CS 130, Midterm 1

Solutions

Short answer. For each question below, provide a brief 1-3 sentence explanation.

Problem 1a (1 point)

Why do we use red, green, and blue when producing images? Why not two or four colors instead of three? Why not a different set of three colors?

The human eye uses three types of color-sensitive cells to distinguish colors; these cells are most sensitive to red, green, and blue light. The eye thus perceives other colors as combinations of these colors.

Problem 1b (1 point)

We saw in class that textures can be used to mimic the appearance of very detailed geometry in ways other than changing the color of the surface. Give an example of (1) an effect that can be "faked" using textures and (2) how one may observe upon closer inspection that the effect is not real.

Bump mapping and normal mapping are both used to produce richer geometry by "offsetting" the geometry or the normals. The trick can be observed for example by the smooth silhouette, lack of self-shadowing, or casting smooth shadows on other objects.

Problem 1c (1 point)

What are environment maps used for?

Environment maps provide a "background image" to display where no objects are intersected. For example, objects may be rendered in front of a background with a sky and clouds.

Problem 1d (1 point)

How might antialiasing be implemented in a ray tracer?

For each pixel, cast multiple rays in random directions through the pixel and average the results.

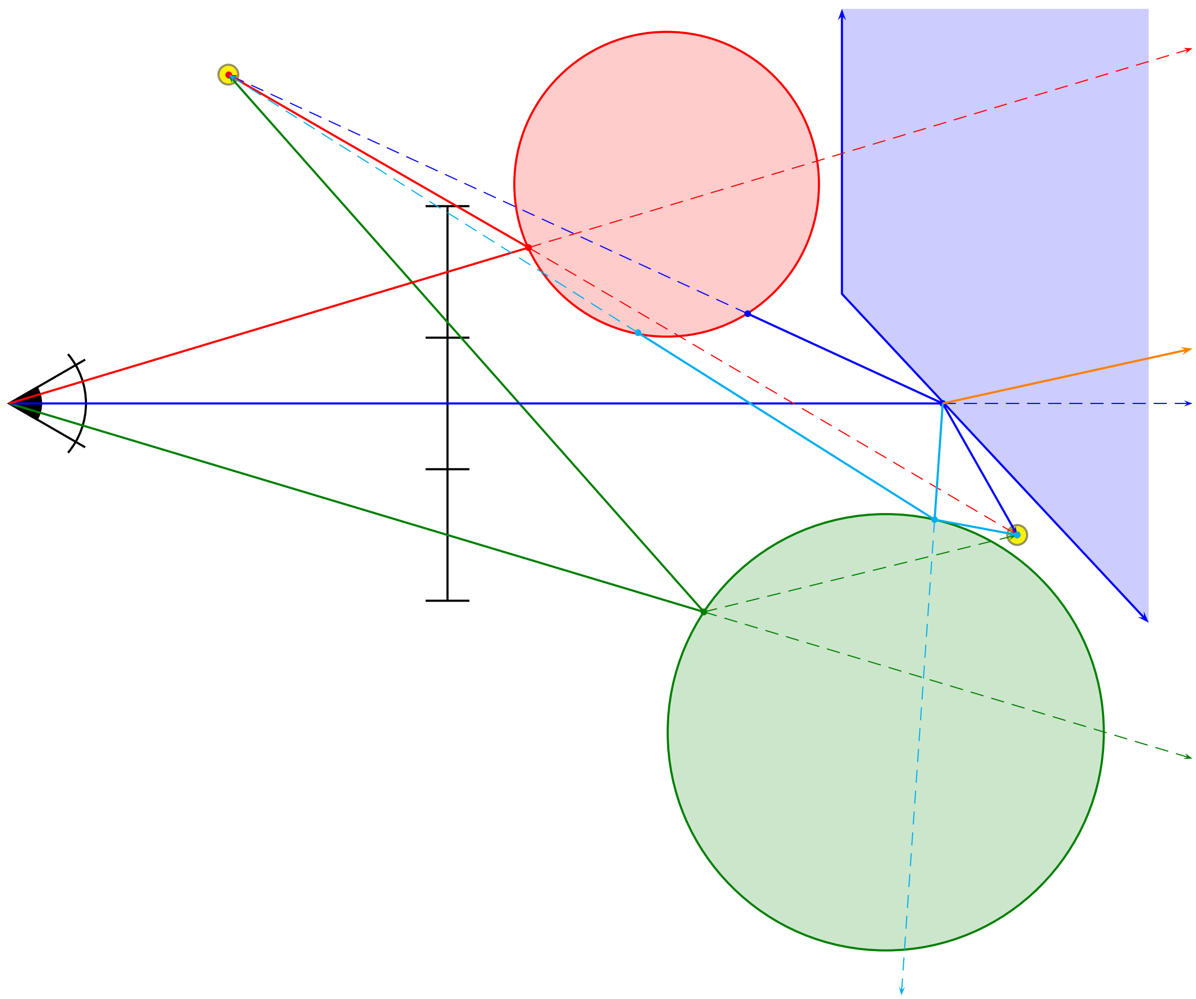
Problem 1e (1 point)

What is a directional light? Give an example of such a light.

A directional light is a light source so far away that all light that arrives from it comes from essentially the same direction. The sun is such a source.

Problem 2 (10 points)

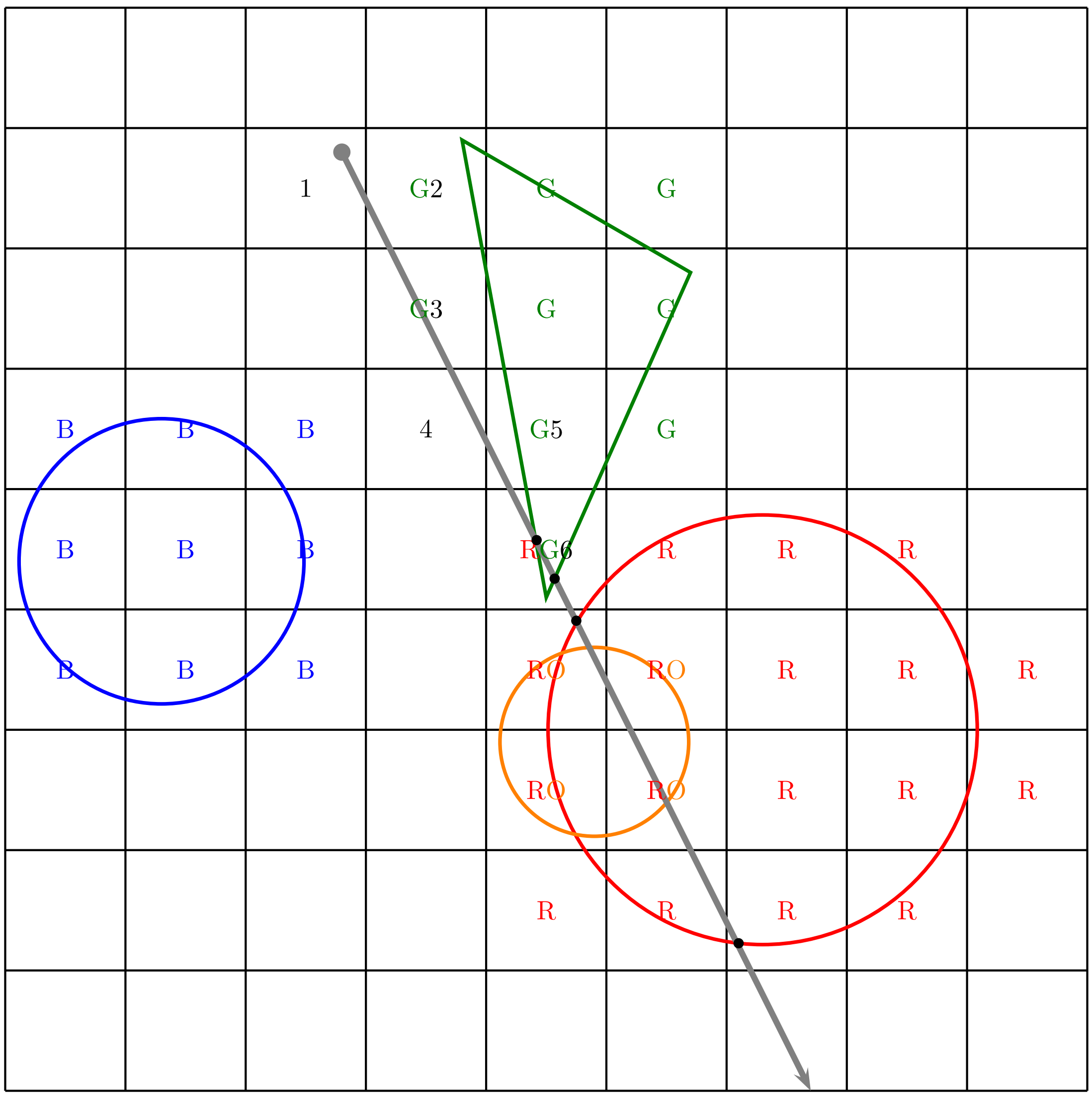
Below is a simple 2D raytracing setup. The 1D image has three pixels. The blue object is made of glass (reflective and transparent). The red and green objects are made of wood. The two yellow circles are point lights. Draw all of the rays that would be cast while raytracing this scene. The portion of each ray before the first relevant point of intersection should be solid. After that, the ray should be continued with a dashed line.



Problem 3 (5 points)

Below is a raytracing acceleration structure. Label the following:

1. Label grid cells with "R", "G", "B", or "O" to indicate that a pointer to the Red, Green, Blue, or Orange object will be stored there.
2. Number cells ("1", "2", "3", . . .) in the order they will be visited to test for intersections along the gray ray. Cells that should not be visited should not be numbered.
3. Place a "•" at each intersection point that will be computed. Intersections that should not be computed should not be marked.



Problem 4 (3 points)

A ray intersects a sphere with center $\mathbf{c}$ and radius r at location $\mathbf{x}$. What is the normal direction at this location?

$$\mathbf{n} = \frac{\mathbf{x} - \mathbf{c}}{\|\mathbf{x} - \mathbf{c}\|} = \frac{\mathbf{x} - \mathbf{c}}{r}$$

Problem 5 (3 points)

Find the intersection between a ray (endpoint $\mathbf{p}$, direction $\mathbf{u}$) and a plane (point $\mathbf{z}$, normal $\mathbf{n}$). You may assume that there is exactly one intersection.

$$\begin{aligned}
\mathbf{x} &= \mathbf{p} + t\mathbf{u} \\
(\mathbf{x} - \mathbf{z}) \cdot \mathbf{n} &= 0 \\
(\mathbf{p} + t\mathbf{u} - \mathbf{z}) \cdot \mathbf{n} &= 0 \\
(\mathbf{u} \cdot \mathbf{n})t &= (\mathbf{z} - \mathbf{p}) \cdot \mathbf{n} \\
t &= \frac{(\mathbf{z} - \mathbf{p}) \cdot \mathbf{n}}{\mathbf{u} \cdot \mathbf{n}} \\
\mathbf{x} &= \mathbf{p} + \frac{(\mathbf{z} - \mathbf{p}) \cdot \mathbf{n}}{\mathbf{u} \cdot \mathbf{n}}\mathbf{u}
\end{aligned}$$