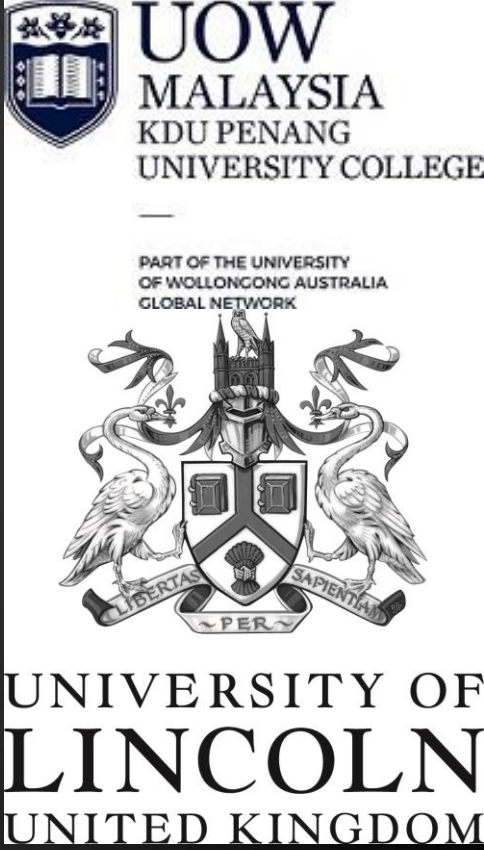
COMPUTER GRAPHICS (CCG3013)

LESSON 8

COLOUR



COURSE OUTLINE

Lesson	Topic
1	Introduction to computer graphics
2	Graphics hardware and software
3	Geometry in 2D graphics
4 & 5	Geometry in 3D graphics
6 & 7	User interfaces and interactions
8	Colour
9	Lighting and rendering
10 & 11	Motion and animation
12	Surface shadings

REVIEW ON EXERCISE 2

1. Identify five UI libraries which are not from the lecture.

2. For each identified UI library, find the following details.

    (a) Developer(s),

    (b) Programming language used to develop,

    (c) License, and

    (d) Latest version

SAMPLE ANSWERS ON EXERCISE 2

UI libraries	Developer	Programming language	License	Latest version
Fast light toolkit (FLTK)	Bill Spitzak	C++	LGPL	1.4.x r12173
Qt	Haavard Nord & Eirik Chambe-Eng	C++	Qt commercial license; GPL 2.0, 3.0, LGPL 3.0	5.9.2
wxWidget	Julian Smart	C++	wxWindows License	3.0.3

ASSESSMENTS

Structure	Marks (%)	Hand-out	Hand-in
Assignment 1 (Individual)	30	Week 1(Unofficial) Week 3(Official)	Week 6
Assignment 2 (Group up to four only)	30	Week 1(Unofficial) Week 3(Official)	Week 12
Final examination	40	Exam week	

LEARNING OUTCOMES

1. Explore the existing colour space models.

2. Identify the colour properties for a pixel/voxel.

3. Implement multi-layer colours in the render component.

CONTENT

No.	Topics	Duration (Minutes)
1	Mini lecturer 1: RGB & RGBA colours	15
2	Exercise 1	10
3	Mini lecturer 2: Colour space models	15
4	Exercise 2	10
5	Break	10
6	Mini lecturer 3: Colour in OpenGL	15
7	Exercise 3	10
8	Mini lecture 4: Colour composition	15
9	Exercise 4	10

MINI LECTURE 1
RGB & RGBA COLOURS

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COLOUR PROPERTIES FOR A PIXEL

1. Stands for picture element.
2. A pixel has four channels, which are red, green, blue, and alpha.
3. Each channel has 1 byte (8 bits) of colour depth measured in intensity unit.
4. The range for intensity value is [0, 255].
5. Each pixel has the maximum of 8 immediate neighbours.
6. Alpha channel is the opacity, which is the opposite of transparency.

PRIMARY COLOURS

1. Primary colours comprise red, green, and blue colours.
2. Colour vector for red, green, and blue is shown in the Table below.

Colours	RGB values, (r, g, b)
Red, R	(255, 0, 0) or (1, 0, 0)
Green, G	(0, 255, 0) or (0, 1, 0)
Blue, B	(0, 0, 255) or (0, 0, 1)

3. The full colours for a 24 bit RGB is 2^{24} or 16,777,216 colours.
4. The full colours for a 32 bit RGBA is 2^{32} or 4,294,967,296 colours.

ADDITION OF RGB COLOUR

1. Secondary colours comprise cyan, magenta, and yellow colours.

2. Secondary colours can be produced by addition of two primary colours.

Yellow, Y = R + G = (255, 0, 0) + (0, 255, 0)

= (255, 255, 0)

Cyan, C = G + B = (0, 255, 0) + (0, 0, 255)

= (0, 255, 255)

Magenta, M = B + R = (0, 0, 255) + (255, 0, 0)

= (255, 0, 255)

BINARY COLOURS

1. Sometimes it refers to black and white colours.

2. Black colour, K has zero vector of RGB, (0, 0, 0).

3. White colour, W is the addition of red, green, and blue colours.

White, W = R + G + B

= (255, 0, 0) + (0, 255, 0) + (0, 0, 255)

= (255, 255, 255).

GREY VALUES

1. Sometimes it refers to monochromatic.

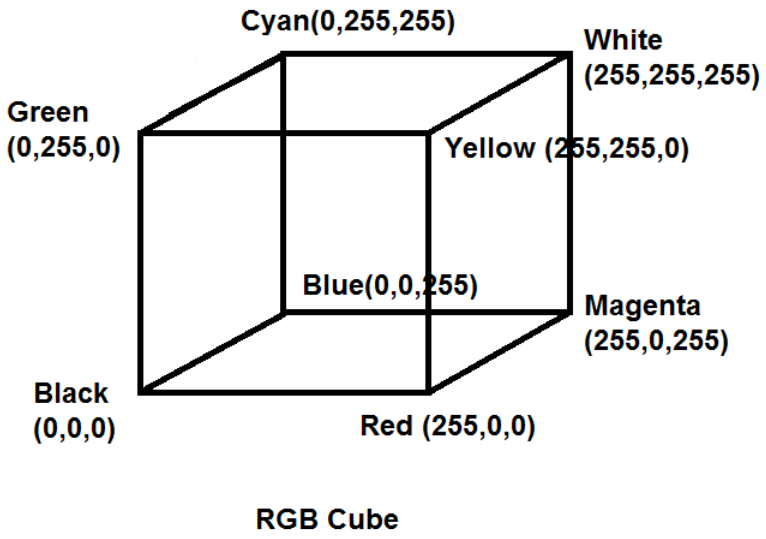
2. Greyscale, E can be produced with the criterion,

$$R = G = B,$$

where the intensity value for red, green, and blue are the same.

3. There are 256 possible grey levels for 8 bit colour depth.

RGB COLOUR SPACE



RGB Cube

EXERCISE 1

This activity will takes about 10 minutes.

1. Derive the secondary colours from primary colours in colour vector.

2. What is the memory size for an RGB image with resolution 128 × 128?

3. Identify grey in RGB cube space.

1. Cyan = G + B = (0, 1, 0) + (0, 0, 1) = (0, 1, 1)
Magenta = R + B = (1, 0, 0) + (0, 0, 1) = (1, 0, 1)
Yellow = R + G = (1, 0, 0) + (0, 1, 0) = (1, 1, 0)

2. 49152 bytes = 48kB

3. Line that lies between Black (K) and white (W) in cube space

MINI LECTURE 2
COLOUR SPACE MODELS

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HSB COLOUR SPACE

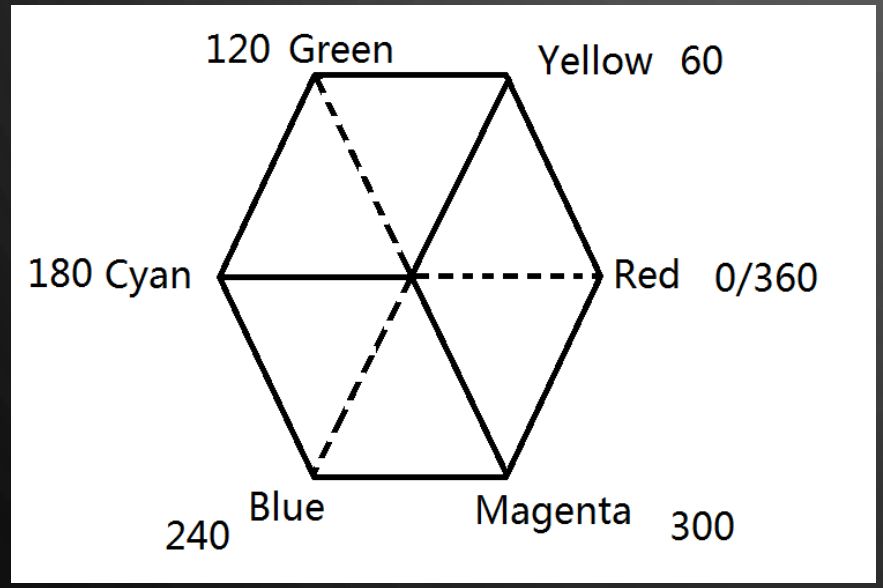
1. HSB stands for hue, saturation, and brightness.

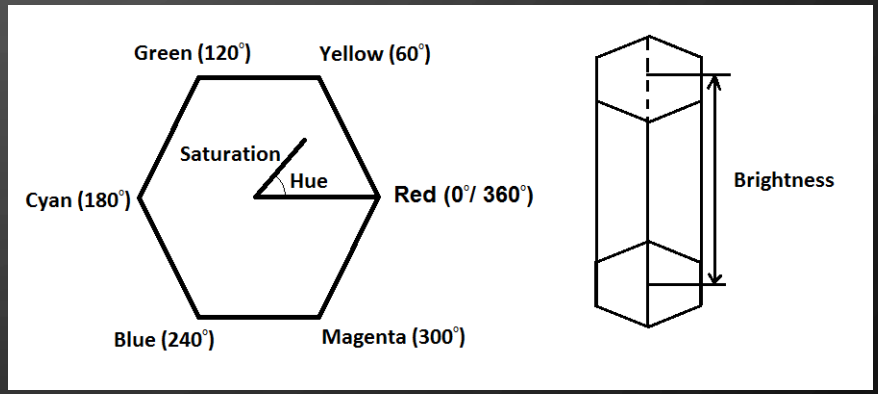
2. Hue determines a rainbow-like colour, which represents the angle in the range of 0 to 360 degree.

3. Saturation represents the fade level of a colour in percentage (0% to 100%).

4. Brightness represents the lightness in intensity of 0 to 255.

HSB COLOUR SPACE





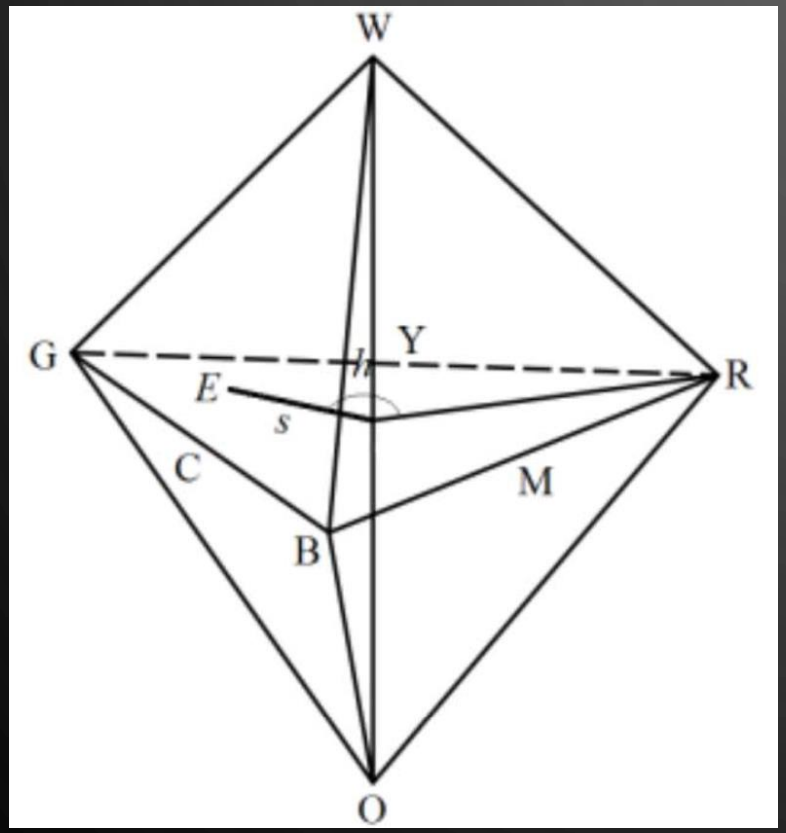
HSI

1. HSI stands for hue, saturation, and intensity.

2. It is an opponent colour space (OCS) which formulated to approximate the non-linear CIE*L*a*b**.

3. The shape of the HSI model is bi-tetrahedron with equilateral triangular based.

RGB TO HSI CONVERSION



$$h = \cos^{-1}\left[\frac{2r - g - b}{2\sqrt{(r-g)^2 + (r-b)(g-b)}}\right]$$

$$I = \frac{r + g + b}{3}$$

$$s = 1 - \frac{\min(r, g, b)}{I}$$

HUE IN HSI

If g ≥ b, then

$$h = \cos^{-1}\left[\frac{2r - g - b}{2\sqrt{(r-g)^2 + (r-b)(g-b)}}\right]$$

else, means g < b, then

$$h = 360° - \cos^{-1}\left[\frac{2r - g - b}{2\sqrt{(r-g)^2 + (r-b)(g-b)}}\right]$$

EXERCISE 2

This activity will takes about 10 minutes.

Convert the following RGB values, (r, g, b) to HSI.

1. Red, (255, 0, 0)
2. Green, (0, 255, 0) [Homework]
3. Blue, (0, 0, 255) [Homework]
4. Yellow, (255, 255, 0), [Homework]
5. Cyan, (0, 255, 255), [Homework]
6. Magenta, (255, 0, 255).

BREAK

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MINI LECTURE 3
COLOUR IN OPENGL

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COLOUR FUNCTIONS

Function name	glColor3f, glColor4f, glColor3i, glColor4i
Purpose	It specifies new red, green, blue, and alpha values for the current colour.
Arguments or parameters	Red; Green; Blue; Alpha;
Return value	None.

COLOUR MATERIAL

Function name	glColorMaterial
Purpose	Material colour to track the current colours. Note that `glEnable(GL_COLOR_MATERIAL)` should be enabled first.
Arguments or parameters	GLenum face; GLenum mode;
Return value	None.

FACE TO TRACK COLOUR

GL_FRONT, it specifies the front face should track the current colour.

GL_BACK, it specifies the back face should track the current colour.

GL_FRONT_AND_BACK, it specifies both front and back faces should track the current colour.

MODE TO TRACK COLOUR

GL_EMISSION

GL_AMBIENT

GL_DIFFUSE

GL_SPECULAR

GL_AMBIENT_AND_DIFFUSE (Default value)

EXERCISE 3

This activity will takes about 10 minutes.

Set the following colours using OpenGL function.

1. Red,
2. Green,
3. Blue,
4. Yellow,
5. Cyan,
6. Magenta.

MINI LECTURE 4
COLOUR COMPOSITION

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TRANSPARENCY

1. Transparency is the opposite of opacity.

   (a) 20% opacity is 80% transparency,

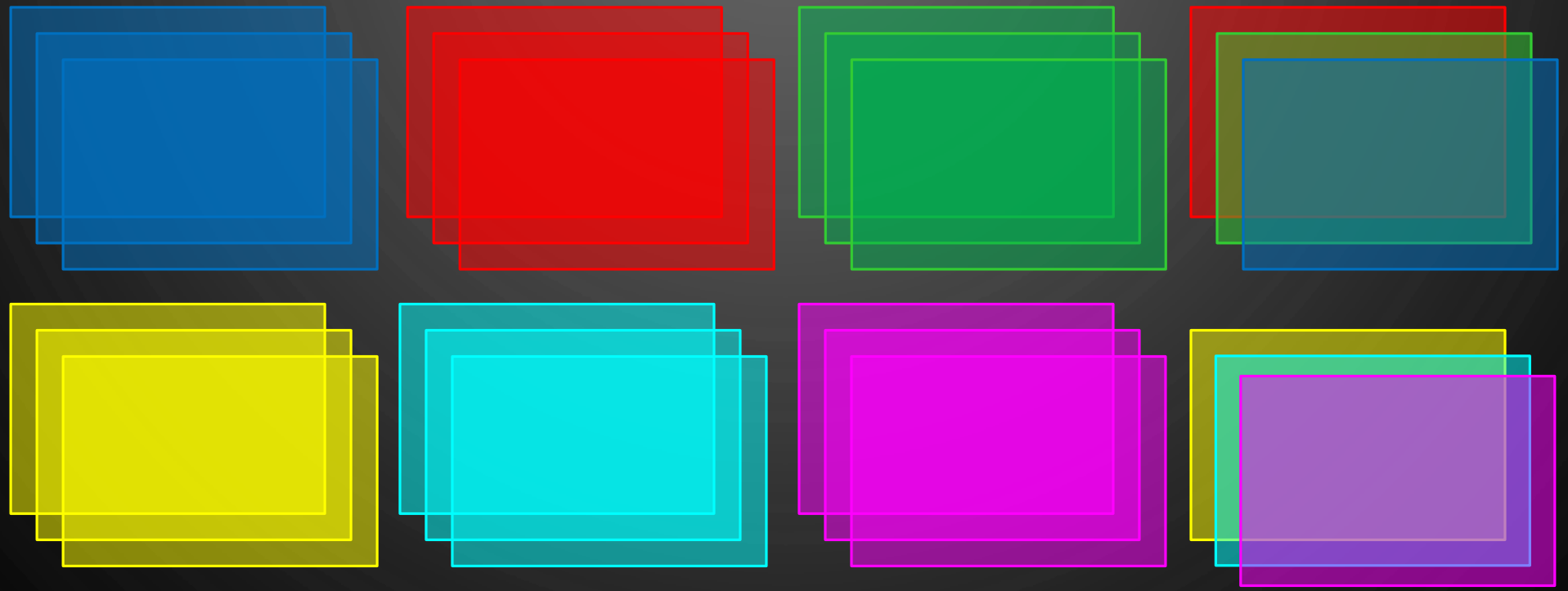
   (b) 0% opacity is 100% transparency,

   (c) 50% opacity is 50% transparency.

2. Alpha channel represents the opacity in the range of [0, 255].

PLANE LAYERING

Glass effects can be produced by overlapping clipping planes.



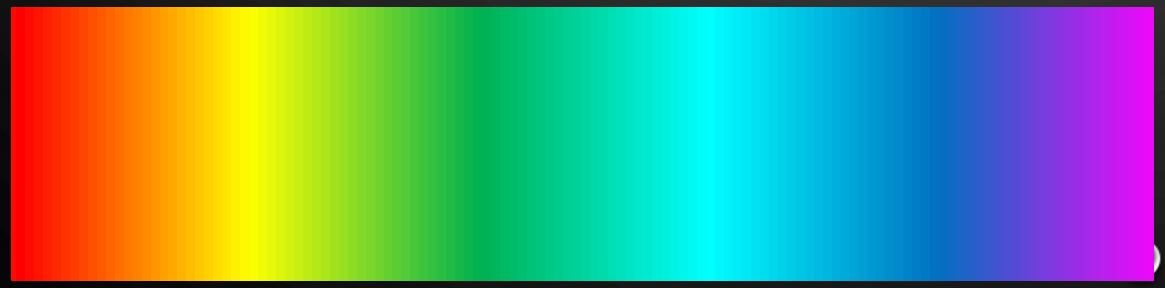
COLOUR GRADIENT

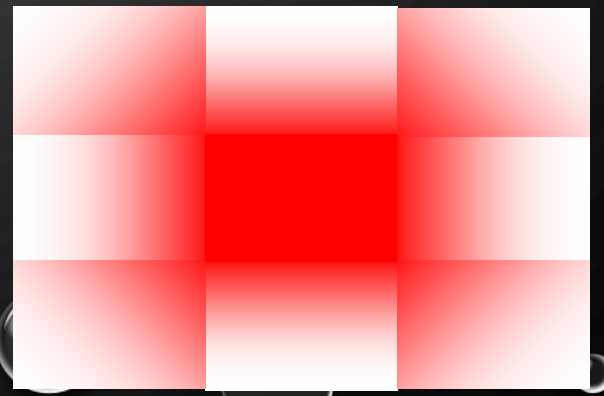
1. It refers to the colour tone.

2. It is the changes of one colour to another.

3. A tone has a start colour and an end colour.

4. Colour changes in a given orientation or direction at certain angle.





EXERCISE 4

This activity will takes about 10 minutes.

1. Specify two approaches to generate a colour composite.

2. What is the colour depth for an alpha channel in RGBA colour mode?

3. How to produce colour composite in OpenGL? [Homework]

REFERENCES

Main reference:

Hajek, D. (2019). Introduction to Computer Graphics 2019 Edition. Independently Published.

Additional reference:

Marschner, S. and Shirley, P. (2021). Fundamentals of Computer Graphics, 5th Edn. CRC Press: Taylor's & Francis.