CS_217 (2009-2010)

COMPUTER GRAPHICS 1: IMAGE PROCESSING AND SYNTHESIS

(*Attempt 2 questions out of 3*)

Question 1

(a) Digital Images

Define the terms *sampling* and *quantization* in the context of digital images. How are digital images stored in memory? Give some figures for storage sizes for various sized example images.

[6 marks]

Continuous images are sampled at a given resolution to create 2D arrays of pixel intensities (and colours). ***[2 marks]*** *The resulting values may have to be quantized to fit the chosen data type (usually 8 bits per colour channel).* ***[2 marks]*** *Typical storage formats are 8 bits (3R3G2B), 8 bit colour tables, 15/16 bits (5R5G5B), true colour (8R8G8B), or floating point (for HDR).* ***[1 marks]****. Pixels are stored in a 2D array within memory. e.g. true colour will be a 2D array of 24 bit values, a 1Mega pixel image would require 3MBytes uncompressed to store.* ***[1 marks]***

*Part **a** subtotal=**[6 marks]***

(b) Aliasing

(i) What is the cause of noticeable aliasing in images? **[2 marks]**

(ii) What is the rate at which signals should be sampled? What name is that frequency known as? **[2 marks]**

(iii) Describe the technique of *Super-sampling* to produce anti-aliased images. **[5 marks]**

(iv) Describe (and draw) four different sampling strategies. Discuss the merits and demerits of each approach. **[4 marks]**

(i) Cause: Regions of high contrast / high frequency - e.g. jump from background colour to object colour ***[2 marks]****.*

(ii) For a signal of frequency f, it should be sampled at 2f. Known as Nyquist rate ***[2 marks]****.*

(iii) For each pixel, many samples are made (for example many rays per pixel are traced). The resulting colours are averaged to create the final pixel colour. For a regular grid of 3 by 3 samples, this approach would take 9 times the amount of work to create the image. It leads to a vast reduction in aliasing, but at the expense of the extra computation. ***[5 marks]***

(iv) Draw the situations for sampling on a regular grid, jittered samples, stochastic sampling and poisson-disk sampling. Computation cost: in order, low, low, low, high. Quality: in order, fourth, second, third, first. Ease of coding: good, good, good, hard. ***[4 marks]***

*Part **b** subtotal=**[13 marks]***

(c) Edge Detection

Discuss how we can use image processing techniques to identify edges within images. You can give a list of all the methods we have studied along with a few sentences about each, or give a more detailed discussion about one particular method (e.g. how examining derivatives leads to a 1st order or 2nd order method).

[6 marks]

List of methods:

(i) Cross correlation with high pass filter such as Sobel and then further processing (they could give a description of cross correlation here).

(ii) Edges are caused by large gradients. Large gradients can be spotted by a large value in the first derivative or a zero-crossing in the second derivative.

(iii) A first order derivative can be approximated by a central difference which can be calculated by cross correlation with a filter such as Prewitt or Sobel (which has some smoothing in-built). The gradient and direction of edges can be obtained.

(iv) A second order derivative can be carried out with the laplacian of gaussian filter, and then search for the zero crossings.

(v) A discussion of discrete derivatives using forward, backward or central differences (particularly derived from the limit definition of derivatives) would justify many marks in itself.

A selection of the above will give the full marks.

[6 marks] *Part **c** subtotal=**[6 marks]***

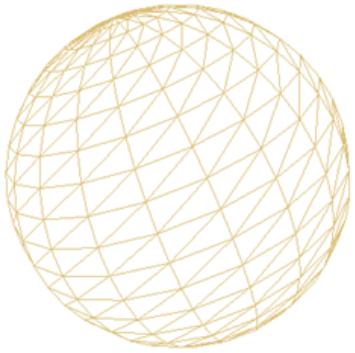
Question **1** total=**[25 marks]**

Threshold: (a) 3 marks, (b) 7 marks, (c) 2 marks = 12 total

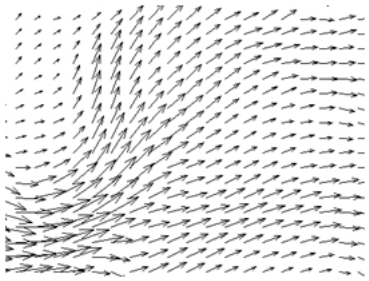
Question 2

(a) Object Representation

What would be the best approach for representing each of the following objects? For each, name the Direct3D drawing primitive and the reason for choosing that representation:



(a)



(b)

[6 marks]

Sphere - use a pointers to a vertex list, so each triangle is made up of three pointers. The vertex list is the list of all 3D points that make up the sphere. In Direct3D, either the D3D_TRIANGLELIST or D3D_TRIANGLESTIP would be a good choice. (Any reasonable explanation is OK - the above is a very advanced answer) ***[3 marks]***

Vectors - each vector is made up of 3 lines. Only one vertex is shared, so they are not a line list. Therefore the best would be to use a 2D array of 3D points where the 1st point is the start of the line, and the 2nd is the end. In Direct3D use the D3D_LINELIST. ***[3 marks]***

*Part **a** subtotal=**[6 marks]***

(b) Halftoning

Given the following pattern dithering matrix:

3	7	5
6	1	2
9	4	8

and the following 3x3 grey-level image (with levels from 0 to 255):

100	100	110
110	110	120
120	140	150

Carry out *Pattern Dithering* upon the image, namely:

(i) What is the average intensity of the image? **[1 marks]**

(ii) What is the scaled average intensity (between 0 and 1)? **[2 marks]**

(iii) Show the equation for calculating the pattern number, and calculate it in this case. **[4 marks]**

(iv) What pattern will be used to represent this 3x3 image? **[2 marks]**

(v) In addition, how does *Ordered Dither* differ from the pattern dithering method? **[3 marks]**

(i) Average=1060/9=117.77 ***[1 marks]***

(ii) Normalised (divide by 255)=0.4619 ***[2 marks]***

(iii) Pattern number=min(floor(I(n^2+1)), n^2 where n=3 and I=0.4619. Pattern number=4.6* ***[4 marks]***

(iv)

#		
	#	#
	#	

(#=pixel turned on) ***[2 marks]***

(v) It applies the equations to each individual pixel, and then compares that pixel to the corresponding entry in the dither matrix ***[3 marks]***

*Part **b** subtotal=**[12 marks]***

(c) **Median Filtering**

Describe the median filtering algorithm. What are its uses, advantages and disadvantages?

[7 marks]

Median Filtering

Set the filtering size - e.g. 3x3 neighbourhood. For each pixel, examine the neighbourhood. Place all pixel values into an array. Sort the array. Select the median. Use that value as the new value for the pixel. The method is used to remove scratches, dust or noise from images. The size determines the size of scratch, etc. that can be removed. The method is far better than low pass blurring filters as it maintains sharp edges, and can completely remove scratches, noise etc. of the defined size. Larger sizes can result in some rounding of corners, and reduction of the dynamic range.

[7 marks]

*Part **c** subtotal=**[7 marks]***

Question **2** total=**[25 marks]**

Threshold: (a) 2 mark, (b) 6 marks, (c) 2 marks = 10 total

Question 3

(a) **Illumination**

Define each of the following terms:

(i) Surface normal. **[2 marks]**

(ii) Ambient reflection. **[1 marks]**

(iii) Lambertian / Diffuse reflection. **[3 marks]**

(iv) Specular reflection. **[3 marks]**

(Diagrams may be useful in your definition. To achieve full marks for (iii) and (iv), the equations need to be given.

(i) Surface normal - vector perpendicular to the plane tangential to the surface at the point of measurement (with diagram) ***[2 marks]***

(ii) Ambient reflection - Light assumed to be incident upon a surface even if it is in shadow. ***[1 marks]***

(iii) Lambertian / Diffuse reflection - Light is scattered in all directions equally around the hit point. Governed by the cosine of the angle between the surface normal and vector to the light (calculated via a dot product). ***[3 marks]***

(iv) Specular reflection - Light reflected within a cone close to the mirror angle. Modelled using Phong illumination (again give equation). ***[3 marks]***

*Part **a** subtotal=**[9 marks]***

(b) **Ray Tracing**

Describe the process of recursive ray tracing. Include diagrams and examples to help with your description. Derive the ray/sphere intersection equation. **[10 marks]**

Ray Tracing

(i) View plane - rays passing through centre of projection (perspective model) or in parallel (orthographic)

(ii) Primary rays hitting a surface, then reflecting as secondary rays.

(iii) Primary rays hitting a surface, then refracting through a transparent object.

(iv) Primary rays hitting a surface, then secondary rays being used to determine light visibility (shadow)

(v) Recursive ray tracing: secondary rays can interact just like primary (i.e. further reflection and refraction)

(vi) Derive ray/sphere intersection equation by substituting the equation of a ray in the equation of sphere.

[10 marks]

*Part **b** subtotal=**[10 marks]***

(c) **Graphics Code**

What does each of the following code fragments do (assuming they are part of a larger program)?

(i)
```
int[][] h;
h=new int[256][3];
for (j=0; j<height; j++)
   for (i=0; i<width; i++)
      for (c=0; c<3; c++)
         h[image[j][i][c]][c]++;
```

[2 marks]

(ii)
```
for (j=0; j<height; j++)
   for (i=0; i<width; i++)
      for (c=0; c<3; c++)
         image[j][i][c]=
               255.0*Math.pow((image[j][i][c]/255.0),g);
```

[2 marks]

(iii)
```
grey[j][i]=grey[j][i]+error
if (grey[j][i]<threshold) {
   bw[j][i]=0
   error=grey[j][i]
}
else {
   bw[j][i]=max_intensity
   error=grey[j][i]-max_intensity
}
```

[2 marks]

*(i) Histogram **[2 marks]***
*(ii) Gamma correction **[2 marks]***
*(iii) The operation carried out at every pixel during error diffusion **[2 marks]***

*Part **c** subtotal=**[6 marks]***

Question **3** total=**[25 marks]**

Threshold: (a) 3 marks, (b) 5 marks, (c) 4 marks = 12 total