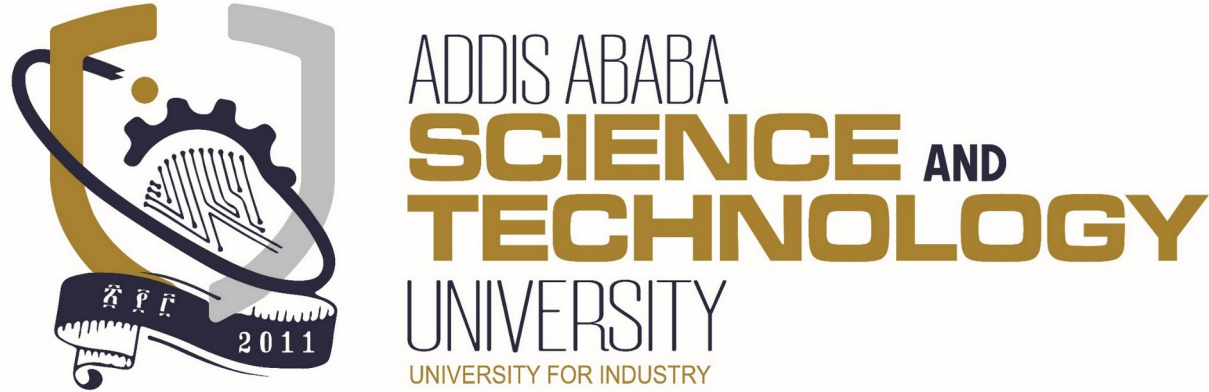




Department of Software Engineering

Computer Graphics

Key terms

Pixel (Picture-Element): is the atomic unit of the image; it is colored uniformly — its single color representing a discrete sample of light e.g. from a captured image.

Pixel is short for “picture element”

Bitmap (bit array /bitmap index /pixmap): is a mapping from some domain (eg: range of integers) to bits (0 or 1)

Resolution: the number of pixels per unit length (eg: cm, inch) in horizontal or vertical direction.

Image's Aspect Ratio: is the ratio of its (the Image) width to its height, measured in unit length or number of pixels.

$$IAR = W/H$$

2D & 3D

Computer Graphics

Computer graphics is generally regarded as a branch of computer science that deals with the theory and technology for computerized image synthesis.

It describes any use of computers to create and manipulate images.

Graphics can be two- or three-dimensional

Computer Graphics ...

- Computer graphics refers to the creation, storage and manipulation of pictures and drawings using a digital computer.
- Producing pictures or images using a computer
- A survey on computer graphics
- We can define computer graphics as the algorithms and hardware required to produce realistic and/or useful images on a computer.

What is Computer Graphics?

- Imaging
 - *Representing 2D images*
- Modeling
 - *Representing 3D objects*
- Rendering
 - *Constructing 2D images from 3D models*
- Animation
 - *Simulating changes over time*

What's Our Scope?

- Not a Tutorial on Commercial Software
 - 3DMax, Maya, Photoshop, etc.
- Not about Graphics Business
 - 3D online-game, E-commerce, etc.
- Graphics = Algorithm for Visual Simulation
 - Imaging, Modeling, Rendering, Animation

Image-Representation

A digital image is composed of discrete pixels.

These pixels are arranged in a row and column fashion to form a rectangular picture area, called raster.

The total number of pixels in an image is a function of the size of the image and the number of pixels per unit length in horizontal or vertical direction.

... Image-Representation

Color Theory

Color theory was originally formulated in terms of 3 primitive colors – red, yellow and blue (RYB).

Scientists established in the late 19th century that color perception is best described in terms of red, green and blue (RGB) (Additive Mixing)

Other color models:

CIE, YUV, HSL/HSV, CMY and CMYK

... Image-Representation

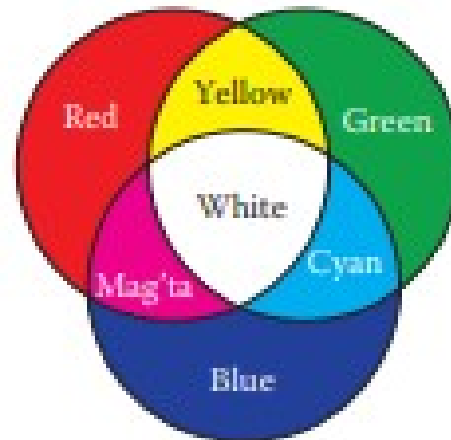
RGB Color

Most computer graphics images are defined in terms of red-green-blue (RGB) color.

RGB color is a simple space that allows straightforward conversion to the controls for most computer screens.

In RGB additive color mixing we have

red + green = yellow,
green + blue = cyan,
blue + red = magenta,
red + green + blue = white



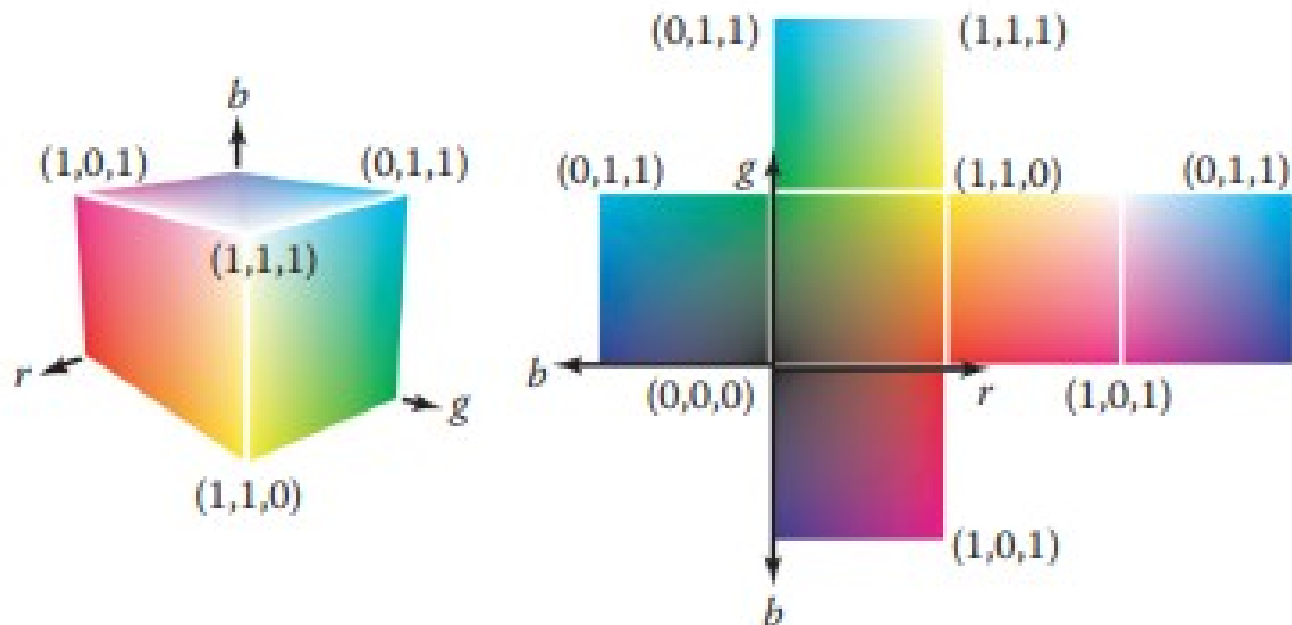
... Image-Representation

... RGB Color

If we are allowed to dim the primary lights from fully off (indicated by pixel value 0) to fully on (indicated by 1), we can create all the colors that can be displayed on an RGB monitor.

The colors at the c

black = (0, 0, 0),
red = (1, 0, 0),
green = (0, 1, 0),
blue = (0, 0, 1),
yellow = (1, 1, 0),
magenta = (1, 0, 1),
cyan = (0, 1, 1),
white = (1, 1, 1).



... Image-Representation

... RGB Color

The most common size for these integers is one byte each, so each of the three RGB components is an integer between 0 and 255.

The three integers together take up three bytes, which is 24 bits. Thus a system that has “24-bit color” has 256 possible levels for each of the three primary colors.

This way we allow each primary color to have 256 different intensity levels corresponding to binary values from 00000000 to 11111111. thus pixel can take on a color from $256 \times 256 \times 256$ or 16.7 million possible choices.

... Image-Representation

CMY Color

Color specification using RGB model is an additive process. We begin with black and add on the appropriate primary components to yield a desired color. This closely matches the working principle of the display monitor.

On the other hand, there is a complementary color model, called CMY.

CMY defines colors using subtractive process, which closely matches the working principles of the printer.

In CMY model, we begin with white and take away the appropriate primary components to yield a desired color.

... Image-Representation

... CMY Color

Eg. If we subtract red from white, what remains consists of green and blue, which is cyan.

So, we can use the amount of cyan (the complementary color of red) to control the amount of red, which is equal to one minus the amount of cyan.

CMY (0,0,0) corresponds to white, whereas (1,1,1) represents black (no red, no green, no blue)

... Image-Representation

RGB <-> CMY Conversion

= -

= -

NB:

RGB colors are usually stated as 0-255 range

eg:

RGB(255,255,255)

whereas

CMY colors are listed as 0-1 range or percent stacked

eg:

CMY(1,1,1)

or

CMY(100%, 100%, 100%)

... Image-Representation

CMYK

CMY color model will be able to cover most lighter color ranges quite easily, compared to using RGB.

However, while CMY by itself will not be able to create very deep dark color or a “true black”, so black (designated ‘K’ for “Key Color”) is added to CMY.

Due to this, much wider range of color can be achieved compared to just RGB.

... Image-Representation

CMYK -> RGB Conversion

$$R = 255 * (1 - C) * (1 - K)$$

$$G = 255 * (1 - M) * (1 - K)$$

$$B = 255 * (1 - Y) * (1 - K)$$

RGB -> CMYK Conversion

$$R' = R/255 \quad G' = G/255 \quad B' = B/255$$

$$K = 1 - \max(R', G', B')$$

$$C = (1 - R' - K) / (1 - K)$$

$$M = (1 - G' - K) / (1 - K)$$

$$Y = (1 - B' - K) / (1 - K)$$

Reading Task 1

☐ HSB/L?

☐ Why CMY is preferred for printing devices?

Image-Presentation (Output) Devices

Converts digitally represented images into visually perceivable pictures.

- Video Monitor/ Display Monitor
 - CRT – Cathode Ray Tube – Monochromatic Display & Color Display
 - FPD – Flat Panel Display
 - LCD – Liquid Crystal Display
 - LED – Light Emitting Diode
 - OLED – Organic LED
 - AMOLED – Active Matrix Organic LED
 - Plasma
 - ELD – Electro-Luminescent Display
 - Supper-AMOLED
 - QD – Quantum Dot
- Printer
 - Impact – Dot-Matrix, Daisy-Wheel, Line, Drum, Band
 - Non-Impact – Inkjet, Laser, Thermal, Electromagnetic

Reading Task 2

- ☐ Compare at least 4 Display Monitors.
- ☐ Compare at least 4 Printers.
- ☐ Which one is better for our eyes from the above Display Monitors?

Vector vs Raster Graphics

Vector Graphics

Is making of sequential commands or mathematical statements or programs which place lines or shapes in 2D or 3D environment.

Print crisply even when they are enlarged.

Much smaller file size.

File extensions: .SVG, .EPS, .PDF, .AI, .DXF

... Vector vs **Raster** Graphics

Raster Graphics

- Raster images use bit maps to store information.
- The larger the image, the more the disk space the image will take up.

Eg: 640X480 image requires information to be stored for 307,200 pixels, while 3072X2048 image needs 6,291,456.

So, In RG, using algorithms which compress images to reduce file size is common (like Jpeg and Gif are common compressed image formats).

File extensions: .BMP, .TIF, .GIF, .JPG

... Vector vs Raster Graphics

Vector	Raster
Composed of paths.	Composed of pixels.
Scan conversion is not required.	Graphic primitives are specified in terms of end points and must be scan converted into corresponding pixels.
Draw continuous and smooth lines.	Can draw mathematical curves, polygons and boundaries of curved primitives, but only by pixel approximation.
Cost more.	Cost less.
Occupy less space.	Occupy more space depending on image quality.
Infinite zoom.	Blurred when zoomed.

... **Vector vs Raster Graphics**

All Image-Presentation (Output) Devices are raster devices. As a result we need to convert vector images to raster format before they can be used.

Vector to Raster Conversion

The required resolution plays a vital role in determining the size of raster file generated.

It is easy to convert a vector to a range of bitmap/raster file format, but going down opposite is harder.

... **Vector vs Raster Graphics**

Raster to Vector Conversion

This is called image tracing or vectorization.

Why?

- To update images and recover work

- To retrieve information that we have lost

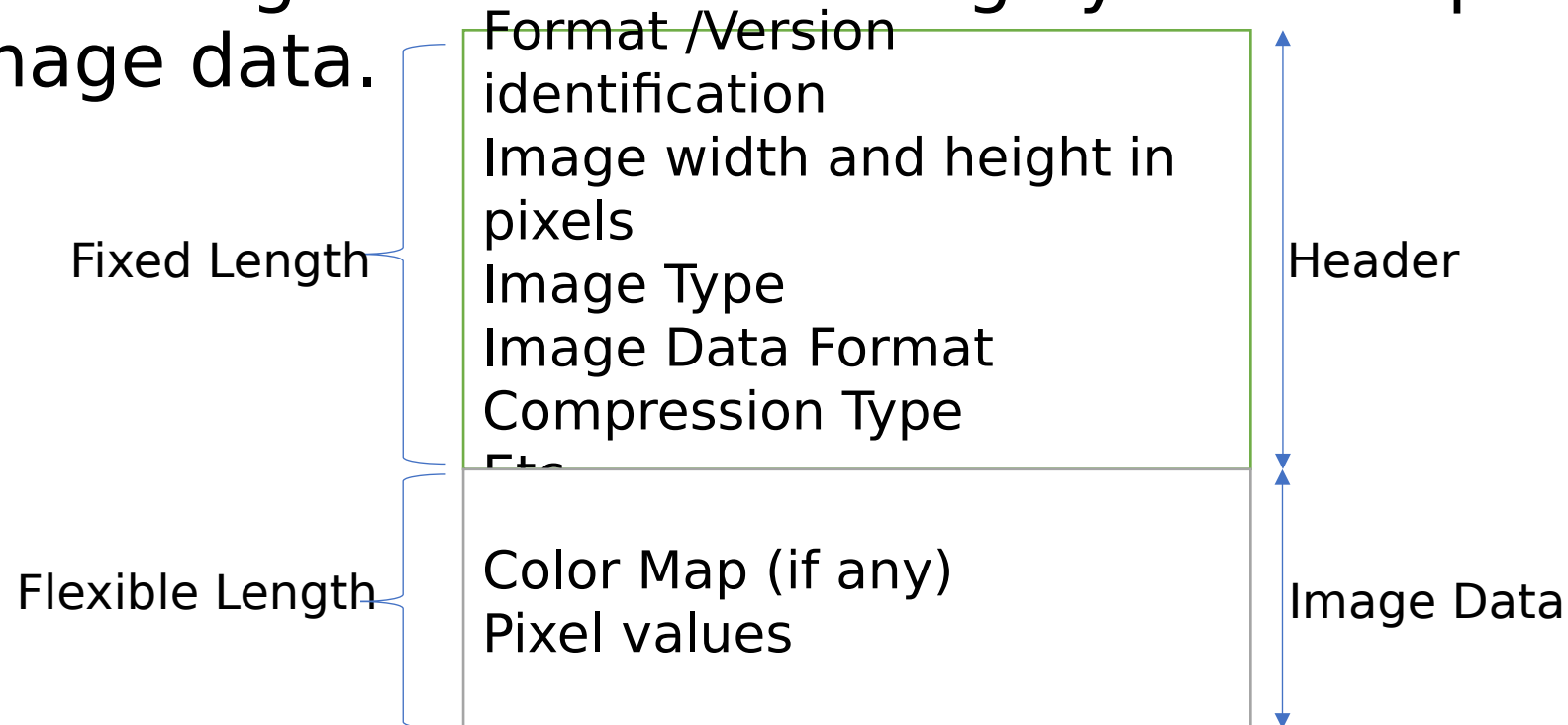
- To reduce image size

Due to various approximation and editing done in this process, the converted image may not be good by the quality.

Image Files

A digital image is often encoded in the form of binary files for the purpose of storage and transmission.

The image file consists largely of two parts: header and image data.



... Image Files

Format /Version identification

A binary code or ASCII string identifies the format being used, along with version number.

Image width and height in pixels

The width and height of the image are given in pixels.

Image Type

Eg: Black & white (1 bit per pixel)

8 bit gray scale (256 levels along gray axis)

8 bit color (lookup table)

24 bit color

Image Data Format: specifies the order in which pixel values are stored in image data section. (the common one is Left to Right and Top to Bottom).

It also specifies if the RGB values in color map or in the image are interlaced.

Compression Type

Eg: RLE (Run Length encoding)

... Image Files

To reduce the storage requirement, most image formats allow for some kind of compression.

At a high level, such compression is either lossless or lossy.

No information is discarded in lossless compression, while some information is lost unrecoverable in a lossy system.

Popular image storage formats include:

JPEG: This lossy format compresses image blocks based on thresholds in the human visual system. This format works well for natural images.

Tiff: This format is most commonly used to hold binary images or losslessly compressed 8- or 16-bit RGB although many other options exist.

PPM: This very simple lossless, uncompressed format is most often used for 8-bit RGB images although many options exist.

PNG: This is a set of lossless formats with a good set of open source management tools.

Graphics Areas

3 major areas of computer graphics -

Modeling: deals with the mathematical specification of shape and appearance properties in a way that can be stored on the computer.

Rendering: is a term inherited from art and deals with the creation of shaded images from 3D computer models.

Animation: is a technique to create an illusion of motion through sequences of images. Animation uses modeling and rendering but adds the key issue of movement over time.

Other areas

User interaction: deals with the interface between input devices, the application, feedback to the user in imagery, and other sensory feedback.

Virtual reality: attempts to immerse the user into a 3D virtual world

Visualization: attempts to give users insight into complex information via visual display

Image processing: deals with the manipulation of 2D images and is used in both the fields of graphics and vision.

3D scanning: uses range-finding technology to create measured 3D models.

Computational photography: is the use of computer graphics to enable new ways of photographically capturing objects, scenes, and environments.

Major Applications

Major consumers of computer graphics technology include the following industries:

- Video games

- Cartoons

- Visual effects

- Animated films

- CAD/CAM - Computer-Aided Design and Computer-Aided Manufacturing

- Simulation

- Medical imaging

- Information visualization