Computer Graphics 2004 p6q5

(a) Human eyes have three types of colour receptors, the colour signal to the brain is three-dimensional (roughly: intensity, red-green and yellow-blue).

Many different illuminations can appear to a human to be identical (metamerism).

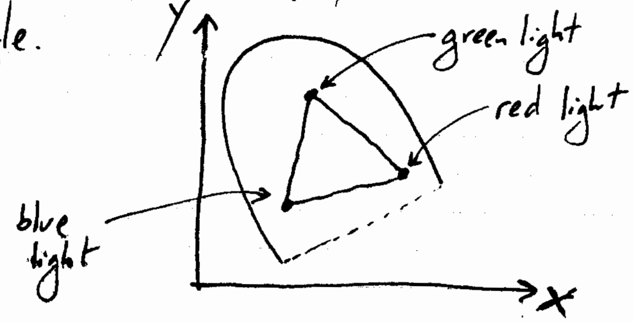
Using red, green and blue light, mixed in various quantities stimulates the colour receptors in the human eye in various ways. These three colours give a very good range of perceived colours.

~~It is not necessary to use more than three~~

It is NOT true that red light stimulates the red receptors, green light the green receptors and blue light the blue receptors. Each of the colours of light stimulates all three types of receptor, but in different quantities.

Three colours of light seems to be optimal because there are three types of receptor.

Some students may draw the CIE chromaticity diagram. All perceivable colours are within the horseshoe; all displayable colours are within the triangle.



(b) could use halftoning, ordered dither, or error diffusion.

ORDERED DITHER

define a 4×4 matrix $d(i,j)$

$$\begin{array}{c|cccc} 3 & 14 & 7 & 15 & 5 \\ 2 & 3 & 11 & 1 & 9 \\ 1 & 12 & 4 & 13 & 6 \\ 0 & 0 & 8 & 2 & 10 \\ \hline & 0 & 1 & 2 & 3 \end{array}$$

for $x = 0$ to width -1
  for $y = 0$ to height -1
    $i'(x,y) =$ if $(i(x,y)/15 > d(x \bmod 4, y \bmod 4))$
      then 1
      else $\emptyset$;

This processes every pixel $(i(x,y))$ to produce a new pixel $(i'(x,y))$ by comparing its value to the corresponding value in the dither matrix d. (hence the use of mod 4).

HALFTONING

as above, with a different matrix, e.g.

$$\begin{array}{c|cccc} 3 & 12 & 10 & 6 & 15 \\ 2 & 4 & 0 & 3 & 11 \\ 1 & 8 & 2 & 1 & 5 \\ 0 & 14 & 7 & 9 & 13 \\ \hline & 0 & 1 & 2 & 3 \end{array}$$

ERROR DIFFUSION

for $x = 0$ to width $- 1$
  for $y = 0$ to height -1
    if $(x > 0)$ $p = i(x,y) + \frac{1}{2} e(x-1, y)$
    else $p = i(x,y)$;
    if $(y > 0)$ $p = p + \frac{1}{2} e(x, y-1)$;
    if $(p \geq 128)$ {
      $i'(x,y) = 1$; $e(x,y) = 255 - p$;
    }
    else {
      $i'(x,y) = \emptyset$; $e(x,y) = p$;
    }

This processes every pixel by simple thresholding but also computes an error, e, for every pixel. Half of the error is passed to the right and half down.

(c) Specular reflection is "shiny" reflection. It is caused by light reflecting off microfacets on the objects' surface. It can generally be seen as a shiny specular highlight around the point where you would see a perfect mirror reflection ~~if the object~~ of the light, if the object were a perfect mirror.

Diffuse reflection is where the object scatters incoming light evenly in all directions. It is also called Lambertian reflection.

Diffuse equation

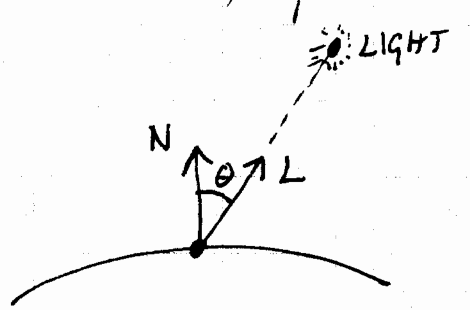
$$I_D = I_L \, (N \cdot L)$$

N is the normal vector to the surface at the point of interest.

L is a normalised vector pointing from the point of interest to the light

I_L is the intensity of the light

I_D is the intensity of the diffuse reflection



Specular equation

$$I_s = I_L (R \cdot V)^{\alpha}$$

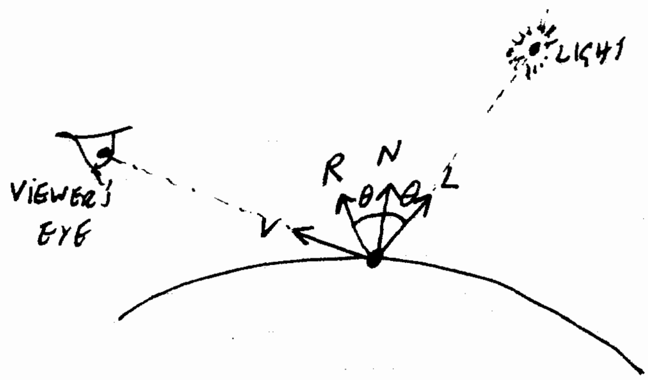
I_L is as above

I_s is the intensity of the specular reflection

V is a normalised vector from the point of interest to the viewer's eye

R is a normalised vector pointing in the direction of perfectly reflected light from the light source

α is a "roughness" co-efficient. The higher α, the smoother the surface and the smaller the shiny specular highlight



2004 p6 q5 MARKING SCHEME

(a) eye contains 3 types of colour receptor — 1
so many different stimuli appear to produce the same response — 1
3 colours of light (at least) are needed ~~to provide all perceived colours~~ because there are 3 types of receptor — 1
red/green/blue provide good coverage of perceptual colour space — 1
LOSE A MARK if say: red light stimulates only red receptors
green " " only green "
blue " " only blue "

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(b) FOR ~~ERROR DIFFUSION~~ ORDERED DITHER OR HALF TONING

a valid dither matrix — 2
correct use of mod — 1
correct division of $i(x,y)$ for comparison — 1
correct thresholding to ϕ or 1 — 1
processes every pixel — 1
clear explanation — 1

— 8

FOR ~~ORDERED DITHER~~ ERROR DIFFUSION — OR

correct thresholding to ϕ or 1 — 2
correctly calculates errors ($255-p$ or p) — 2
correctly adds errors to adjacent pixels — 2
processes every pixel — 1
clear explanation — 1

— 8

— 8

(c) FOR EACH OF SPECULAR & DIFFUSE

correct real-world description — $2 \times 1 = 2$
correct equation — $2 \times 1 = 2$
correct explanation of the variables — $2 \times 2 = 4$

— 8

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