COMP4610/COMP6461

Week 1 - Introduction

<Print version>

Outline

Lecture Outline

1. Course Information
2. A (brief) History of Computer Graphics
3. Graphics Hardware
4. Colour
5. The Frame Buffer

Course Information

Course Outline

Week	Content
1	Introduction to Computer Graphics
2	2D Graphics
3	2D Transformations and Hierarchical Modeling
4	Animation
5	Vector and Matrix Math
6	Physics and Introduction to 3D Graphics
7	Shaders and Texture Mapping
8	Visible Surface Algorithms, Clipping and Shadows
9	Introduction to Lighting
10	The Phong Reflection Model and Raytracing
11	Radiosity and Blender
12	Antialiasing and Image Formats (+bonus)

Bonus Content

If we have time on Week 12, I'll cover some recent developments in computer graphics.

- Nanite - Vertex virtualization in Unreal Engine 5.
- Superscaling - High resolution, high framerate, for free?
- Imposters - LOD used in Fortnight, long draw distances with fast frame rates on low end devices.

Assessment

Assessment Task	Weighting
Labs (6x)	30%
Individual Assignment	20%
Group Assignment	30%
Final Exam	20%

Assessment

Week	Content
3	Lab 1
5	Lab 2
6	Individual Assignment
7	Lab 3
9	Lab 4
11	Lab 5
12	Lab 6
12	Group Assignment

Plagiarism

- Outside of the group project all work should be completed individually.
- I take an 'honour' approach to plagiarism. However, all submitted material will be run through plagiarism detection, which can detect duplicate submissions at a structural level (i.e. when variables have been renamed).

Labs

- Labs run each week starting week 2
- There are 6 lab assignments, each worth 5% each.
- Discussion in labs is encouraged, but submitted work must be completed individually.

Office Hours and Q&A

- Office hours are after the lecture (Monday 12pm - 1pm) in my office CSIT Building 108 room N204.
- Can use this to ask questions about the course material.
- We will also be running a drop-in Q&A session starting week 2, on Tuesdays from 1 pm to 2 pm.

Textbook

- We use an open source textbook for this course.
- The lectures, labs, and assignments cover all the required material, the textbook is there as a supplementary resource.
- The textbook is available online, and has interactive demos.

About Us

About Me

- PhD Student (about to finish!)
- Have been building graphics engines for 30 years (if you count ASCII art graphics).
- Expertise is in AI, and training AI to play video games.
- Spend far too much time watching AI play Atari games.
- AI and graphics has more and more overlap every day. I'll try to point out some of the more interesting connections as we go.

Our Tutors

Alexei

Patrick

Runze

Context Slides

- I'm trialling 'context slides' this semester.
- These 'blue' slides contain additional context but are (generally) not examinable.

A (brief) History Of Computer Graphics

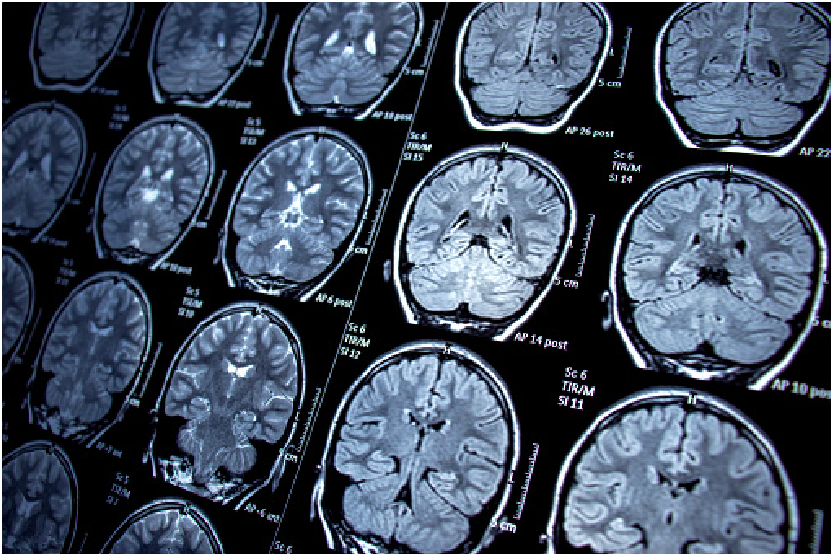
Computer Graphics in Modern Society


Gift Giving
CHECKOUT
PLEASE SLIDE YOUR CARD
Apples, Red Delicious
Asparagus, Green
Bakery, Bagels
Bakery, Muffins, Assorted
Bakery, Rolls, Assorted
Bananas, Yellow
Broccoli
Broccoli Crowns
Cantaloupe
Cucumbers
Granny Smith Apples
Grapes, Crimson
Grapes, Red, Seedless
Grapes, Wht-Grn, Seedless
Green Beans
Melon, Watermelon, Seedless
Nectarines
Oranges, Western Navel, Lg
Peaches
Salad Bar, Lg
Tomatoes, Extra Lg
Tomatoes, On Vine, Red
Cancel
Next Page
Le-Nu
Ok-Pe
Pe-Ra
Ra-Sq
Sq-Z


Fame Focus

Games

Public Displays

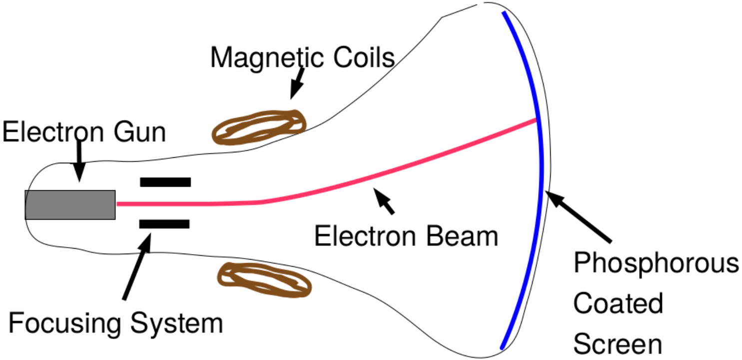

AP 26 post
5 cm
Sc 6
TIR/M
SI 14
AP 14 post
5 cm
Sc 6
TIR/M
SI 11

And many other applications...

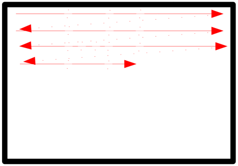
- Mobile Phones/Tablet computing
- Desktop computing (Computer-Aided Design, document editing, the web)
- Data Visualizations
- Education and Training
- Image Processing

Graphics Hardware

Cathode-Ray Tube (CRT)



Raster-Scan Display

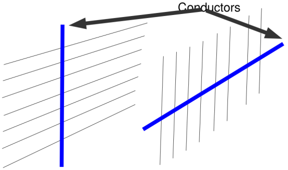


- Resolution: Number of non-overlapping points that can be displayed - columns $\times$ rows.
- Framebuffer stores the picture.
- Depth - bits per pixel.
- Aspect ratio - columns / rows.
- Also, pixel aspect ratio is not always 1:1.

Interlacing

Interlaced video can produce combing artefacts if not correctly processed.

Liquid-Crystal Displays (LCD)

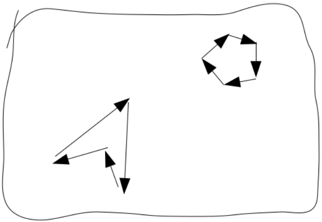


- Polarization blocks light emitting from a back pannel.
- Uses Nematic Liquid Crystal between Polarisers.
- Can be very cheap.
- Used in calculators, older laptops etc.
- Often a LED back light is used.
- Often has high persistence (ghosting).

Light Emitting Diodes (LEDs) Displays

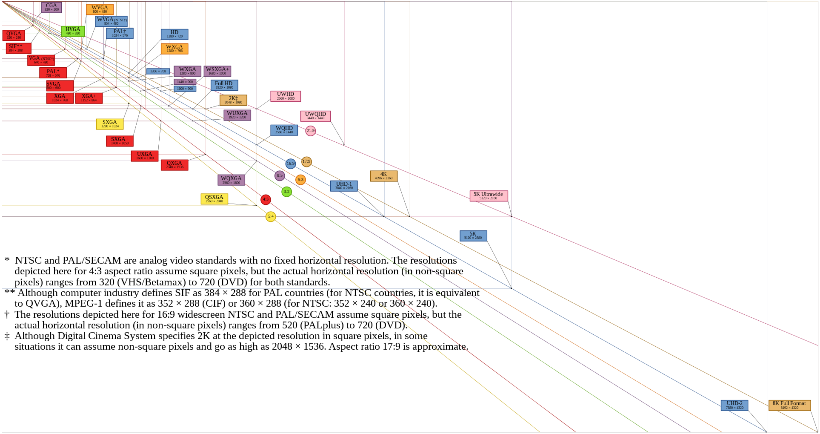
- Requires less power.
- Less persistence.
- All colors are made up of red, green and blue LEDs.

Vector Graphics Displays

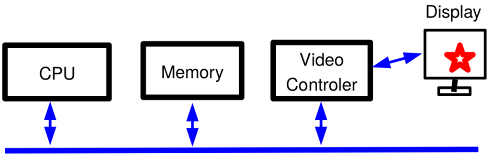


- Some early computer graphics system used vector graphics displays rather than raster display devices. In these displays the electron beam would repeatedly follow the line segments that made up the image.
- This required considerably less memory than the frame buffer use in a raster display.
- These displays were used in systems such as the SAGE air defence system and Atari's Asteroids video arcade game.

Resolution

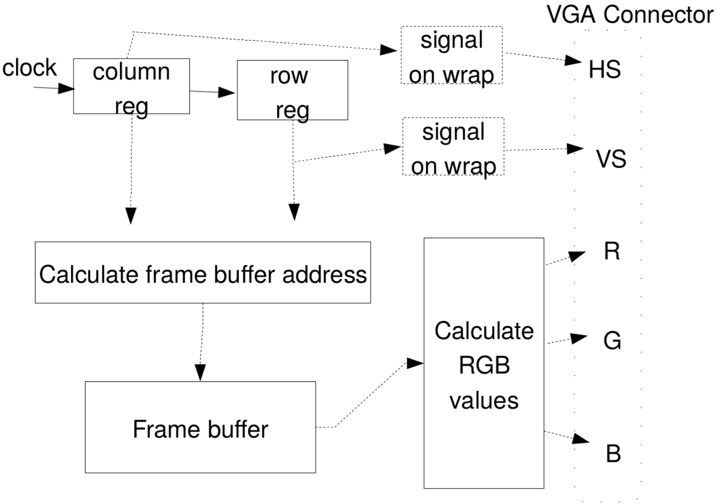

CGA 320 × 200
WVGA 800 × 480
WVGA (NTSC†) 854 × 480
QVGA 320 × 240
HVGA 480 × 320
PAL† 1024 × 576
HD 1280 × 720
SIF** 384 × 288
WXGA 1280 × 768
VGA (NTSC*) 640 × 480
1366 × 768
WXGA 1280 × 800
WSXGA+ 1680 × 1050
PAL* 768 × 576
1440 × 900
Full HD 1920 × 1080
SVGA 800 × 600
1600 × 900
XGA 1024 × 768
XGA+ 1152 × 864
UWHD 2560 × 1080
2K‡ 2048 × 1080
WUXGA 1920 × 1200
UWQHD 3440 × 1440
SXGA 1280 × 1024
WQHD 2560 × 1440
21:9
SXGA+ 1400 × 1050
UXGA 1600 × 1200
17:9
16:9
QXGA 2048 × 1536
4K 4096 × 2160
8:5
5:3
WQXGA 2560 × 1600
UHD-1 3840 × 2160
3:2
5K Ultrawide 5120 × 2160
QSXGA 2560 × 2048
4:3
5:4
5K 5120 × 2880
* NTSC and PAL/SECAM are analog video standards with no fixed horizontal resolution. The resolutions depicted here for 4:3 aspect ratio assume square pixels, but the actual horizontal resolution (in non-square pixels) ranges from 320 (VHS/Betamax) to 720 (DVD) for both standards.
** Although computer industry defines SIF as 384 × 288 for PAL countries (for NTSC countries, it is equivalent to QVGA), MPEG-1 defines it as 352 × 288 (CIF) or 360 × 288 (for NTSC: 352 × 240 or 360 × 240).
† The resolutions depicted here for 16:9 widescreen NTSC and PAL/SECAM assume square pixels, but the actual horizontal resolution (in non-square pixels) ranges from 520 (PALplus) to 720 (DVD).
‡ Although Digital Cinema System specifies 2K at the depicted resolution in square pixels, in some situations it can assume non-square pixels and go as high as 2048 × 1536. Aspect ratio 17:9 is approximate.
UHD-2 7680 × 4320
8K Full Format 8192 × 4320

Raster-Scan System



- Generally, a special purpose processor will be used for driving the display.
- Usually, separate memory is used for the frame buffer, to which the video controller has direct access.
- (Analogue) VGA uses horizontal sync(HS), and vertical sync(VS) signals along with RGB signals to transport an image to a display.
- HDMI, DVI, and DisplayPorts are digital approaches for connecting a computer to a display.

Video Controller



Course Rep

Course Representatives

Why become a course representative?

- **Develop skills sought by employers**, including interpersonal, dispute resolution, leadership and communication skills.
- **Become empowered**. Play an active role in determining the direction of your education.
- **Become more aware of issues influencing your University** and current issues in higher education.
- **Ensure students have a voice** to their course convener, lecturer, tutors, and college.

Course Representatives

Roles and responsibilities:

- Act as the official liaison between your peers and convener.
- Be creative, available and proactive in gathering feedback from your classmates.
- Attend regular meetings, and provide reports on course feedback to your course convener and the Associate Director (Education).
- Close the feedback loop by reporting back to the class the outcomes of your meetings.

More information about roles and responsibilities contact

- ANUSA CECS representative Sophie Burgess sa.cecs@anu.edu.au
- ANUSA President, Lachy Day sa.president@anu.edu.au

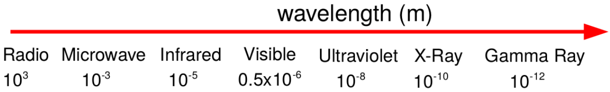
Colour

Colour

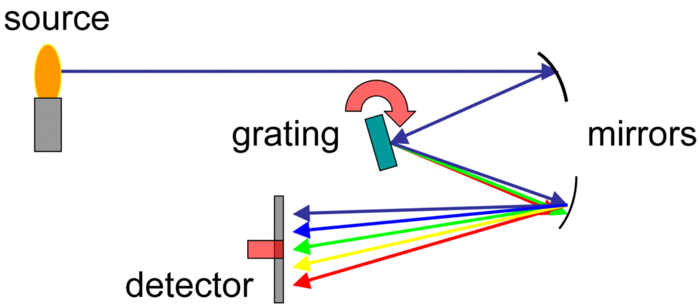
Physical Properties

Physical Properties of Color

- Visible light is a small part of the electromagnetic spectrum.
- Light travels at the speed of light!! Which in a vacuum is: c $= 299{,}792{,}458$ m/s.
- Light is made up from electric and magnetic field oscillating perpendicular to each other as it moves through space.
- Light has three main properties: intensity, wavelength (or frequency), and polarisation.
- The frequency and wavelength is related to each other by the speed of light ($c = \lambda f$)



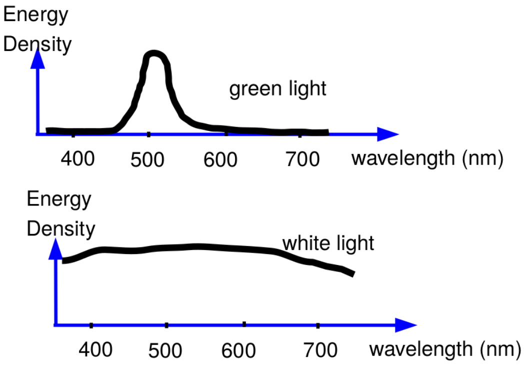
Spectrometer



Source http://en.wikipedia.org/wiki/File:Spectrometer_schematic.gif

Colour

- Colour is high dimensional (technically you need a Hilbert space to describe such functions!).

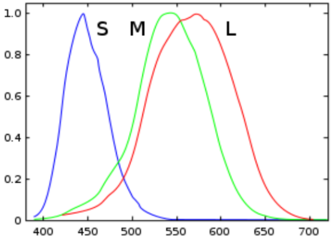


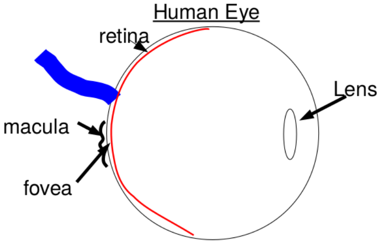
Colour

Colour Perception

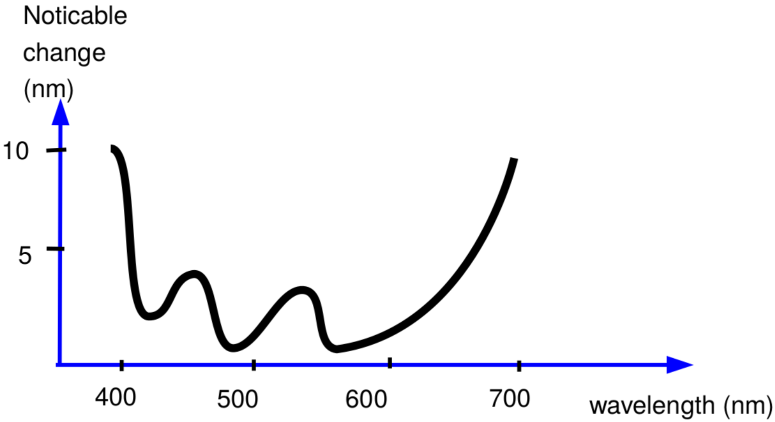
The Eye

- Our eyes makes life much simpler for us (people doing computer graphics!) as it reduces an infinite dimensional space down to a 3 dimensional space.
- The retina is light sensitive tissue lining the eye. The two main types of photo sensitive cells are cones and rods.





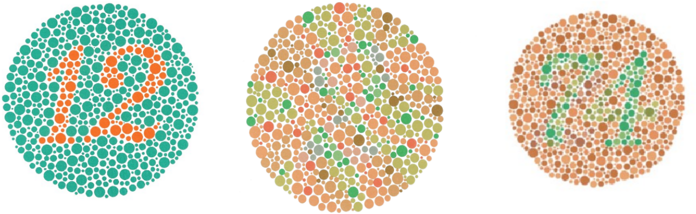
Distinguishing Colours



Just-noticeable colour differences change as a function of wave length.

Red-green Colour Deficiencies

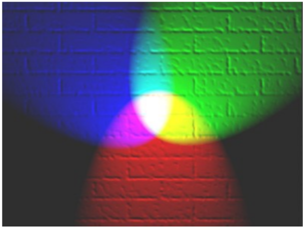
- Ishihara Colour Plates help uncover deficiencies in people's colour perception.
- Colour perception limitations are not just for people with colour deficiencies.



Not suitable for diagnosis.

Grassmanns Law

- When two light sources are combined the energy density functions of two different colours can be added together.
- To work out what colour we perceive we could, for each type of cone (S,M,L), integrate over the response curve times the energy density function.
- This integration preserves the additive property on the intensities we perceive. (Grassmanns Law)



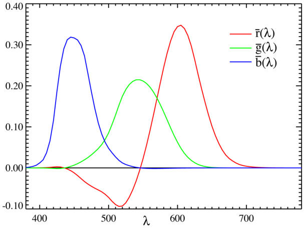
RGB Color Matching Functions

- In 1931 the International Commission on Illumination (CIE) created a standard for colour matching.
- Their colour matching can be done with standard primaries: Red 700nm, Green 546.1nm, Blue 435.8nm
- These functions give us an objective way of mapping a real colour (energy density function) to RGB values.

$$R = \int I(\lambda)\bar{r}(\lambda)d\lambda$$

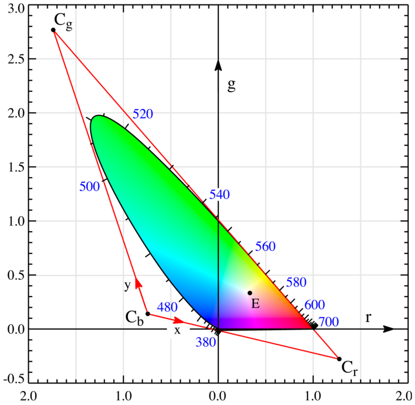
$$G = \int I(\lambda)\bar{g}(\lambda)d\lambda$$

$$B = \int I(\lambda)\bar{b}(\lambda)d\lambda$$



Chromaticity

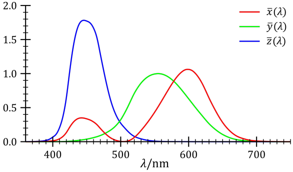
If we say R+B+G = 1 (same intensity) we can plot in 2d.

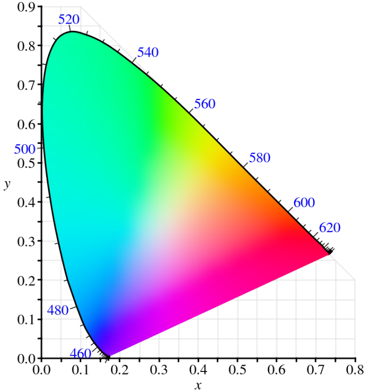


CIE 1931 chromaticity diagram showing the boundaries of the [00], [01], [10] triangle in xy space. Data from Wyszecki, Günter and Stiles, Walter Stanley (2000). Color Science: Concepts and Methods, Quantitative Data and Formulae, 2E, Wiley-Interscience.

XYZ Color Model

- The CIE chromaticty diagram is useful for: evaluating primaries; determining complementary colours; and working out the purity and dominate wavelength of a colour.

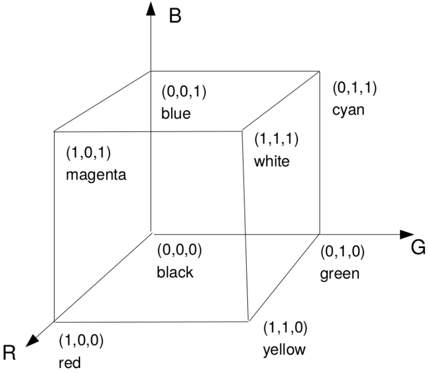




Colour

Colour Models

RGB Colour Model



The RGB model of colour can be represented by the unit cube. The dimensions are red, green, and blue.

YUV

- The YUV colour model describes colours in terms of their luma (the Y part) and its chrominance (the UV part).
- Such a system is often used in an image pipeline as our sensitivity changes in brightness is more important than changes in chrominance. So formats can give more 'bits' for the Y part than the UV part.
- This type of format is also used in PAL and NTSC (colour and black and white TVs can work from the same signal!). Typically a webcam would provide image data using such a format. Also commonly used within JPEG.

YUV

- To convert from RGB to YUV one can use the below matrix.
$$\begin{bmatrix} Y' \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.14713 & -0.28886 & 0.436 \\ 0.615 & 0.51499 & 0.10001 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$
- The inverse is also possible
$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1.13983 \\ 1 & 0.38465 & 0.58060 \\ 1 & 2.03211 & 0 \end{bmatrix} \begin{bmatrix} Y' \\ U \\ V \end{bmatrix}$$
- Noting that RGB values may need to be clapped to with the [0,1] range. Y, U, and V would have the ranges [0,1], [-0.436,0.436], and [-0.615,0.615] respectively.
- Matrices values from https://en.wikipedia.org/wiki/YUV, this is also a good source of information on YUV.

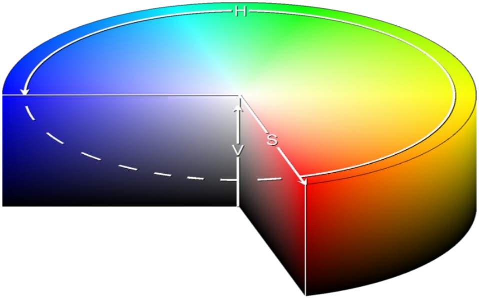
CMY(k) Colour Space

- Colour we see reflected off printed material is a subtractive process (unlike colour from a computer screen which is an additive process).
- The CMY Colour space enables us to deal with colours when using printers and the like.
- The primary colours in this case are: magenta, cyan, and yellow.
- There is a simple mapping between RGB and CMY colour spaces:
- Sometimes add k in aswell (black). [Why might this be a problem?]

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

HSV Colour Space

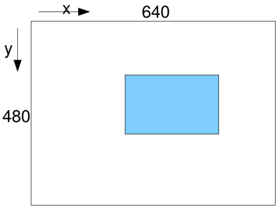
- The HSV Colour Model provides a more intuitive model for someone selecting colours in a computer application.
- The model is made up of: the H - hue, the S - saturation, and the V - value.



The Frame Buffer

Co-ordinates and the Frame Buffer

- Drawing content onto a screen will involve a number of different co-ordinates including:
  - screen/device co-ordinates.
  - absolute/relative co-ordinates.
  - user co-ordinates.
- Which way is up will depend on graphics API you are using. A function must map from user to device co-ordinates and then into addresses in the frame buffer.



End of slides for Week 1.