

# Part 1a/1b Introduction to Graphics

## Supervision exercises

Michaelmas 2021/2022

### 1 Supervision 1

The questions cover the material from lectures 1-4

#### Warm up questions

1. An image has the width of  $w$  pixels, the height of  $h$  pixels and is stored in a column-major order with interleaved RGB colour channels. Write the formula for the memory index of a pixel at the coordinates  $(x, y)$  and with the colour index  $c \in \{0, 1, 2\}$ .
2. Explain the difference between sampling and quantisation.
3. Which depth cues can be reproduced on a 2D monitor and which require a special 3D display?
4. Explain why, in a typical ray tracing algorithm, the rays are traced from the eye to the scene and not the other way around.
5. What is the value of the ray parameter  $s$  at the intersection points between the ray  $[1, 1, 1] + s[-1, -1, -1]$  and the sphere centred at the origin with radius 1?
6. How to avoid aliasing when ray tracing?
7. What is the difference between a finite-aperture camera and a pinhole camera? How to simulate one and another in raytracing?
8. We often use triangles in computer graphics to represent 3D objects. Why are they good? Why are they bad? Can you think of any alternatives?
9. Why do we need to use different transformations for vertices and normal vectors?

#### Longer questions

1. Derive a formula for the intersection of a ray with a cylinder that has its base centered in  $[x_b, y_b, z_b]$  and extends along z-axis so that the centre of its top is at  $[x_b, y_b, z_b + h]$ , where  $h$  is the height of the cylinder. Derive only the formula for the intersection with the sides, not the base and the top. The ray equation is  $[x, y, z] = [x_o, y_o, z_o] + s[x_d, y_d, z_d]$ , where  $[x_o, y_o, z_o]$  is the origin of the ray and  $[x_d, y_d, z_d]$  is its direction.

2. Explain the Phong reflection model:
  - Explain each reflection component.
  - Why is there a cosine term in the diffuse component?
  - What does the ambient illumination component approximate?
  - When the camera moves, which of the reflection components change and which stay constant?
3. Explain how Ray tracing can achieve the following effects:
  - reflections
  - refraction
  - shadows
4. Explain why we use homogeneous coordinates.
5. Discuss the modelling, view and projection transformations used in a typical graphics pipeline.

## 2 Supervision 2

The questions cover material from lectures 5–8

### Warmup questions

1. What is the geometric interpretation of the barycentric coordinates of a triangle?
2. Which component(s) of the Phong reflection model require interpolating surface normal vector between vertices?
3. What are the major differences between OpenGL, DirectX and Vulkan?
4. What is GPGPU and what APIs could be used for that?
5. What are “in”, “out” and “uniform” variables in GLSL? How are the values of these variables set?
6. What kind of artefacts would you expect to see when rendering using a texture without a Mipmap?
7. Give an example in which normal (bump) mapping and displacement mapping will produce very different results.
8. What colours do we call metamers?
9. Why do we need to encode colours for displays?
10. Which colour spaces are suitable for
  - Efficiently encoding colours for displays, using possibly few bits;
  - User interfaces, such as a colour palette tool;

- Calculating the perceived difference between colours.
11. What is the difference between luma and luminance?
  12. What is the rationale behind sigmoidal tone-curves?
  13. Why do we need/want to simulate glare due to the lens or eye's optics in rendering?

### Longer questions

1. What is the worst case scenario, in terms of a number of times a pixel colour is computed, when rendering  $N$  triangles using the Z-buffer algorithm? How could we avoid such a worst-case scenario?
2. Put the following stages of the OpenGL rendering pipeline in the correct order. Very briefly explain what each stage does.
  - Rasterization
  - Vertex shader
  - Fragment shader
  - Primitive assembly
  - Clipping
3. Explain the following OpenGL concepts:
  - Array Buffer (Vertex Buffer)
  - Element Array Buffer (Index buffer)
  - Vertex Array (object)
4. How many vertices do you need to model a cube with normals as a triangle mesh, with and without an index buffer?
5. How could you use the following texture types to texture a sphere in OpenGL?
  - 2D
  - 3D
  - CUBE\_MAP
6. Explain how can OpenGL map a texture to the area that
  - contains more pixels than the texture;
  - contains fewer pixels than the texture.
7. Discuss strategies for avoiding tearing artefacts when rendering an animation.
8. What is the relation between LMS cone sensitivities and XYZ colour matching functions?
9. Explain the difference between linear and gamma-corrected (display encoded) colour values.
10. What do the ITU recommendations 709 and 2020 specify?
11. Explain the purpose of tone-mapping and display-encoding steps in a rendering pipeline.