Graphics Supervision 2 Work (srns2)

Warmup Questions

1. Barycentric coordinates of a triangle measure the distance from each vertex of the triangle, so provide an easy way to refer to points within and outside the triangle in context of the triangle. The three components of a point in barycentric coordinates add up to 1. If a component is less than 0, it is behind the corresponding vertex, if it is between 0 and 1 it is between the corresponding vertex and its opposite side, and if it is greater than 1 it is further than the opposite side.

2. The specular and diffuse components need to be interpolated as they aren't necessarily the same in one pixel as in another. However, the ambient component does not as it is the same everywhere.

3. OpenGL and Vulkan are cross-platform and open source, while DirectX is proprietary to Microsoft and only works on Windows and Xbox. OpenGL is designed for general 3D graphics, DirectX is designed for games, and Vulkan is designed for high performance 3D graphics. OpenGL is simpler to write than Vulkan but offers less flexibility and features.

4. GPGPU is general purpose GPU computing, and can be used to use a GPU for non-graphics related computing that would benefit from matrix and vector optimisations that a GPU has, such as in Bitcoin mining. The two main APIs for it are CUDA and OpenCL. CUDA is proprietary to NVIDIA and only works on NVIDIA GPUs, while OpenCL is open source and is cross-platform, and can run on CPUs in addition to GPUs.

5. `in` variables are input variables that may be different for each fragment and are therefore calculated separately for each fragment. `out` variables are output variables. `uniform` variables are input variables which are the same for all fragments and are therefore calculated just once. `in` and `uniform` variables are calculated outside of GLSL and passed in, for example in Java, while `out` variables are calculated in GLSL and returned.

6. A mipmap provides multiple resolutions so without a mipmap you may see pixellated graphics with larger objects.

7. When you have a very bumpy surface with a complicated surface, displacement mapping will look far more realistic than bump (normal) mapping as the surface itself is modified to make it closer to what it is supposed to be rather than trying to use shading angle to achieve the effect.

8. Metamers are colours which have different light spectra but which look the same to the human eye.

9. Colours are made of many different wavelengths but displays can only display red, green, and blue light, so colours must be encoded into combinations of these three primary colours to be displayed.

10. i. sRGB would be a suitable colour space for efficiently encoding colours for displays using as few bits as possible, as even though it can represent few colours, it represents them using a small number of its.
    ii. HSV or HLS would be suitable colour spaces for user interfaces, such as a colour palette tool, as even though they use more bits, they are easy to interpret.
    iii. CIE Lab or CIE Luv would be suitable colour spaces for calculating the perceived difference between colours as they are designed in such a way that the Euclidean distance between two points representing colours in 3D space corresponds to the approximate perceptually uniform colour difference.

11. Luminance is a physical quantity which can be approximated using linear RGB units, while Luma is pixel brightness in gamma-corrected RGB units, meaning it's more perceptually uniform, and is therefore used in image/video coding.

12. Scene luminance has to be compressed for display luminance as displays can't show such a wide range of luminances. A linear tone curve is a solution but reduces contrast as parts of the scene luminance range with many pixels have the same display luminance range as those with fewer pixels, so sigmoid tone curves address this by giving areas with more pixels (likely the more important regions) a greater range of the display luminance range and possibly clipping less important regions, resulting in better contrast.

13. Glare causes an illusion in the eye that makes an object with glare appear brighter, and since we are constrained with how big our luminance range is, glare is a good way to make objects appear brighter.

Long Questions

1. A calculation is done for every fragment of every triangle. The worst case scenarios occur when triangles are large with many fragments and there are many triangles. This scenario can be avoided by increasing the number of triangles and making them smaller.

2. The order is as follows:

    i. **Vertex Shader**, which processes vertices, normals, and texture coordinates.

    ii. **Primitive Assembly**, which organises vertices into primitives and prepares them for rendering.

    iii. **Clipping**, which removes or modifies vertices to make sure they are all on the display.

    iv. **Rasterisation**, which generates fragments to be drawn for each primitive, and interpolates vertex attributes.

    v. **Fragment Shader**, which computes the colour for each fragment and can modify pixels' depth value, and is also used for tone mapping.

3. A **vertex buffer (array buffer)** contains a list of positions and normals for each vertex, with an index. These indices are stored in an **index buffer (element array buffer)** to store the vertices which make up each triangle. A **vertex array** contains the array buffers of positions and normals, and the index buffer.

4. Each face of a cube is made up of 2 triangles of 3 vertices each (so 6 vertices overall). With an index buffer, 2 of these vertices can be used twice each as they are part of both triangles on the face. Therefore, it would take 4 vertices per face with an index buffer. This means that a cube would require 24 vertices with an index buffer, or 36 vertices without an index buffer.

5. i. 2D textures could be used by texturing each triangle that makes up the sphere.
    ii. 3D textures could be used by having empty texels in locations that the sphere does not take up.
    iii. Cubemap textures could be used in a similar way to ray tracing by drawing a vector from each fragment to the inside of the cube and using the value at that point.
6. i. If there are more pixels than texels then upsampling is done. This is done either by using nearest neighbour, or by using bilinear interpolation.
    ii. If there are fewer pixels than texels then downsampling is done. This involves averaging the values of the texels covered by each pixel.

7. Double buffering can be used to reduce tearing artefacts. This involves having two buffers to write to. The first buffer is first the front buffer being displayed while the second buffer is the back buffer is being drawn. Then these are switched: the 2nd buffer which has already been drawn while the first was displayed is the new front buffer, and the 1st buffer is now the back buffer and is drawn to, and they are then switched again for the next frame, and so on. Triple buffering can even be used to avoid having to wait for swapping to start drawing the next frame.

8. XYZ colour matching functions can be achieved by applying a linear transformation to LMS cone sensitivities. XYZ colour matching functions are derived from LMS cone sensitivities by experimentation, to match LMS cone excitations by photons as closely as possible.

9. Linear colour values are stored as floating point numbers, while display-encoded colour values are stored as integers, taking 8-12 bits per colour channel. This has the side effect of display-encoded colour values taking less space in memory to store than linear colour values. Linear colour spaces are directly related to measurements of light, while display-encoded ones are focused on the display. Linear colour spaces can be converted between using linear transformation matrices. Display-encoded colour values are intended for efficient encoding, easy interpretation of colour, or perceptual uniformity. For example, gamma-corrected colour values (a type of display-encoded colour values) aim for perceptual uniformity and

adjust pixels' brightness to make them more uniform to the human eye so that each equal jump in value appears to be an equal change according to perception by the human eye.

10. ITU Recommendation 709 (ITU-R 709) is used in Standard Dynamic Range (SDR) and has a bit depth of 8 to 10 bits. ITU Recommendation 2020 (ITU-R 2020) is used in High Dynamic Range (HDR) and has a bit depth of 10 to 12 bits.

11. Tone-mapping has many purposes, such as reducing the dynamic range, simulating a human eye or camera, or making an image look more realistic, but its underlying primary purpose is to transform an image from scene-referred colours to display-referred colours. Display encoding is then used to model the display itself and account for display contrast, brightness, and ambient light levels.