# Chapter 2 – 2D Graphics and Animation

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  - Pixel Color and Bit Depth
  - Refresh Rate
  - Switching the Display to Full-Screen Mode
  - Anti-Aliasing
  - Which Display Mode to Use

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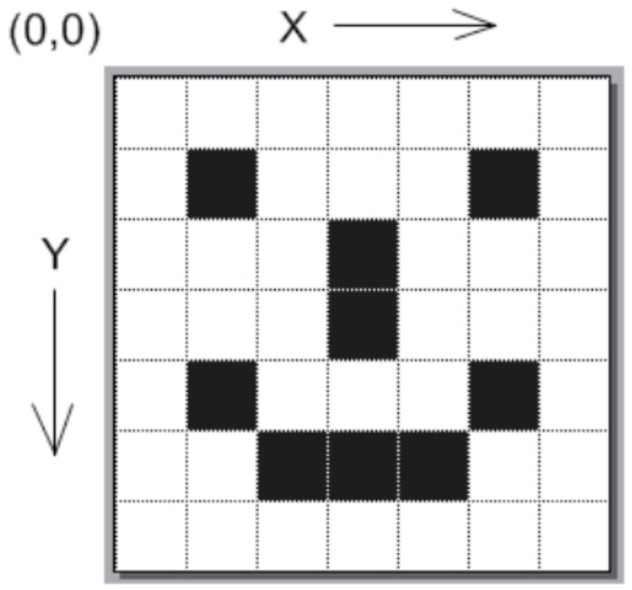
# Full-Screen Graphics

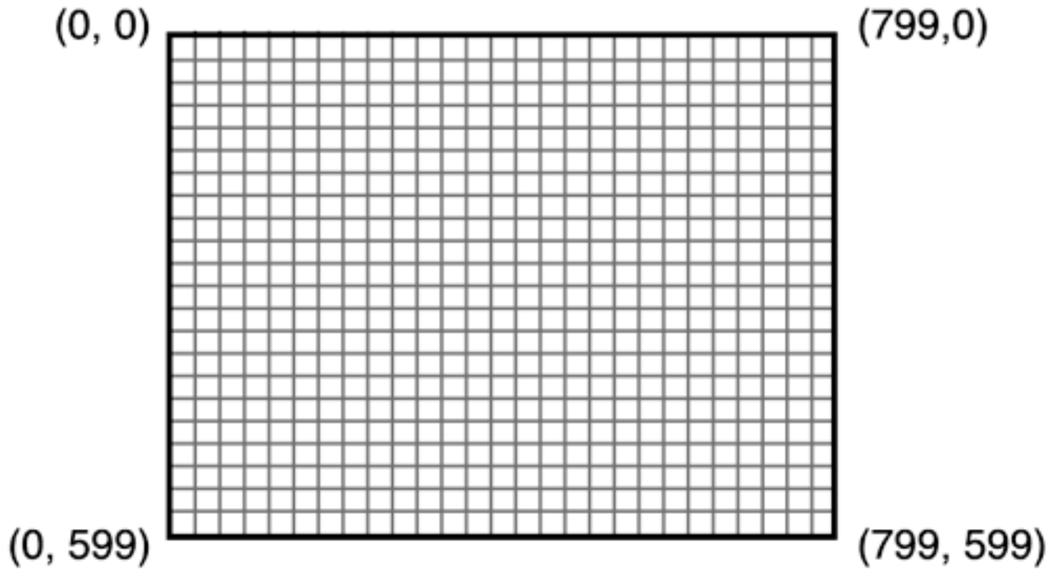
Key Ideas: The display on a computer consists of two main parts, the *video card* and the *monitor*.

- The video card stores the screen contents and can also hold images for hardware-accelerated graphics.
- The monitor translates the stored screen image into an actual light image.

# Screen Layout

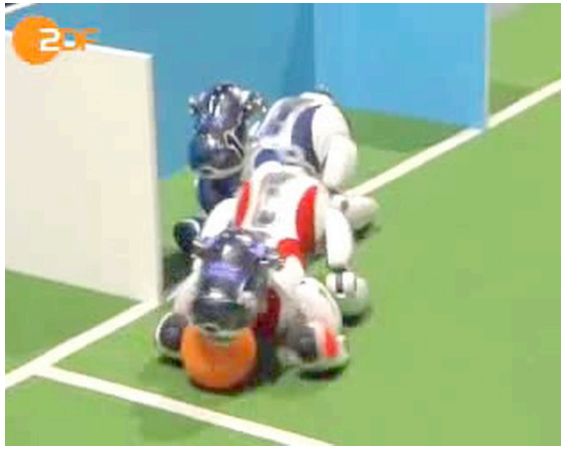
The screen of a computer is divided into pixels, single points of a certain color, that are arranged in a grid format with it's origin at the top left of the screen.

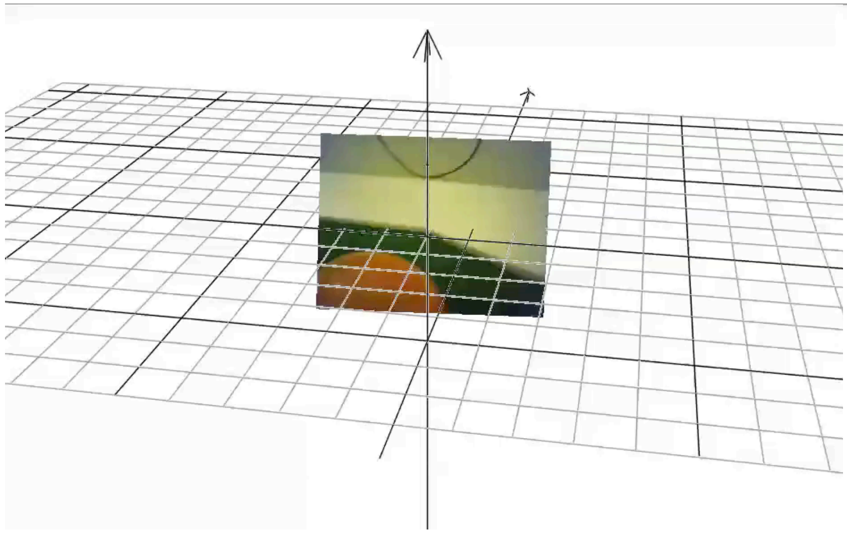


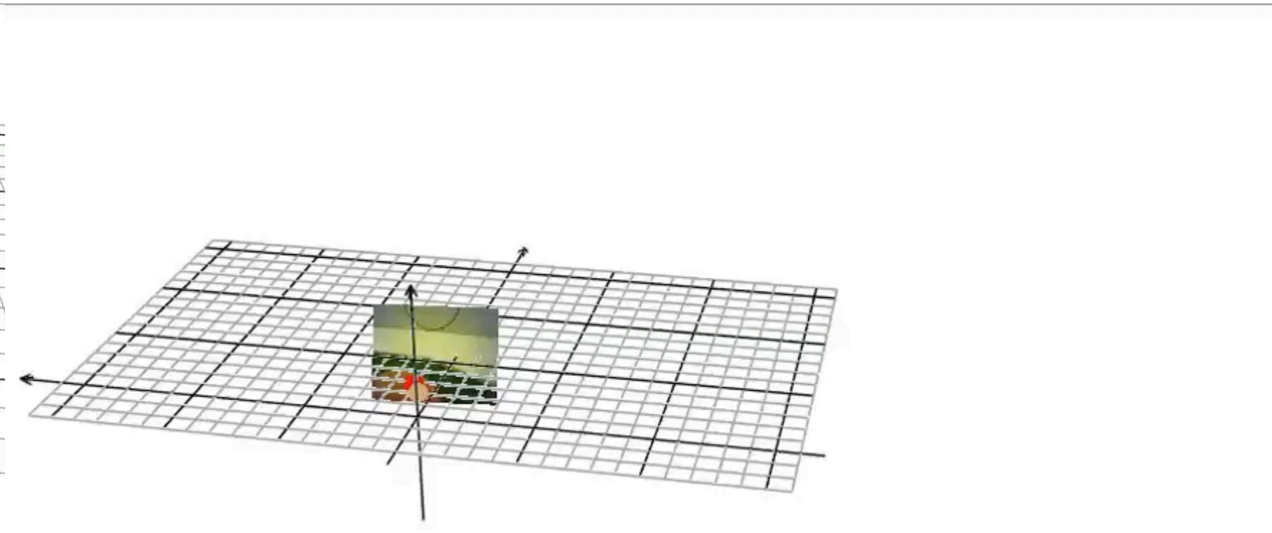


The available resolutions depend on both the video card and the monitor. Typical resolutions include 640x480, 800x600, 1024x768, and 1280x1024. You should offer more than one resolution in your game because players will want to adjust for performance and because newer LCD displays can have problems with non-native resolution graphics.

# Importance of Color

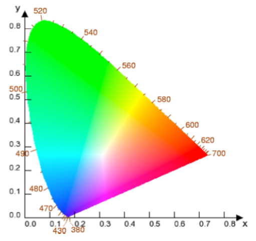




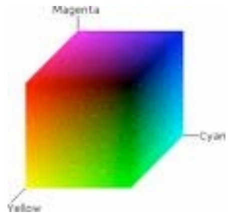


# Color Models and Primary Colors

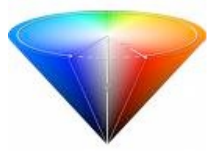
- Color Models



CIE



CMY(K)

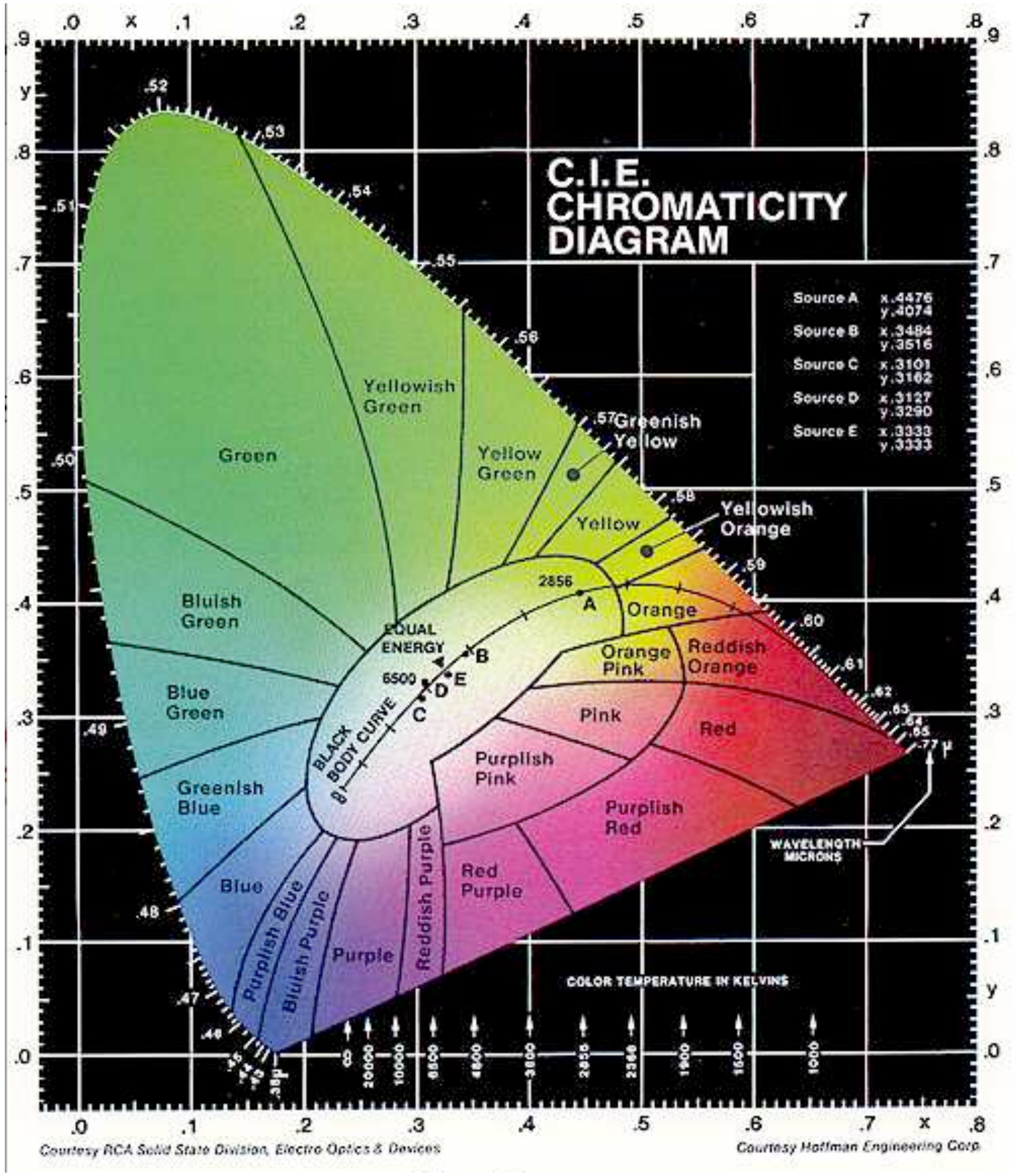


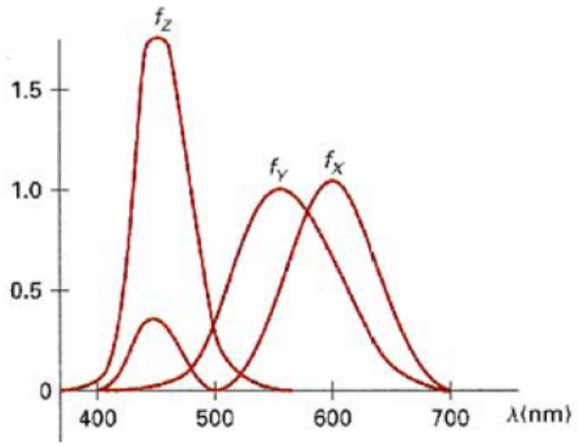
HSV

RGB

- Primary Colors
  - Dominant frequency
  - Combine two or more sources with different dominant frequency we can generate additional colors
  - The hues of the sources are called primary colors.
  - Two primaries that produce white are called complementary colors
  - No finite set of real primary colors can produce all visible colors
  - Given a set of 3 colors a fourth can be produced

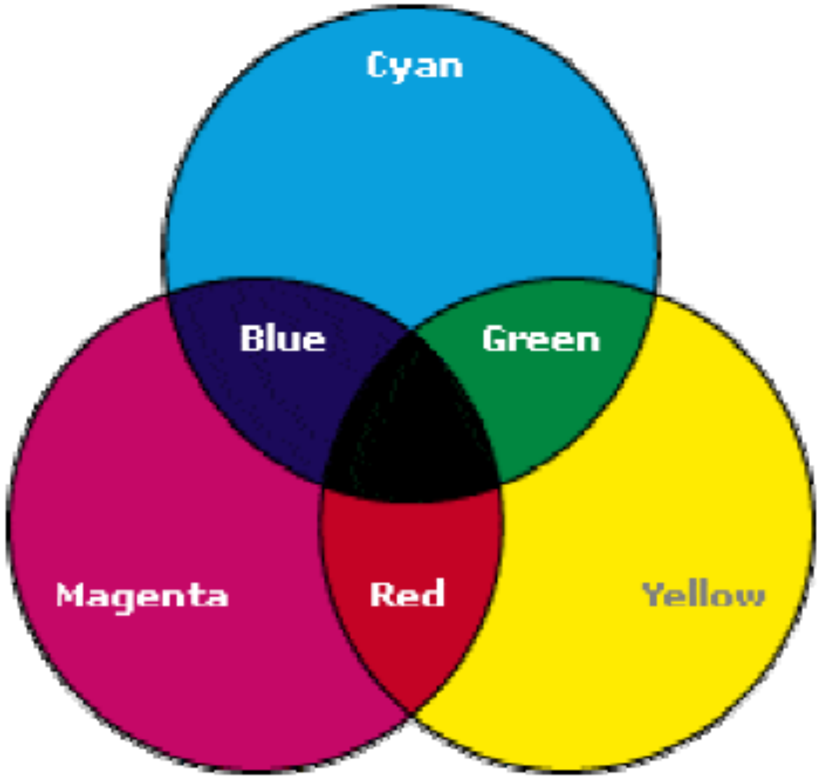
## CIE Chromaticity Diagram





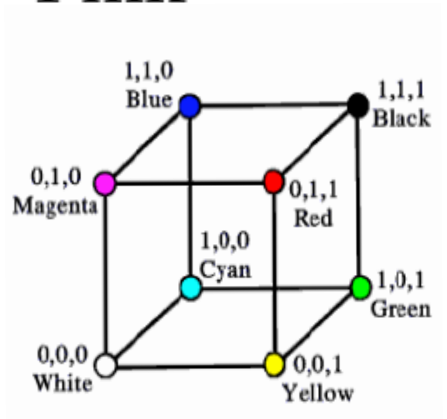
# CMY(K) Color Model and Cube

Cyan, Magenta and Yellow are primary colors

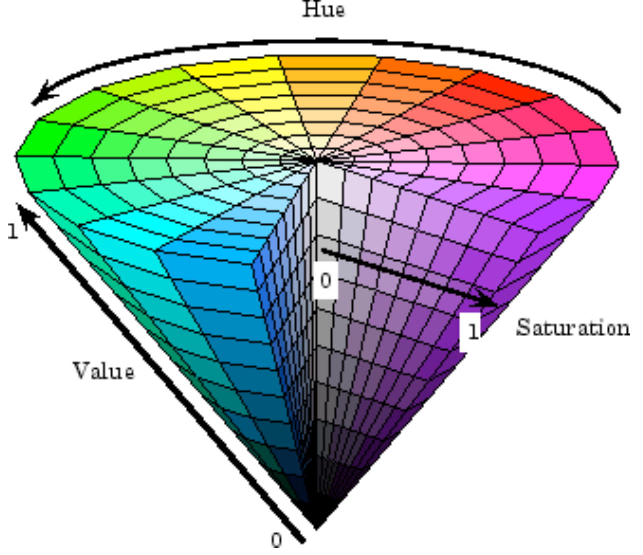


| C | M | Y | Color |
|---|---|---|---|
| 1.0 | 1.0 | 1.0 | Black |
| 0.0 | 1.0 | 1.0 | Red |
| 0.0 | 0.0 | 1.0 | Yellow |
| 0.5 | 0.5 | 0.5 | Grey |
| 0.0 | 0.3 | 0.3 | Pink |

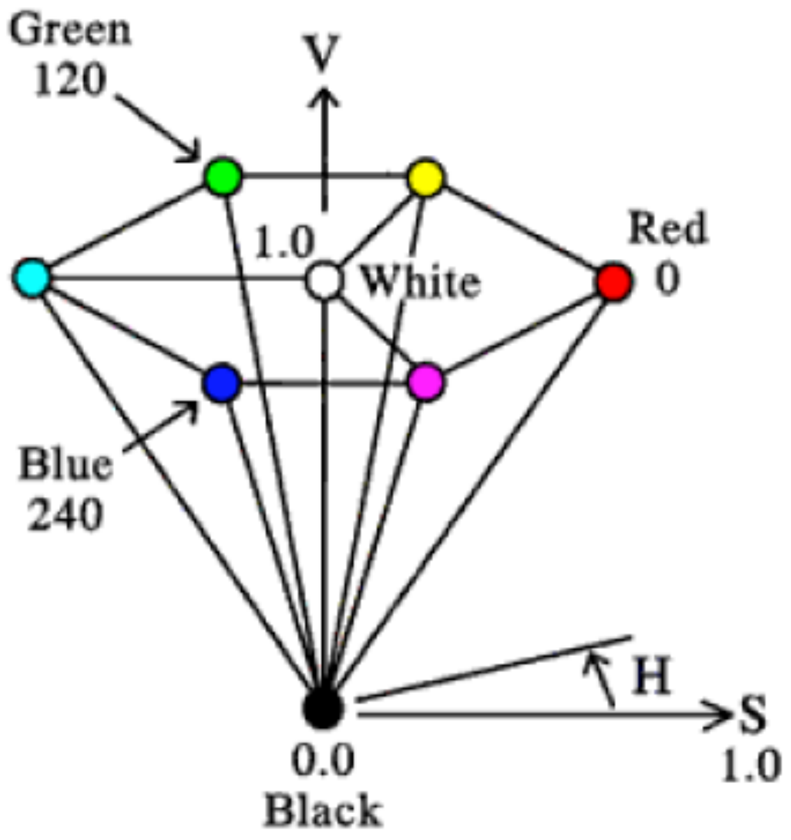
- Printing



# HSV Color Model



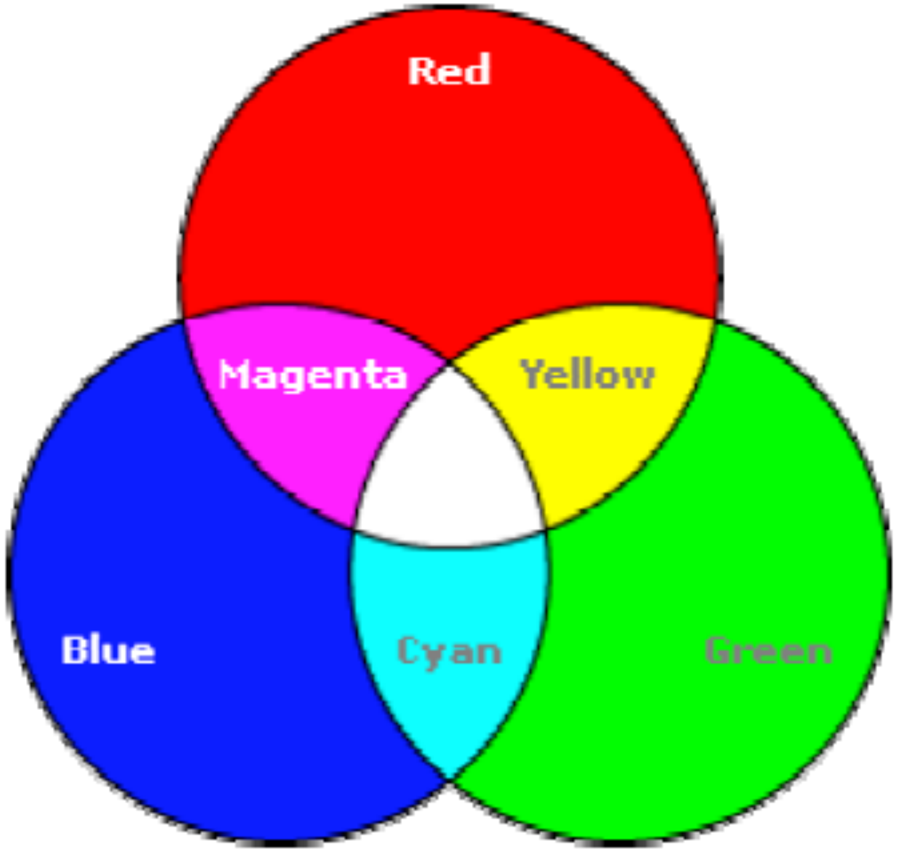
- Hue, Saturn, Value



| H | S | V | Color |
|---|---|---|---|
| 0° | 0.0 | 0.0 | Black |
| 0° | 1.0 | 1.0 | Red |
| 60° | 1.0 | 1.0 | Yellow |
| 0° | 0.0 | 0.5 | Grey |
| 0° | 0.3 | 1.0 | Pink |

# RGB Color Model

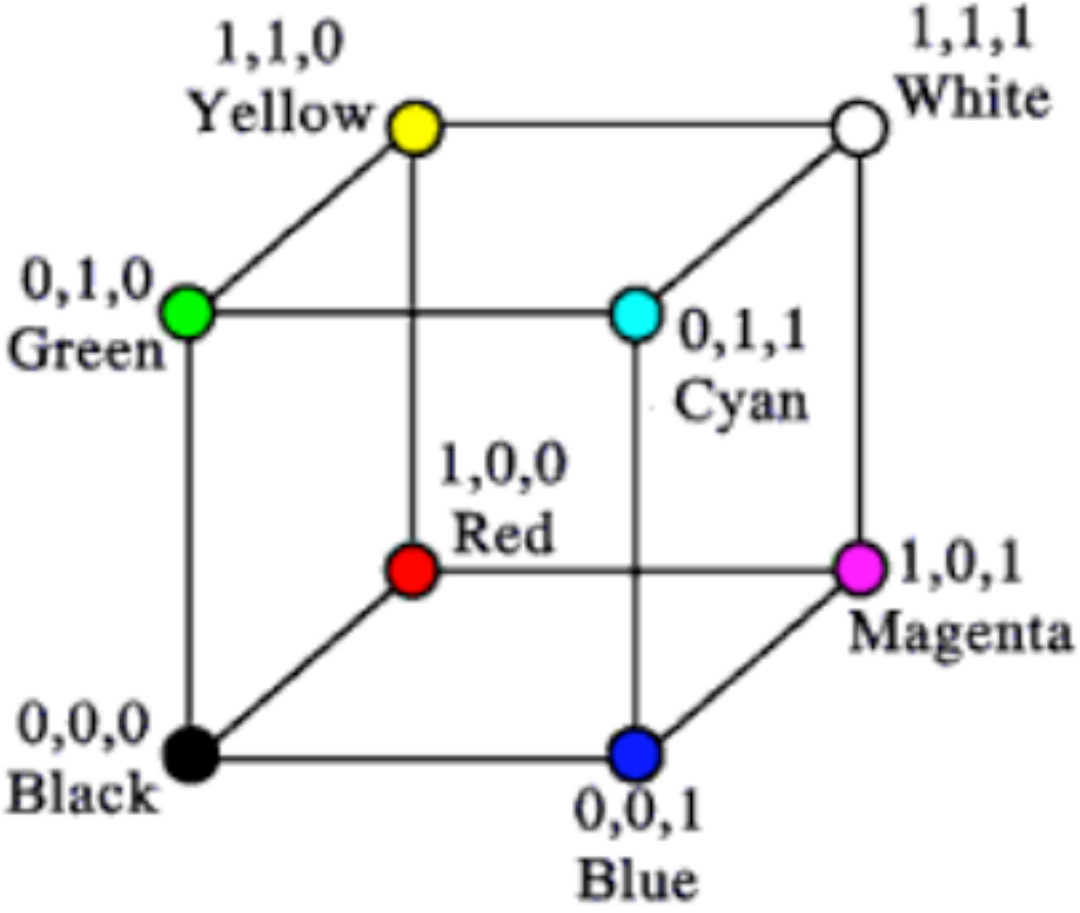
Red, Green and Blue primary colors



| R | G | B | Color |
|---|---|---|---|
| 1.0 | 1.0 | 1.0 | Black |
| 1.0 | 0.0 | 0.0 | Red |
| 1.0 | 1.0 | 0.0 | Yellow |
| 0.5 | 0.5 | 0.5 | Grey |
| 1.0 | 0.7 | 0.7 | Pink |

- Monitors

# RGB Color Cube



# Pixel Color and Bit Depth

**Pixel Color**
Computers use the RGB color model to control pixel color. In this system different levels of red green and blue are combined to make a color for display.

The number of colors a monitor can display depends on bit depth which is the number of bits used to store each pixels color information.

**Bit Depth**

- 8 bit - $2^8$ = 256 colors
- 15 bit - 5 bits per color - $2^{15}$ = 32,768 colors
- 16 bit - 5 bits for red and blue, 6 bits for green - $2^{16}$ = 65,536 colors [note: the human eye is twice as sensitive to tones of green]
- 24 bit - 8 bits per color - $2^{24}$ = 16,777,216 colors
- 32 bit - same as 24 bit, but it fits into a 32 bit space which is more convenient for computers to work with

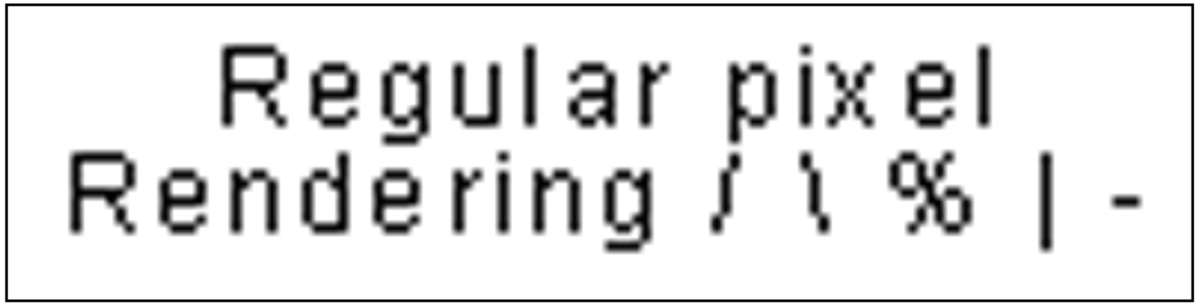
## Refresh Rate

- The *refresh rate* is the number of times per second that the monitor redraws itself based on the content of the video card. Common rates are between 75Hz and 85Hz. Lately, rates are changing to 60Hz, 120Hz, 144Hz over even more.

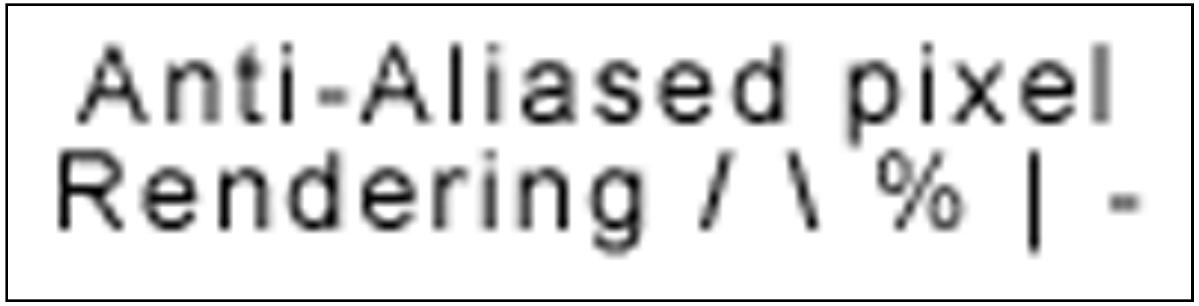
- Refresh rate of video card vs refresh rate of monitor

# Anti-Aliasing

In the FullScreenTest program the text on the screen had jagged edges because it was not *anti-aliased*. Anti-aliased text is blurred or in some cases rendered at the sub-pixel level in order to make the edges look smother.



Regular pixel
Rendering / \ % | -



Anti-Aliased pixel
Rendering / \ % | -

These enlarged images show the difference anti-aliasing makes.

To make text anti-aliased, set appropriate rendering hint before drawing any text. The functionality is present only in the Graphics2D class, a subclass from Graphics.

## Which Display Mode to Use

- Your game should be able to run in more than one display mode.
- When possible allow the player to select the same resolution as the current resolution.
- Bit depth: 16, 24, and 32 bit color are all good selections. 16 bit is faster while 24 and 32 bit graphics look better.
- A refresh rate between 75Hz and 85Hz is suitable for the human eye.

# Images

- Transparency
  - There are three types of image transparency, opaque, transparent, and translucent.

  - **Opaque** - every pixel is drawn
  - **Transparent** - a pixel is either visible or not visible
  - **Translucent** - a pixel can be partially visible (the final color is a weighted average of the color in the picture and the color behind it)

## File Formats

Java supports three image formats, GIF, PNG, AND JPEG.

- **GIF** - can be opaque or transparent. Limited to 8 bit color.
- **PNG** - can be opaque, transparent, or translucent. PNG images also support any bit depth.
- **JPEG** - opaque 24 bit images only.  Works well for photographs, however the compression method is based on an 8x8 grid which can give diagonal lines a stair-step appearance.

Apache's Scalable Vector Graphics (SVG) implementation, called Batik, at http://http://xmlgraphics.apache.org/batik/

The ImageTest program uses the SimpleScreenManager class to establish fullscreen mode then draws a JPEG background image and four PNG foreground images.

View
SimpleScreenManager
and
ImageTest Code

Run ImageTest

# Image Drawing Benchmarks

The ImageSpeedTest program is a modified version of the ImageTest program that spends one second each drawing the four types of images tested in the ImageTest program and prints a display of how many of each type of image was drawn.

View ImageSpeedTest Code

Run ImageSpeedTest

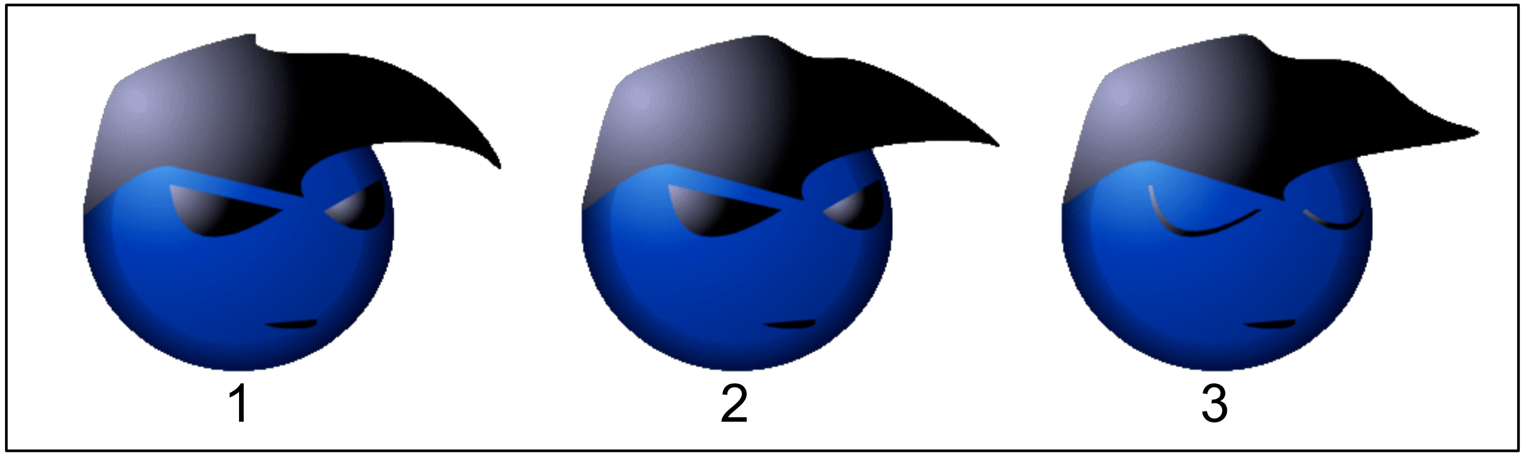
Note: You should not spend large amounts of time in the **paint()** method as in ImageSpeedTest. It will prevent the AWT event dispatch thread from performing its other duties such as handling user input.

To give you an idea, here are the results of this test on a 600MHz Athlon with a GeForce-256 video card, a display resolution of 800x600, and a bit depth of 16—and in a good mood at the time:

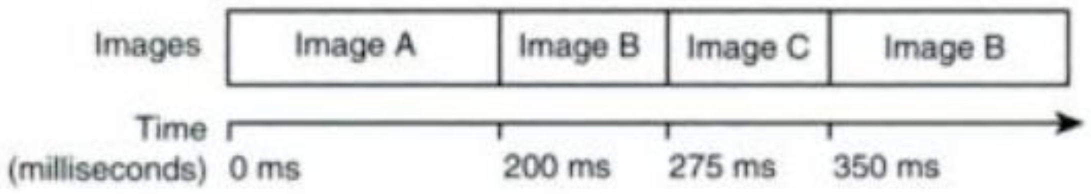
```
Opaque: 5550.599 images/sec
Transparent: 5478.6953 images/sec
Translucent: 85.2197 images/sec
Translucent (Anti-Aliased): 113.18243 images/sec
```

# Animation

First will look at cartoon-style animation. This is where several images are drawn in a sequence to create the illusion of movement.



Each image is a frame and each frame is displayed for a certain amount of time. An example of how this can be done in code is shown in Animation.java.



# Active Rendering

*Active Rendering* is a term used to describe drawing directly to the screen in the main thread. Using active rendering means that you do not need to wait for the **paint()** method to be invoked by the AWT event dispatch thread which may be busy. The following code shows an example of using active rendering:

```
Graphics g= screen.getFullScreenWindow().getGraphics();
draw(g);  // draw is a method you define
g.dispose();
```

In this code the graphics context for the screen is obtained using **Component**'s **getGraphics()** method. Then the draw method, defined in the main class, draws directly onto the screen. The graphics device is disposed because the garbage collector may take some time to get to it and the object is created on every screen update.

## The Animation Loop

The following program, AnimationTest1, uses active rendering to draw the animation continuously in a loop. The steps of the animation loop are:

1. Update any animations
2. Draw onto the screen
3. Optionally sleep for a short time
4. Return to step 1

View AnimationTest1 Code

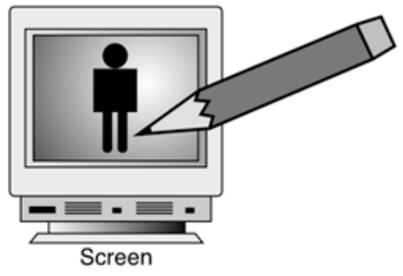
Run AnimationTest1

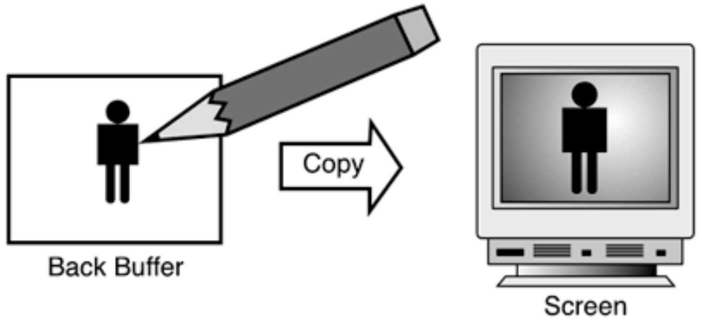
## Flicker and Tearing elimination

You probably noticed that AnimationTest1 looks terrible. The image may be constantly flickering because it is being drawn directly on the screen and then drawn over by the background before it is drawn again. To address this problem we introduce a *buffer*.

### Double Buffering

An animation that is double buffered is first drawn to an image somewhere in memory (the back buffer), then that image is copied to the screen once it is completed.



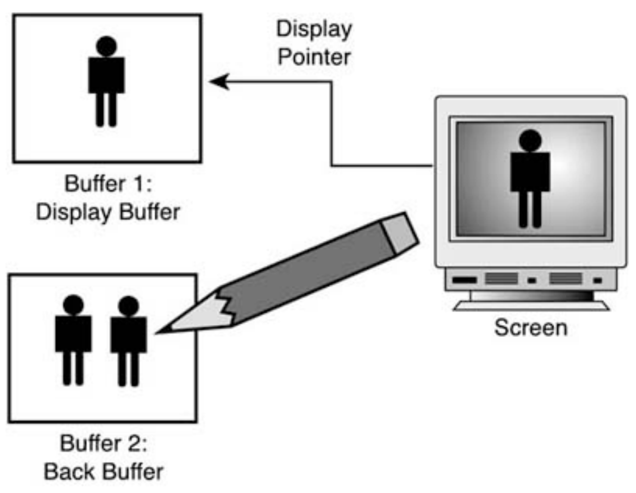


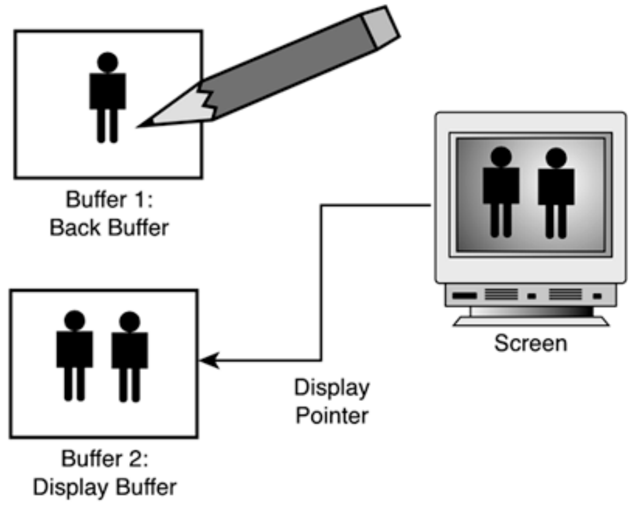
# Page Flipping

- When using double buffering you always have to copy an image the size of the entire screen to draw each frame. *Page Flipping* allows you to skip this extra copying step.

- In page flipping you have two buffers that are usually both in video memory. One buffer acts as the screen device and the other holds the next frame until it is ready to be displayed. Then the graphics device's display pointer is changed from one buffer to the other making it the source for the monitor's screen refresh instantly. The process repeats with the buffers in exchanged roles.

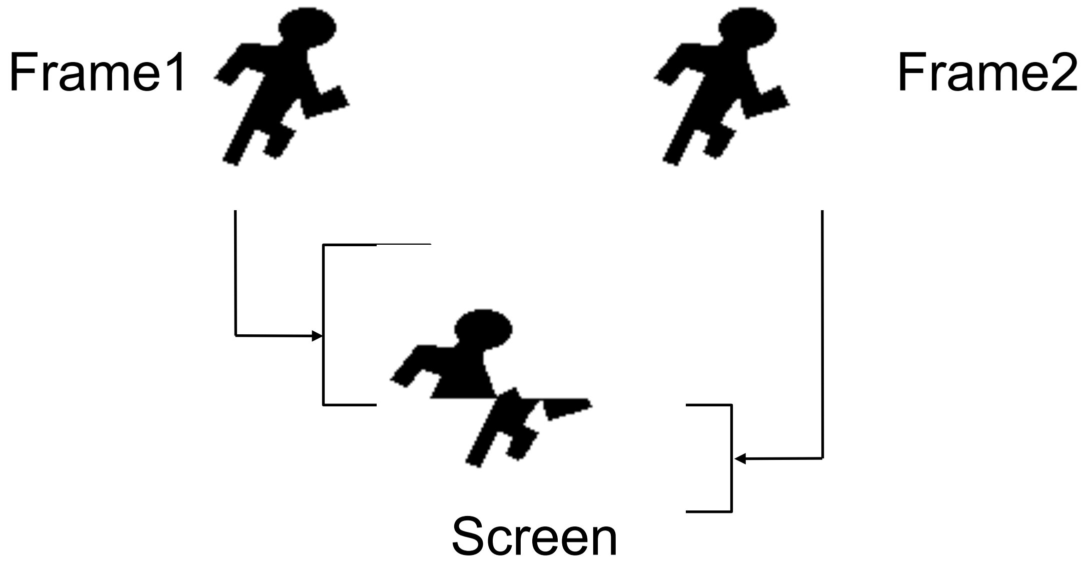
- In page flipping the screen is updated instantly without any copying of data.





## Monitor Refresh and Tearing

The monitor will update itself based on video memory a certain number of times per second. If the display pointer is changed from one image to another during a redraw then the top of the monitor displays a different image than the bottom. This is called tearing because it looks as though things on screen are being torn in half.



To avoid this problem the display pointer must be changed between refresh cycles. This can be achieved using java's **BufferStrategy** class.

# Creating a Screen Manager

The ScreenManager class is an improved version of the SimpleScreenManager class that adds the following features:

- Double buffering and page flipping using the BufferStrategy class
- **getGraphics()** which gets the graphics context for the display
- **update()** which updates the display
- **getCompatibleDisplayModes()** Gets a list of the compatible display modes
- **getCurrentDisplayMode()** gets current display mode
- **findFirstCompatibleMode()** which gets the first compatible mode from a list of modes

ScreenManager.java

In the new ScreenManager class make sure to note the new methods:

- **displayModesMatch()** and
- **createCompatibleImage()**

The program AnimationTest2 updates AnimationTest1 to use the new ScreenManager class.

View AnimationTest2 Code

Run AnimationTest2

## Sprites

A *sprite* is a graphic that moves independently around the screen. Sprites can also be animated.

The following Sprite class defines a movement based on its position and velocity. By basing the velocity on time the sprite is made to move the same speed no matter what speed the machine renders frames.

Sprite.java

The program SpriteTest1 creates a sprite with random velocity and makes it bounce around the screen.

View
SpriteTest1
Code

Run
SpriteTest1

# Simple Effects

## Transforms

Transforming an image allows you to do such things as rotate, scale, flip, and shear images. These effects can be performed in real time but they are not hardware accelerated.

The AffineTransform object describes a transform. The class provides methods for controlling transforms such as **rotate()**, **scale()**, and **translate()**.

There is a special drawImage() method int the Graphics2d object that takes an AffineTransform object as a parameter.

SpriteTest2 uses transforms to make the sprite face in the direction it is going.

View SpriteTest2 Code

Run SpriteTest2