Computer Graphics

Adam Finkelstein

Princeton University

COS 426, Spring 2013

Overview

- Administrivia
  - People, times, places, etc.
- Syllabus
  - What will I learn in this course?
- Raster Graphics
  - Getting started …

Administrative Matters

- Instructors
  - Adam Finkelstein
  - Mark Browning and Fisher Yu (TAs)
- Book
  - *Computer Graphics with OpenGL, 4th Ed,*
    Hearn, Baker, and Carithers,
    Prentice Hall, 2010. ISBN: 978-0136053583
- Web page
  - www.cs.princeton.edu/courses/archive/spr12/cos426

Questions / Discussion

- We will use Piazza (www.piazza.com) to handle question/answer and general help
- Set up for everyone enrolled/invited as of today
- Use this instead of email to instructors/TAs
- Answer other students questions (good will & EC)

Coursework (approx. dates)

- Exams (30%)
  - In class (3/14 and 5/2)
- Programming Assignments (50%)
  - Assignment #1: Image Processing (due 2/12 and 2/21)
  - Assignment #2: Modeling (due 3/12)
  - Assignment #3: Ray Tracing (due 4/4 and 4/18)
  - Assignment #4: Animation (due 5/30)
- Final Project (20%)
  - Game! (due at end of semester)

Programming Assignments

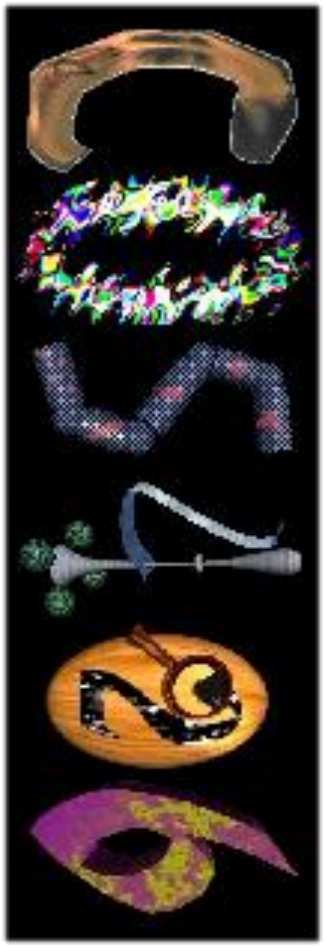
- When?
  - Roughly every 2-3 weeks
- Where?
  - Anywhere you want, e.g. home or clusters
- How?
  - C and C++
  - OpenGL, GLUT
- What?
  - Basic feature lists
  - Extra credit lists
  - Art contest

Art Contest

- Everybody should submit entries!
  - 1 point for submitting
  - 2 points for winning contest/banner

Cool Images/Videos
(James Percy, CS 426, Fall99)

Bloopers
(Alex Combs, CS 426, Spr05)



Characters for web banner

Collaboration Policy

- Overview:
  - You must write your own code (no credit for other code)
  - You must reference your sources of any ideas/code
- It's OK to …
  - Talk with other students about ideas, approaches, etc.
  - Get ideas from information in books, web sites, etc.
  - Get "support" code from example programs
    - » But, you must reference your sources
- It's NOT OK to …
  - Share code with another student
  - Use ideas or code acquired from another sources without attribution

Precepts

- Schedule
  - Wed 3:30-4:30 (Friend 108)

  OR
  - Wed 7:30-8:30 (CS 102)

Overview

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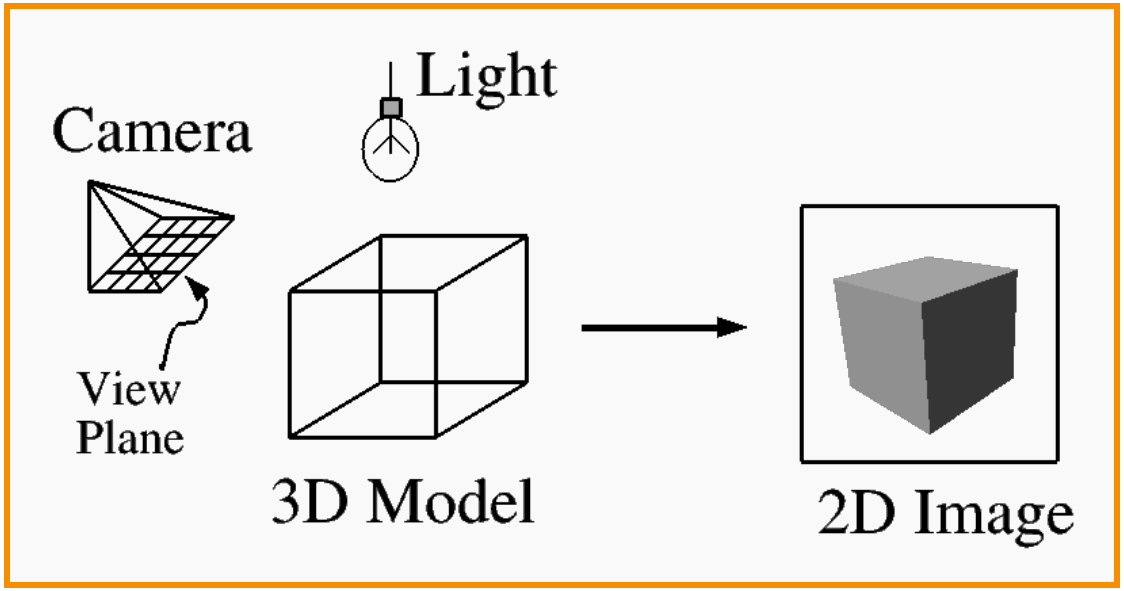
Introduction

- What is computer graphics?
  - Imaging = *representing 2D images*
  - Modeling = *representing 3D objects*
  - Rendering = *constructing 2D images from 3D models*
  - Animation = *simulating changes over time*



Syllabus

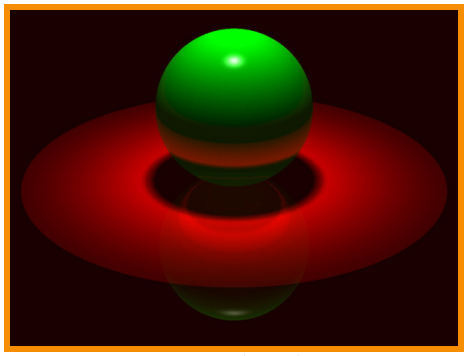
I. Image processing

II. Modeling

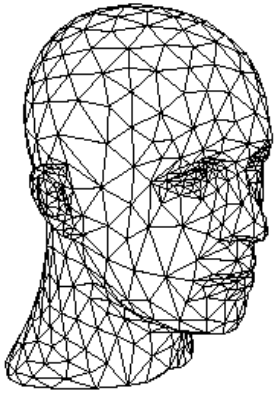
III. Rendering

IV. Animation

Image Processing
(Rusty Coleman, CS426, Fall99)



Rendering
(Michael Bostock, CS426, Fall99)



Modeling
(Dennis Zorin, CalTech)

Animation
(Pixar)

Part I: Image Processing

- Raster Graphics
  - Display devices
  - Color models
- Image Representation
  - Sampling
  - Reconstruction
  - Quantization & Aliasing
- Image Processing
  - Filtering
  - Warping
  - Composition
  - Morphing

Image Composition
(Michael Bostock, CS426, Fall99)

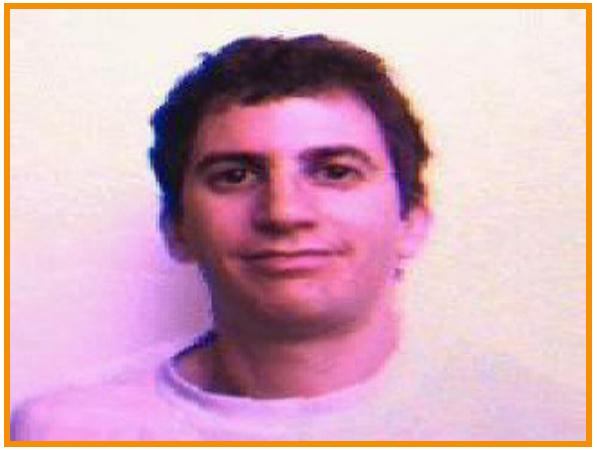
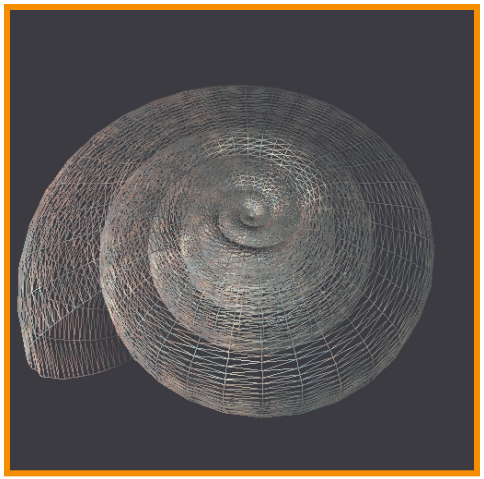


Image Morphing
(All students in CS 426, Fall98)

Part II: Modeling

- Representations of geometry
  - Curves: splines
  - Surfaces: meshes, splines, subdivision
  - Solids: voxels, CSG, BSP
- Procedural modeling
  - Sweeps
  - Fractals
  - Grammars



Shell

(Douglas Turnbull, CS 426, Fall99)

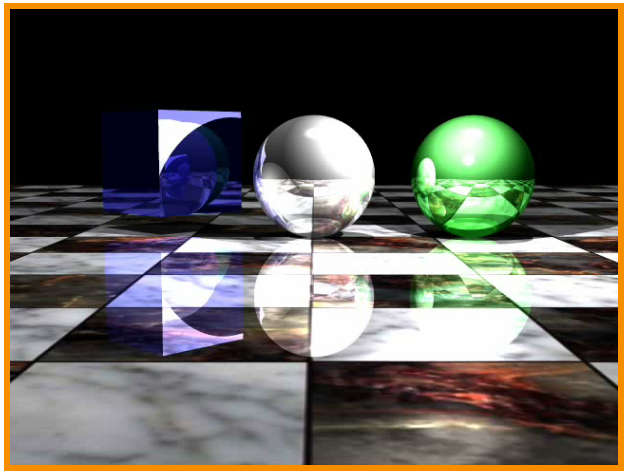
Scenery Designer

(Dirk Balfanz, Igor Guskov, Sanjeev Kumar, & Rudro Samanta, CS426, Fall95)

Part III: Rendering

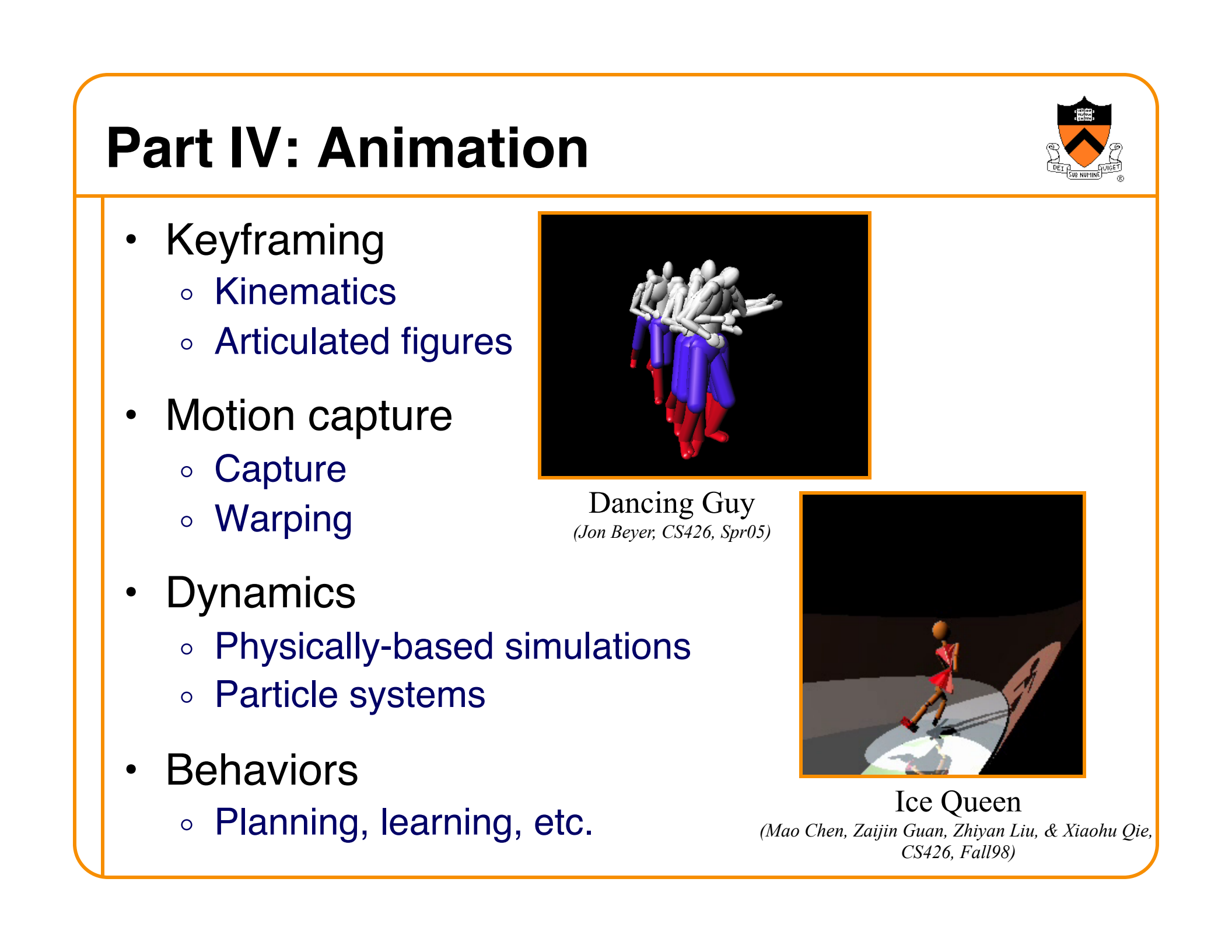
- 3D Rendering Pipeline
  - Modeling transformations
  - Viewing transformations
  - Hidden surface removal
  - Illumination, shading, and textures
  - Scan conversion, clipping
  - Hierarchical scene graphics
  - OpenGL
- Global illumination
  - Ray tracing
  - Radiosity

Pixel Shading
(Final Fantasy, Square Pictures)



Ray Tracing
(Sid Kapur, CS 426, Spr04)

Part IV: Animation



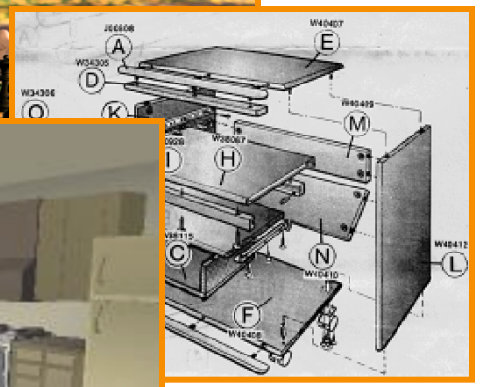
- Keyframing
  - Kinematics
  - Articulated figures
- Motion capture
  - Capture
  - Warping
- Dynamics
  - Physically-based simulations
  - Particle systems
- Behaviors
  - Planning, learning, etc.

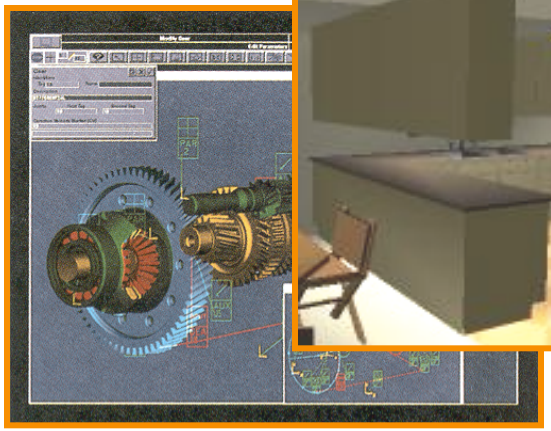
Dancing Guy
(Jon Beyer, CS426, Spr05)

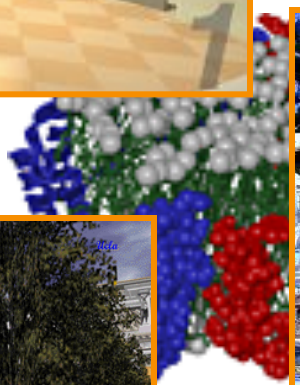
Ice Queen
(Mao Chen, Zaijin Guan, Zhiyan Liu, & Xiaohu Qie, CS426, Fall98)

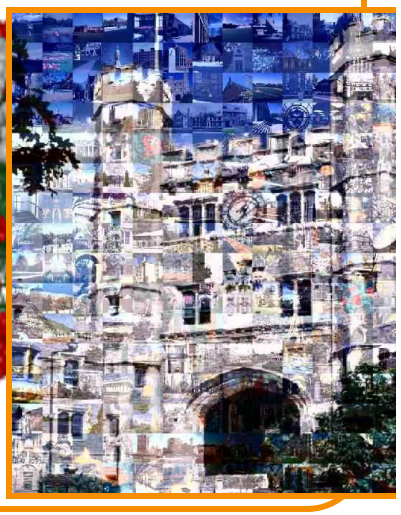
Applications

- Entertainment
- Computer-aided design
- Scientific visualization
- Training
- Education
- E-commerce
- Computer art









Overview

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  - People, times, places, etc.
- Syllabus
  - What will I learn in this course?

➢ Raster Graphics
  - Let's get started …

Raster Graphics

- Images
  - What is an image?
  - How are images displayed?
- Colors
  - How do we perceive colors?
  - How do we represent colors in a computer?

What is an Image?

- An image is a 2D rectilinear array of pixels

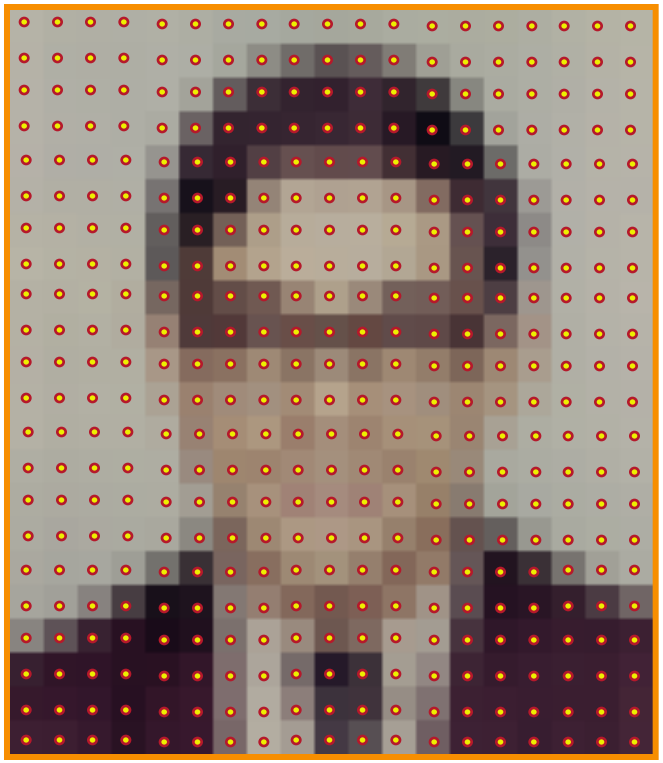
Continuous image

Digital image

What is an Image?

- An image is a 2D rectilinear array of pixels

Continuous image



Digital image

A pixel is a sample, not a little square!

What is an Image?

- An image is a 2D rectilinear array of pixels

Continuous image

Digital image

A pixel is a sample, not a little square!

Image Acquisition

- Pixels are samples from continuous function
  - Photoreceptors in eye
  - CCD cells in digital camera
  - Rays in virtual camera

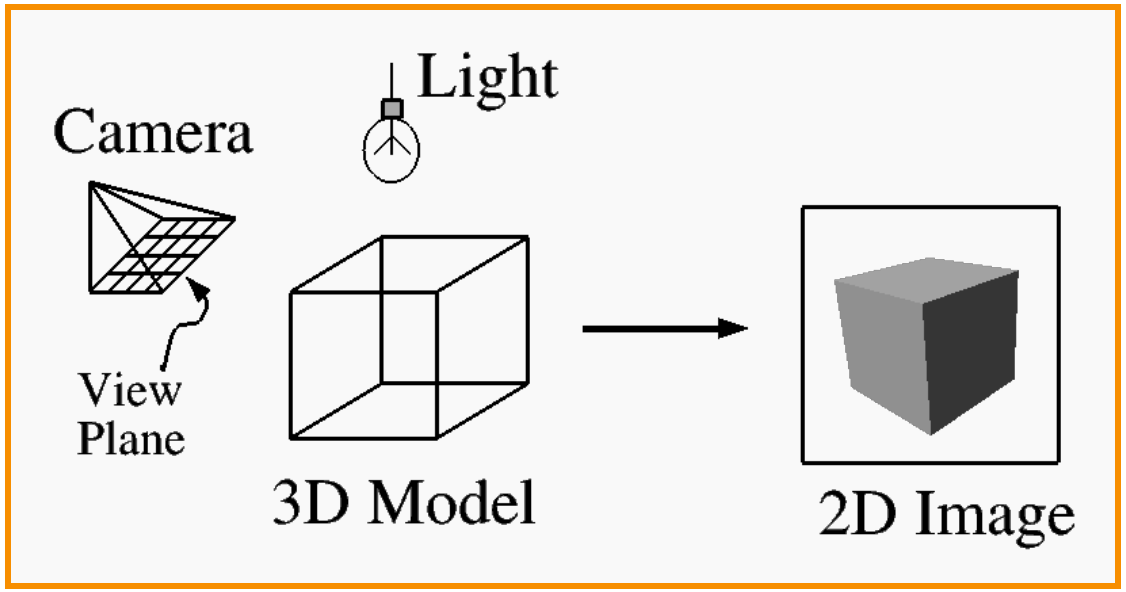
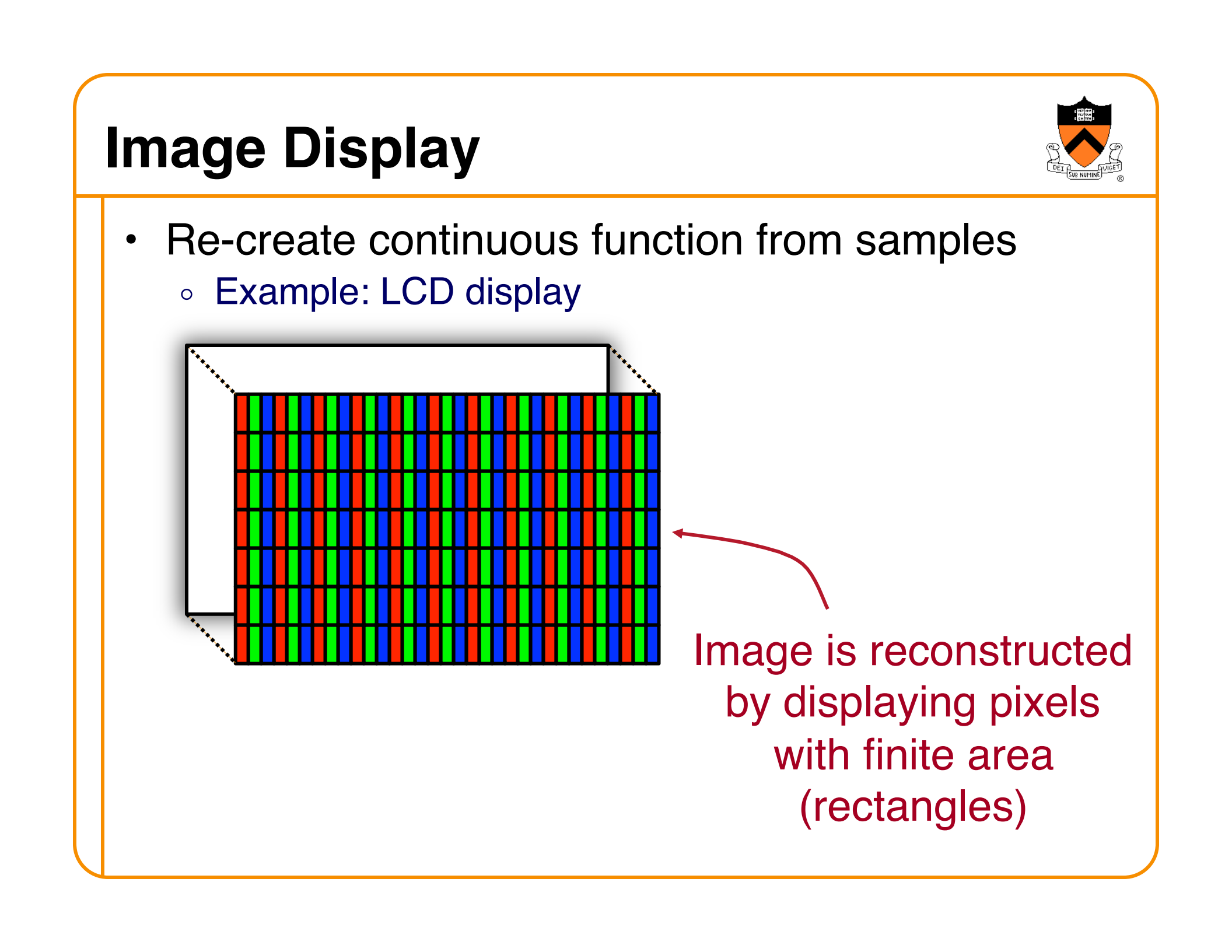


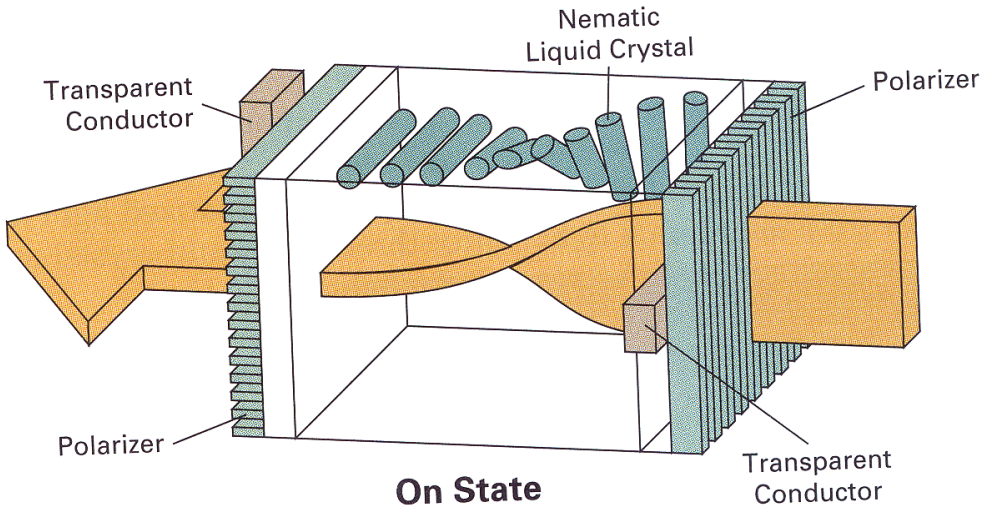
Image Display



- Re-create continuous function from samples
  - Example: LCD display

Image is reconstructed by displaying pixels with finite area (rectangles)

Liquid Crystal Display (LCD)



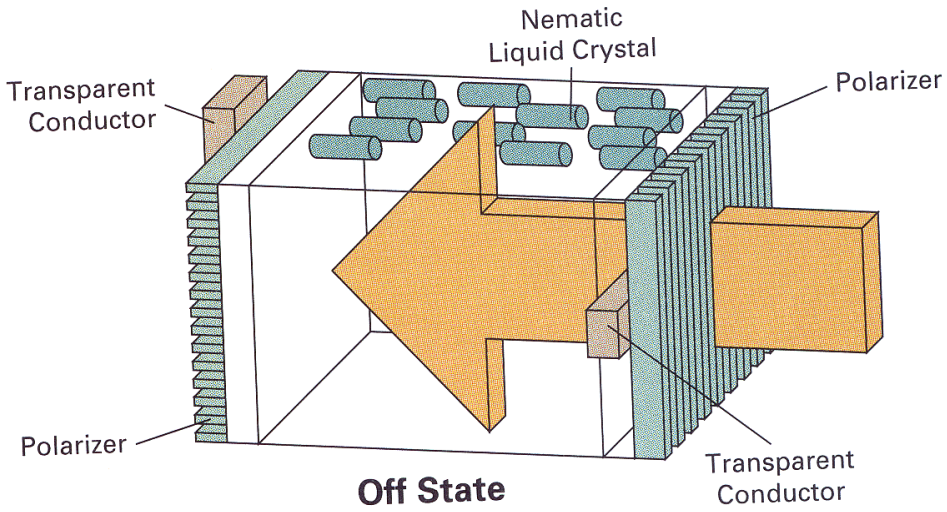


Figure 2.16 from H&B

Display Hardware

- Video display devices
  - » Cathode Ray Tube (CRT)
  - » Liquid Crystal Display (LCD)
  - ◦ Plasma panels
  - ◦ Thin-film electroluminescent displays
  - ◦ Light-emitting diodes (LED)
- Hard-copy devices
  - ◦ Ink-jet printer
  - ◦ Laser printer
  - ◦ Film recorder
  - ◦ Electrostatic printer
  - ◦ Pen plotter

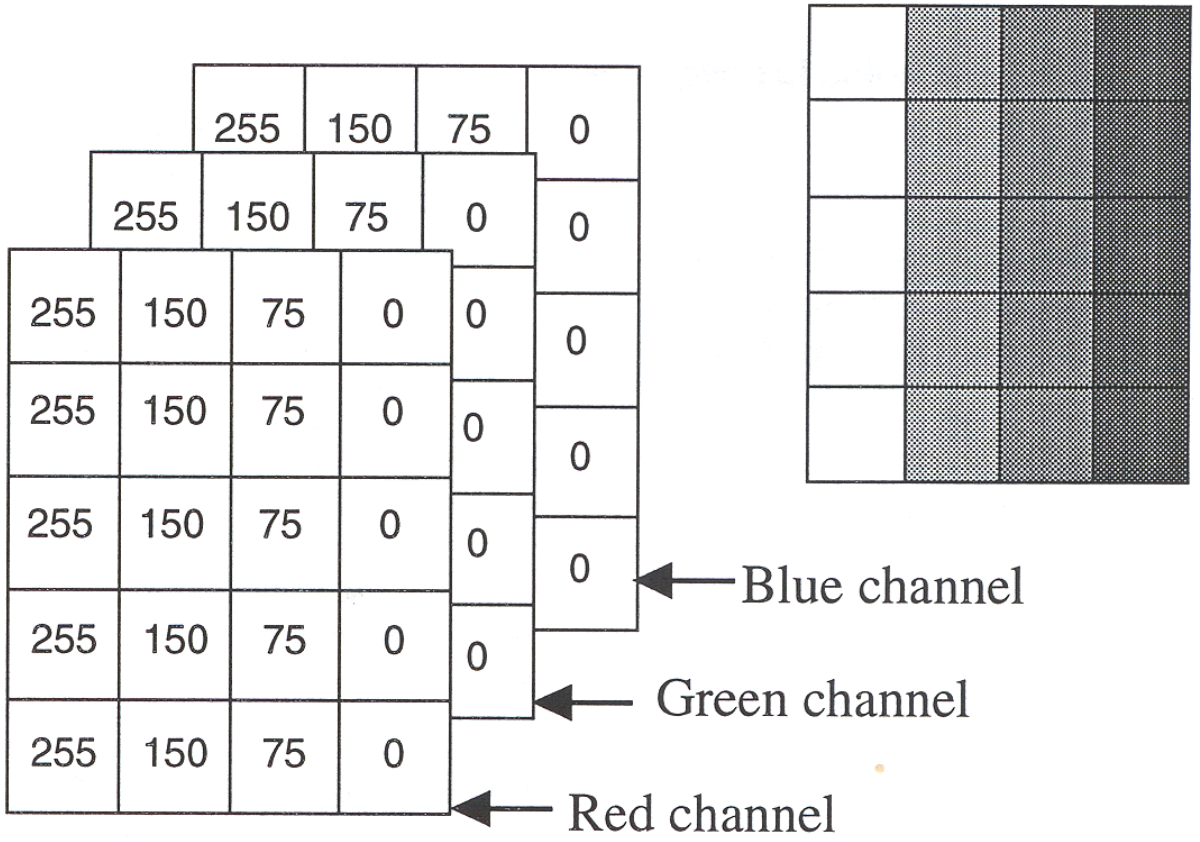
Image Resolution

- Intensity resolution
  - Each pixel has only "Depth" bits for colors/intensities
- Spatial resolution
  - Image has only "Width" x "Height" pixels
- Temporal resolution
  - Monitor refreshes images at only "Rate" Hz

Typical Resolutions

	Width x Height	Depth	Rate
NTSC	640 x 480	8	30
Workstation	1280 x 1024	24	75
Film	3000 x 2000	12	24
Laser Printer	6600 x 5100	1	-

Color Frame Buffer



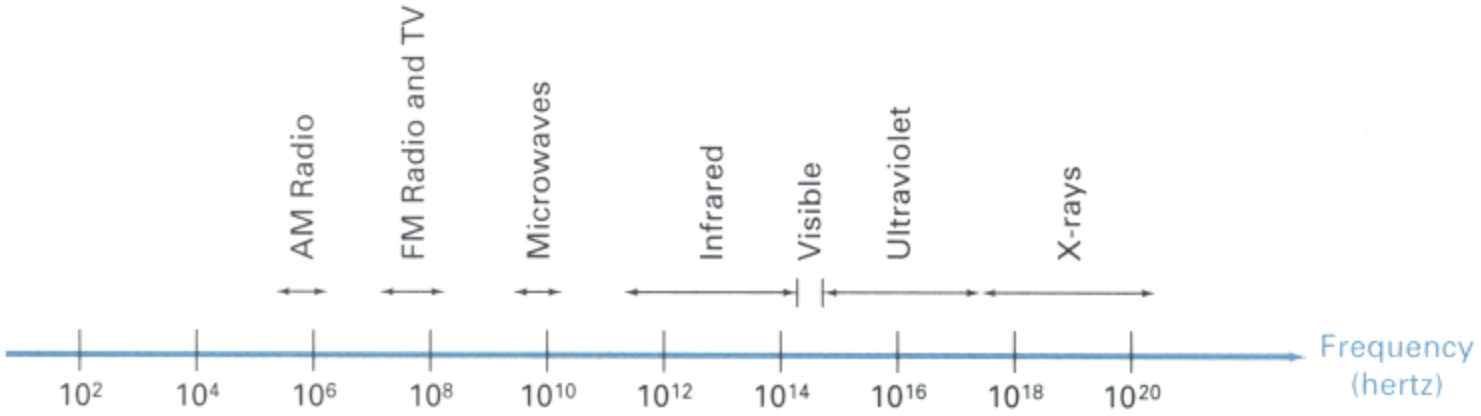
Raster Graphics

- Images
  - What is an image?
  - How are images displayed?

➢ Colors
  - How do we perceive colors?
  - How do we represent colors in a computer?

Electromagnetic Spectrum

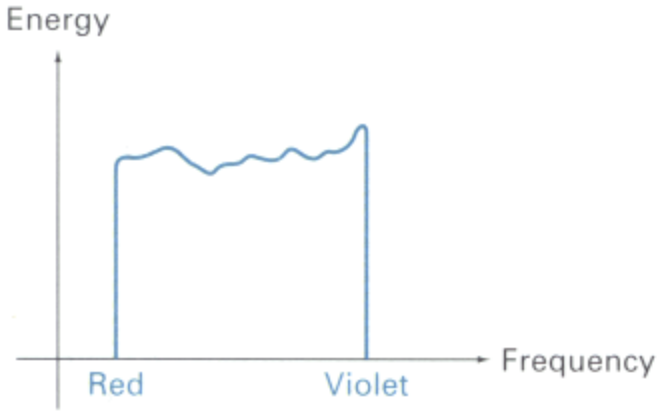
- Visible light frequencies range between ...
  - Red = 4.3 x 10^{14} hertz (700nm)
  - Violet = 7.5 x 10^{14} hertz (400nm)



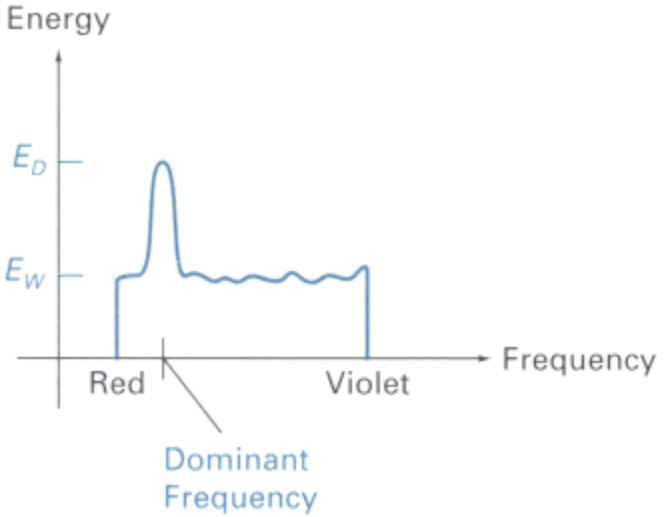
Figures 15.1 from H&B

Visible Light

- The color of light is characterized by …
  - Hue = dominant frequency (highest peak)
  - Saturation = excitation purity (ratio of highest to rest)
  - Lightness = luminance (area under curve)



White Light

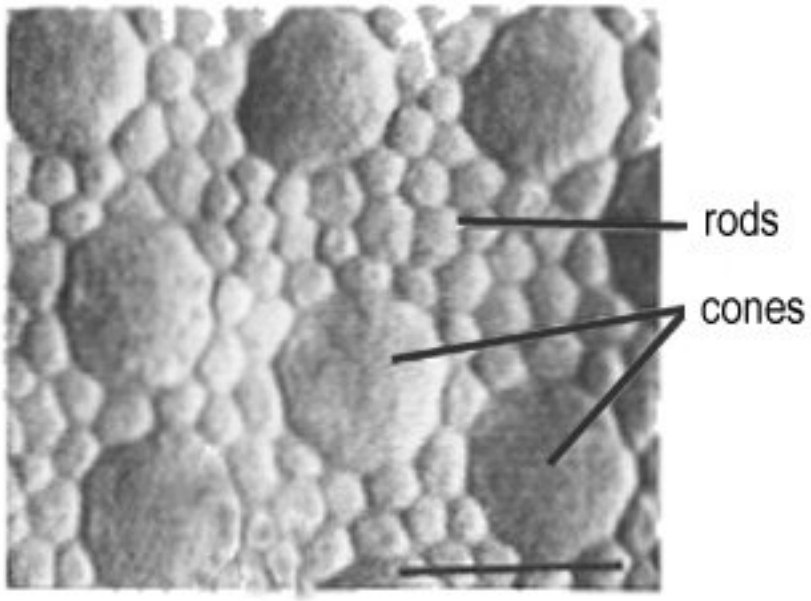


Orange Light

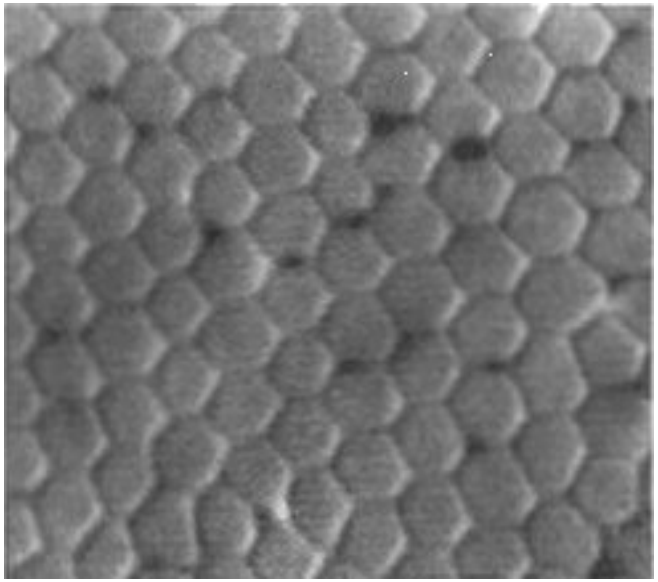
Figures 15.3-4 from H&B

Modern Understanding of Color

- Two types of receptors: rods and cones

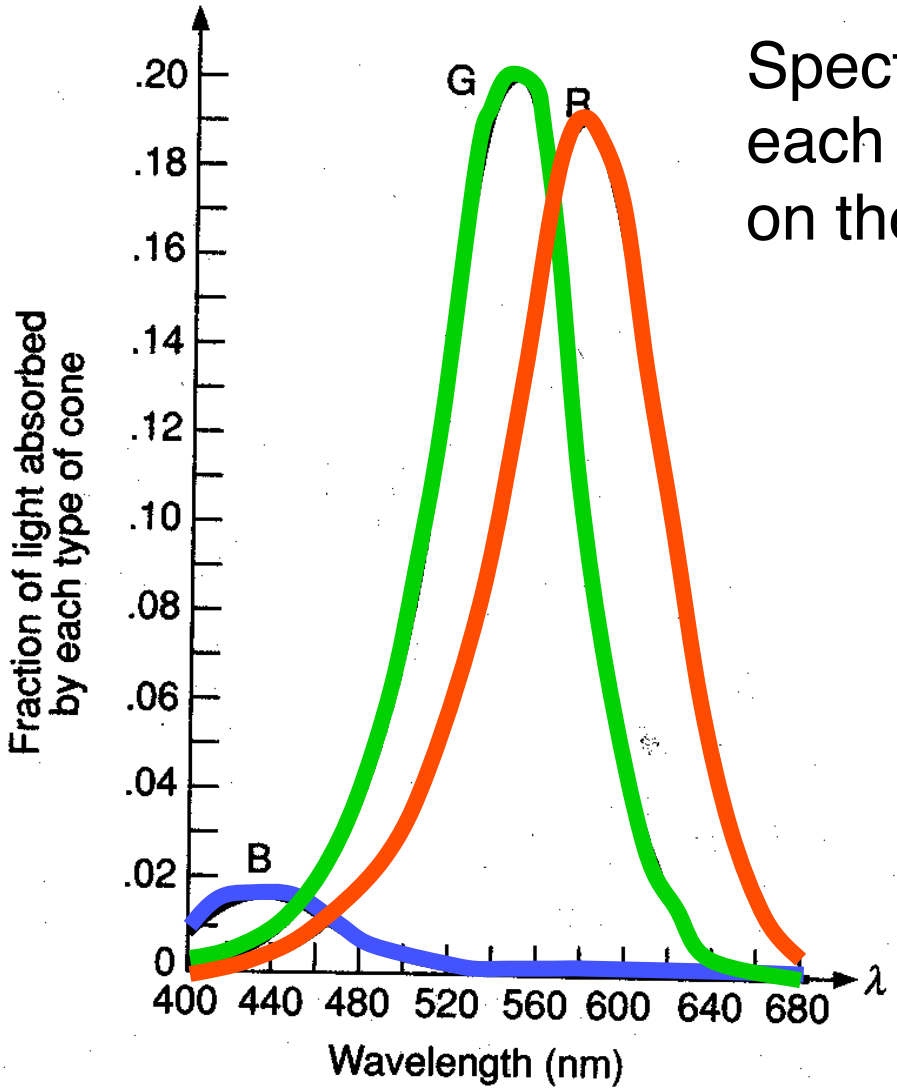


Rods and cones



Cones in *fovea*
(central part of retina)

Color Perception



Spectral-response functions of each of the three types of cones on the human retina.

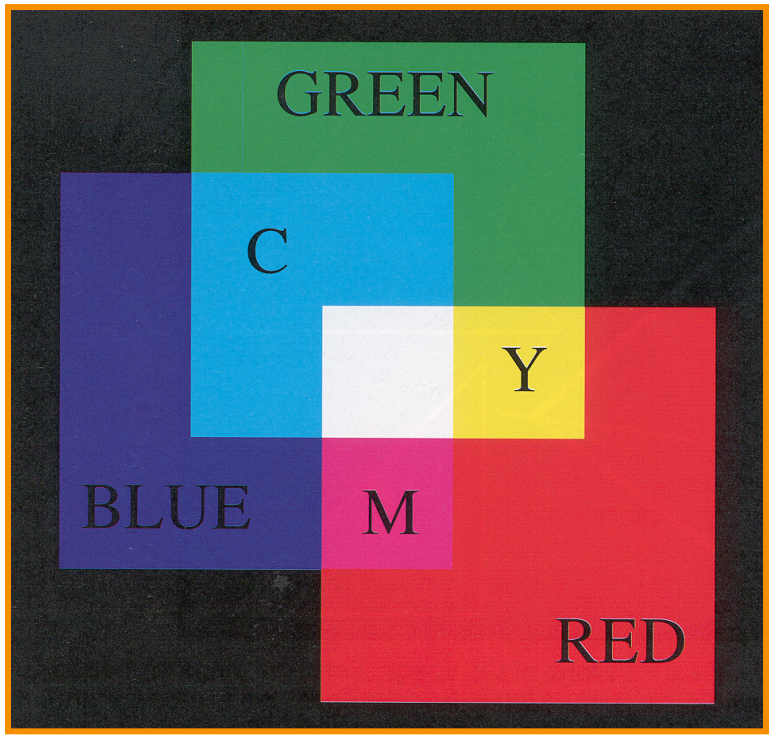
Tristimulus theory of color

Figure 13.18 from FvDFH

Color Models

- RGB
- XYZ
- CMY
- HSV
- Others

RGB Color Model

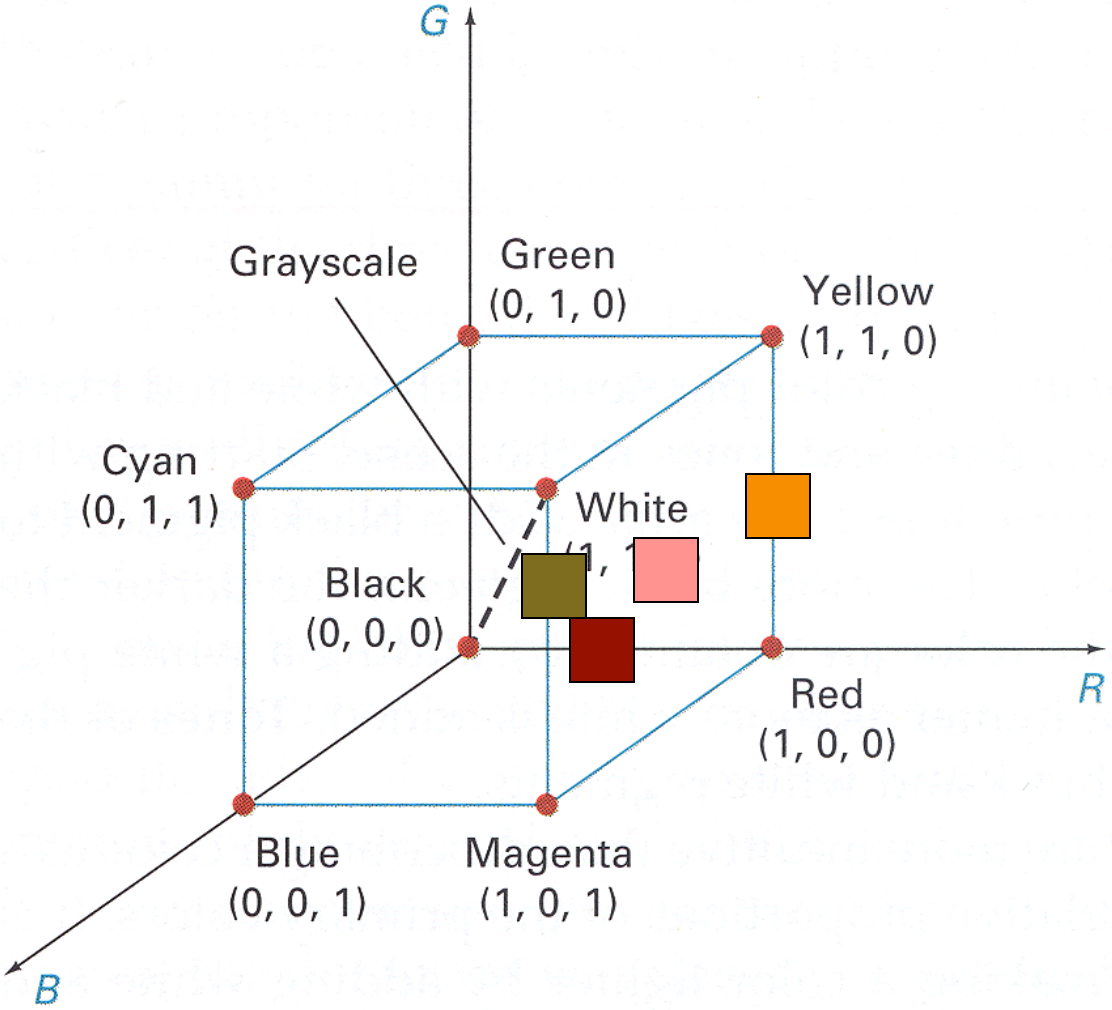


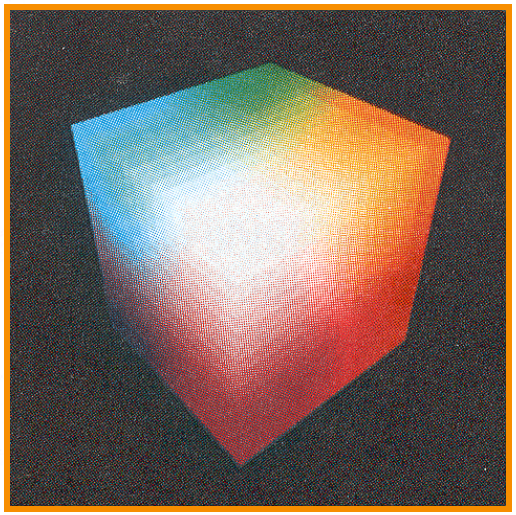
Colors are additive

R	G	B	Color
0.0	0.0	0.0	Black
1.0	0.0	0.0	Red
0.0	1.0	0.0	Green
0.0	0.0	1.0	Blue
1.0	1.0	0.0	Yellow
1.0	0.0	1.0	Magenta
0.0	1.0	1.0	Cyan
1.0	1.0	1.0	White
0.5	0.0	0.0	?
1.0	0.5	0.5	?
1.0	0.5	0.0	?
0.5	0.3	0.1	?

Plate II.3 from FvDFH

RGB Color Cube





Figures 15.11&15.12 from H&B

CIE Chromaticity Diagram

Normalized amounts of X and Y for colors in visible spectrum

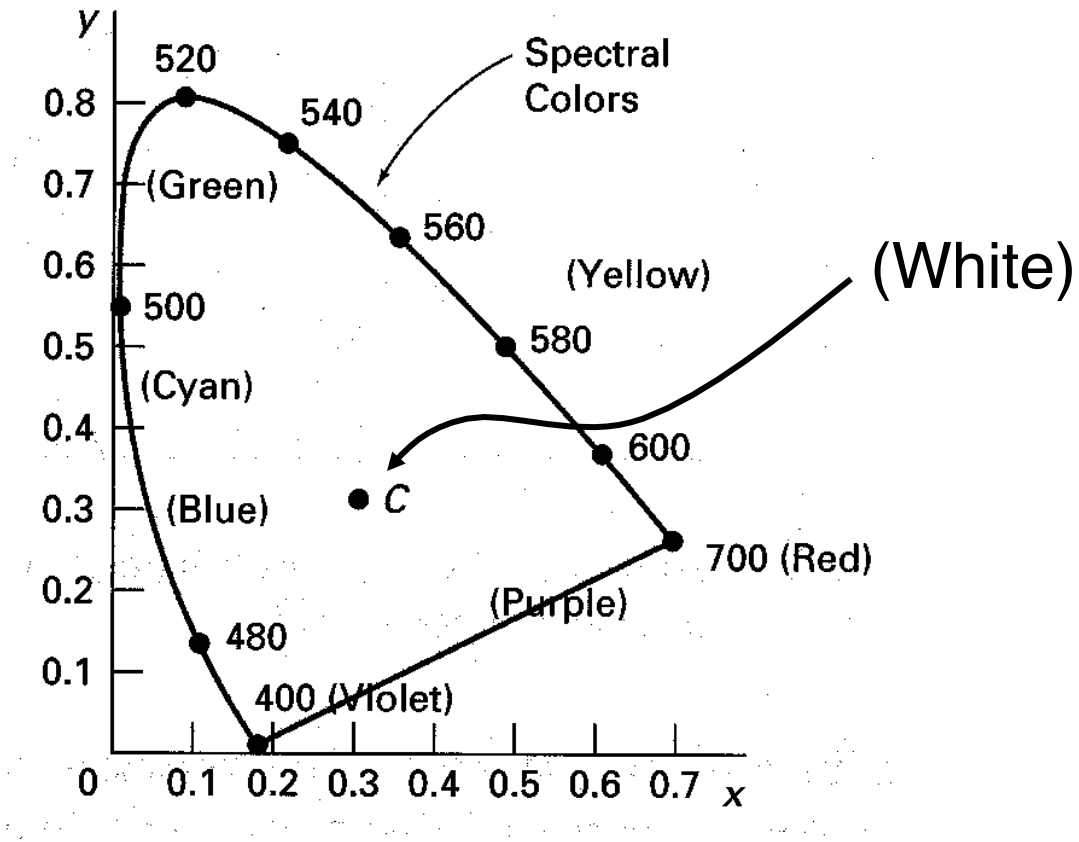
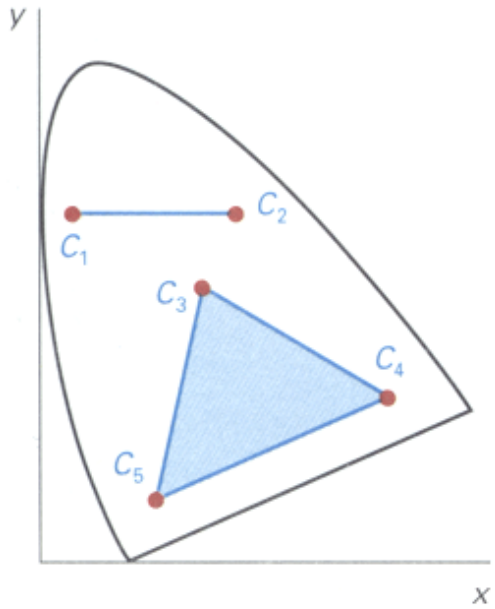
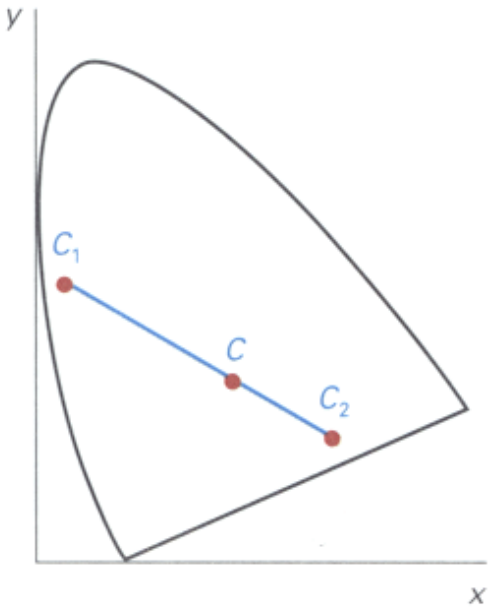


Figure 15.7 from H&B

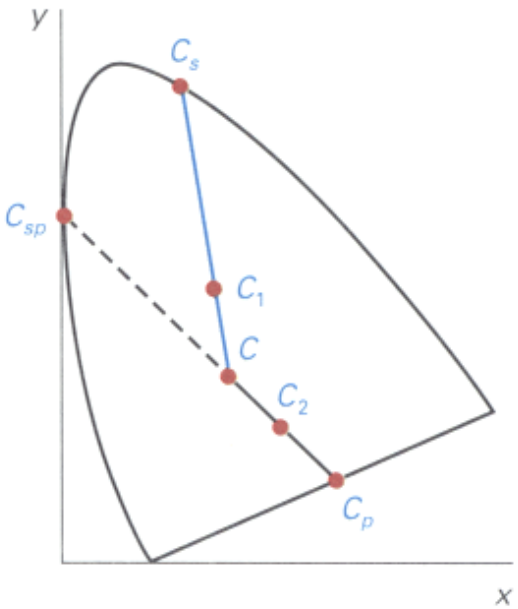
CIE Chromaticity Diagram



Compare Color Gamuts



Identify Complementary Colors



Determine Dominant Wavelength and Purity

Figures 15.8-10 from H&B

RGB Color Gamut

Color gamut for a typical RGB computer monitor

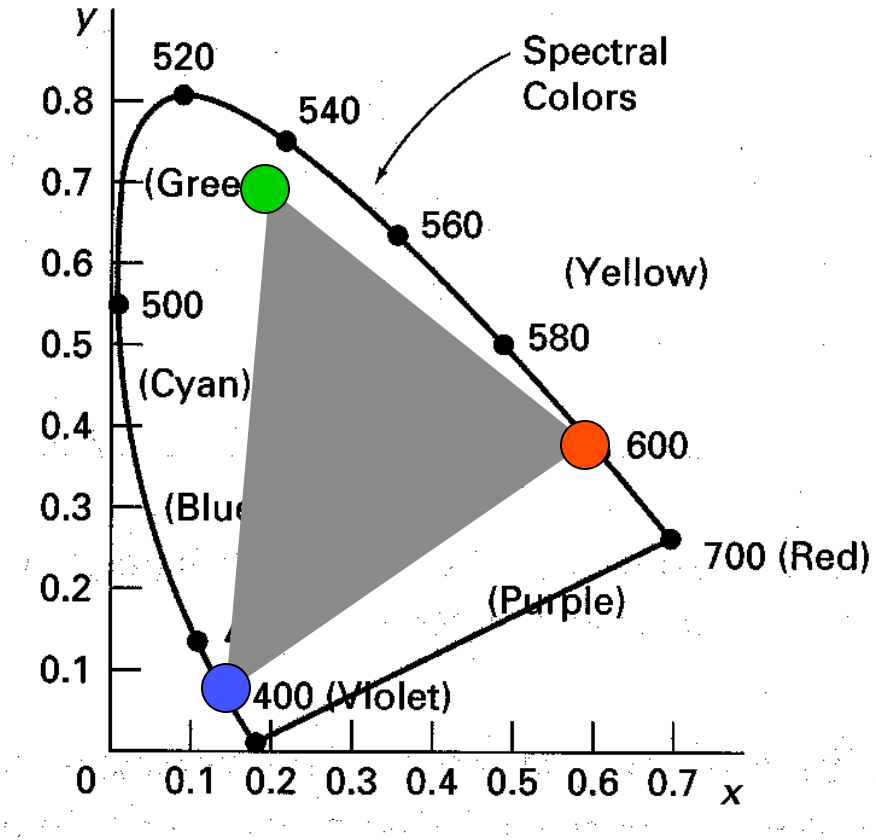
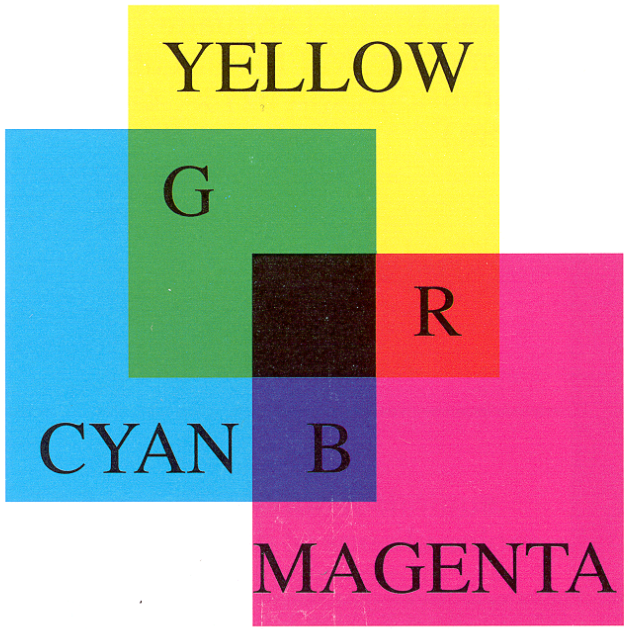


Figure 15.13 from H&B

CMY Color Model



Colors are subtractive

C	M	Y	Color
0.0	0.0	0.0	White
1.0	0.0	0.0	Cyan
0.0	1.0	0.0	Magenta
0.0	0.0	1.0	Yellow
1.0	1.0	0.0	Blue
1.0	0.0	1.0	Green
0.0	1.0	1.0	Red
1.0	1.0	1.0	Black
0.5	0.0	0.0	
1.0	0.5	0.5	
1.0	0.5	0.0	

Plate II.7 from FvDFH

CMY Color Cube

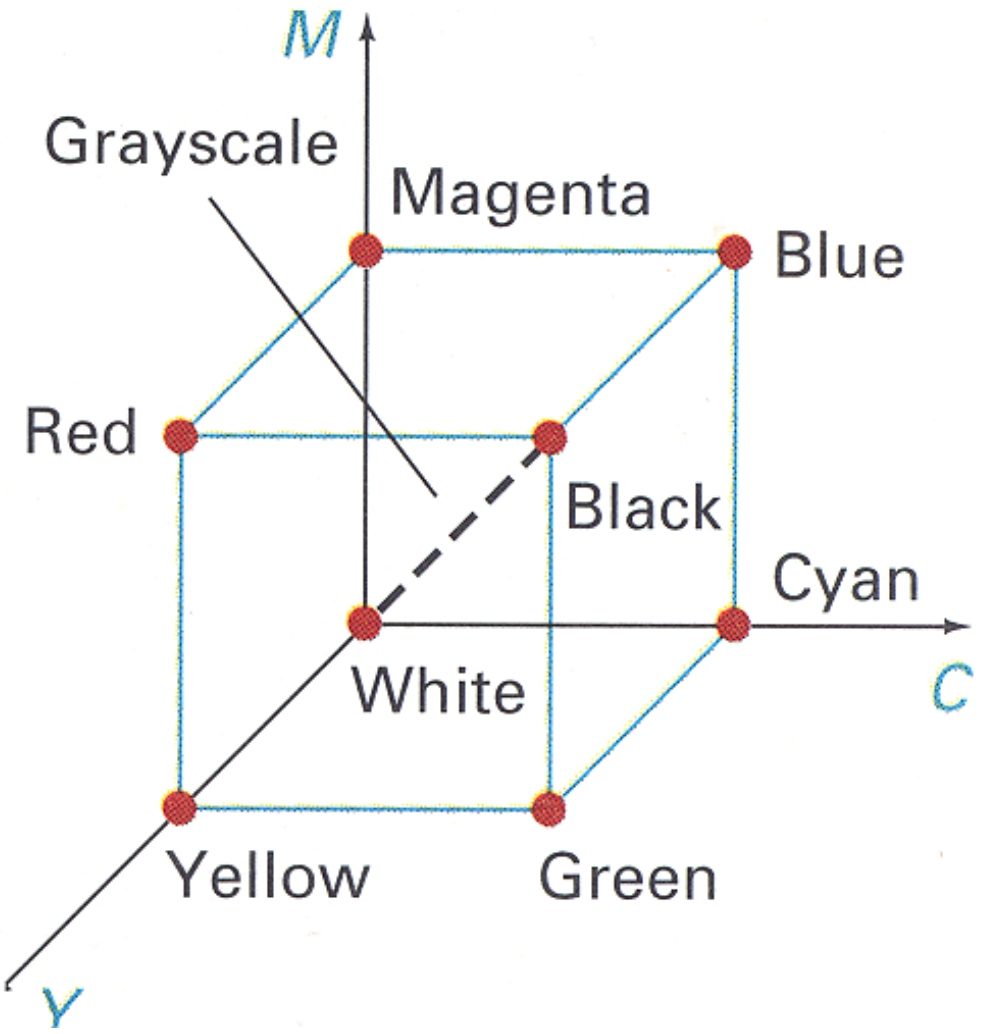
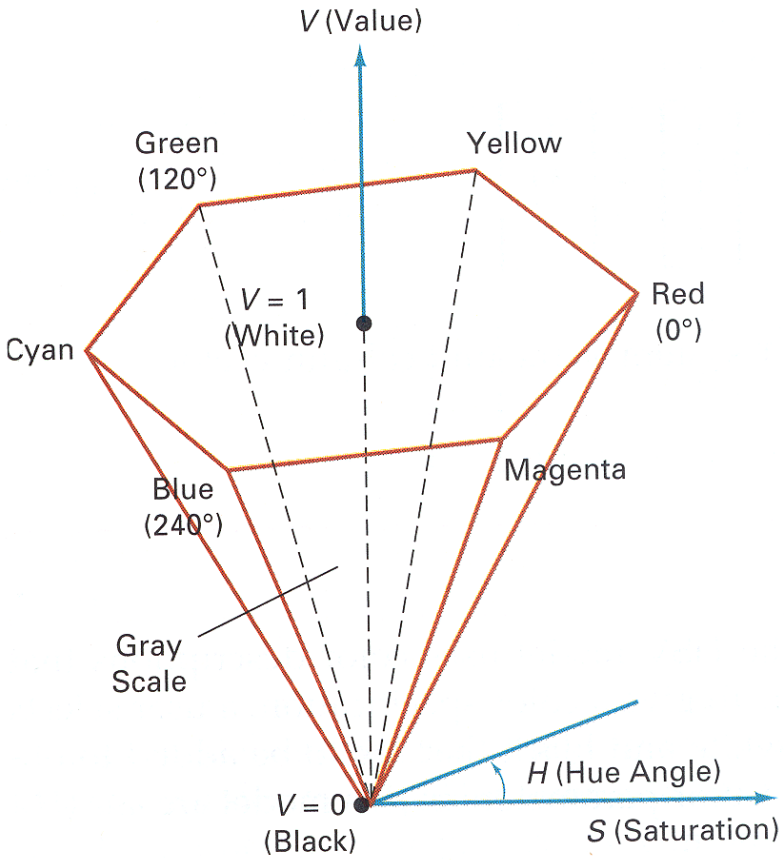


Figure 15.14 from H&B

HSV Color Model



H	S	V	Color
0	1.0	1.0	Red
120	1.0	1.0	Green
240	1.0	1.0	Blue
*	0.0	1.0	White
*	0.0	0.5	Gray
*	*	0.0	Black
60	1.0	1.0	
270	0.5	1.0	
270	0.0	0.7	

Figure 15.16&15.17 from H&B

Summary

- Images
  - Pixels are samples
  - Frame buffers
  - Display hardware (CRTs, LCDs, printers, etc.)
  - Devices have limited resolution
- Colors
  - Tristimulus theory of color
  - CIE Chromaticity Diagram
  - Different color models for different devices, uses, etc.