyone. Open book, open notes, but no Internet connection.

1. Term Project (5%)
   What is your term project for this semester? What are the technical difficulties involved in the project? (You can refer to the project listing).

2. (10%) When using the Cohen-Sutherland line clipping algorithm, how do we check the out codes to see if a line can be trivially accepted or rejected?

3. (10%) BSP Tree

A. Construct the Binary Space Partitioning (BSP) tree of the model in Figure below. Please use the node "6" as the root. Split any line segment as you wish, and mark them as 1.a, 1.b,1.c, etc. Please choose smaller numbers/alphabets as the sub-tree root node.



B. From the BSP tree in (a), derive the display sequence in terms of the given viewing position in this figure.

4. (10%) Painter's Algorithm

A. "86 Eighty Six " is a famous animation during 2021-2022. It talks about war, AI, racism, self-identity and a classic boy-meets-girl story. Here is a picture of the main character in the story. What is the drawing order in the picture below, if we use painter's algorithm?

B. Painter's algorithm is the easiest way to solve visibility problems in the computer graphic area. However, it has some obvious disadvantages. Try to draw a simple picture which the painter's algorithm cannot deal with and explain the reason.

5. Ray intersection (10%)

Consider the 3D real vector space R3. A triangle surface S has three vertices: (6, 8, 10), (7, 9, 6), and (8, 6, 8). There is a light ray shooting from (1, 2, 3) to (2, 3, 4) (and continue to go away). Will the ray hit the triangle S? Please answer yes or no and provide your reasoning and calculation.

6. Bezier curve (10%)

Recall the Bezier curve mentioned in the lecture. Bezier function is defined as follows:

$$Bézier(n,t) = \sum_{i=0}^{n} \binom{n}{i} (1-t)^{n-i} t^i \cdot w_i$$

A cubic Bezier curve is defined with four points (n = 3 hence four terms) by substituting Wi above with their coordinates with t ∈ [0, 1] (Bezier interval). Let L(t) be the cubic Bezier curve in R2 defined by the four points (0, 0), (1, 1), (2, −1), (3, 1/2) in order. This curve L(t) is equivalent to the curve y = f(x) in R2. How many unique real x are there for f(x) = 0? Choose an answer below and provide your reasoning and calculation.

(A) 0

(B) 1
(C) 2
(D) 3

7. Error diffusion dithering (10%)
The following is the pseudo-code of a version of Floyd-Steinberg error diffusion dithering for an n×n matrix with some specific diffusing pattern. Here, the index i is from top to down and the index j is from left to right.

Algorithm 1 Floyd-Steinberg error diffusion dithering

```
A ← n × n pixel matrix
q ← quantization number
(pretending to) pad A at right and bottom to (n+1) × (n+1) matrix so the following won't err.
for i from 0 to n − 1 do
    for j from 0 to n − 1 do
        old_pixel ← A[i][j]
        new_pixel ← floor(old_pixel/q) · q
        A[i][j] ← old_pixel − new_pixel
        A[i + 1][j] ← A[i + 1][j] + floor((2/5) · err)
        A[i][j + 1] ← A[i][j + 1] + floor((2/5) · err)
        A[i + 1][j + 1] ← A[i][j + 1] + floor((1/5) · err)
    end for
end for
return A ignoring the padding part
```

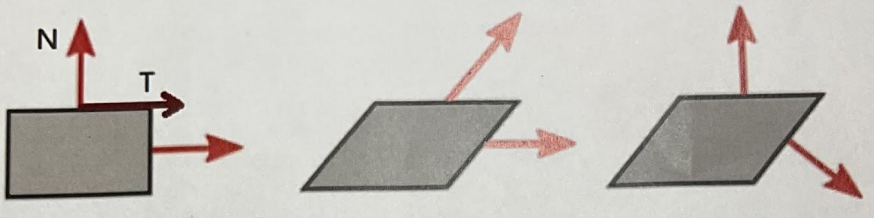
Given a 2x2 matrix below,

$$\begin{bmatrix} 19 & 48 \\ 31 & 18 \end{bmatrix}$$

and the quantization number q = 7, calculate and show the final matrix after running the algorithm.

8. Transformation of normal vectors (10%)

In homework1, when you modify the upper left 3x3 in a 4x4 transformation matrix to a normal vector, most situations work; however, it may go wrong when the transformation matrix contains shear operations such as in Figure (2) given below.



Figures 1,2,and 3.

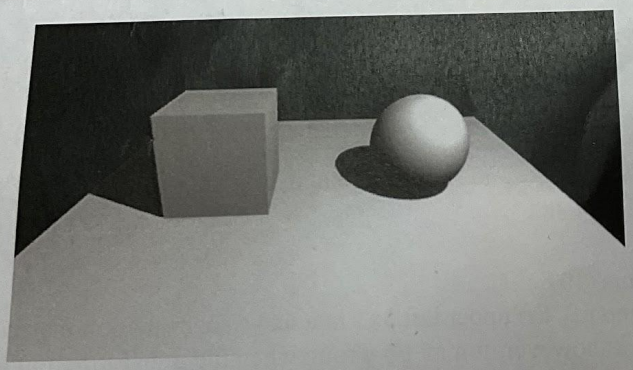
1. original object with normal vectors shown in red	2. same transform is applied to object and normal vectors	3. transformed object with the correct normal vectors

Now consider a special case of 3x3 inside a 4x4 matrix M which only has shear operations. How do you modify M to make it correctly transform a normal vector shown in Figure (3)? (10%)

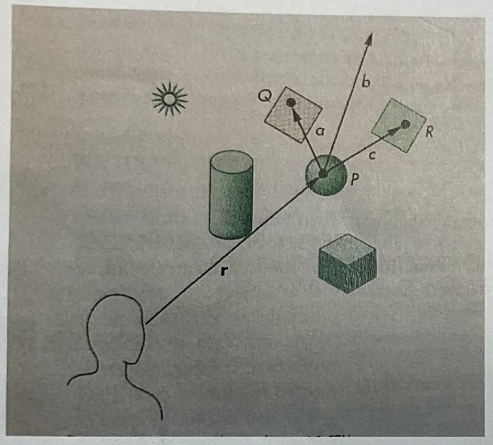
9. Rendering Shadows (10%)

How do you modify homework1 to make it render fake shadows like the image below? (10%) (Hint: similar to Z-buffer)

(Hint: you cannot use ray-object intersection test, it costs too much computationally to use in real-time rendering.)



10. Ray-tracing variations. (15%)



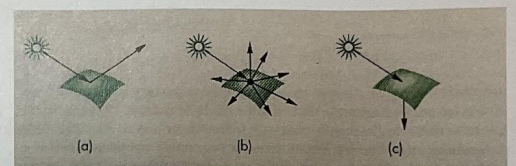


FIGURE 6.4 Light–material interactions. (a) Specular surface. (b) Diffuse surface. (c) Translucent surface.

In the left figure, traditional ray-tracing will shoot one rays, however, when the ray hits an object at point P, since it is a diffuse surface (such as a brick wall), three rays or more will branch from point P. Please refer to the right figure, the reflection rays from a diffuse surface is a function, such as Cosine (Theta).

A. (8%) Please describe this new algorithm to handle diffuse surfaces in the environment for ray-tracing variations. How efficient is this computational complexity as compared to the original ray-tracing?

B. (7%) How can you design a more efficient algorithm in your new algorithm, considering the left two conditions in the above right figure?