- 98-026 Nintendo. January 21, 2004
- Good Emulators
  - I will place links to all of these emulators on the webpage.
  - Mac OSX
    - The latest version of RockNES (2.5.1) has various problems under OSX 1.03 Pather. You may want to use 2.4.0 instead.
    - Nestopia seems to work well, but it requires a fast computer.
  - Windows
    - JNes works rather well, and it has good display options and speed.
    - FCE Ultra has the most accurate emulation I have seen in Windows.
  - Linux
    - FCE Ultra for Linux should work as well as the Windows version
  - Playstation / Playstation 2
    - imbNES was written by Allan Blomquist, a student in this class. Reports are that it works very well.
  - Dreamcast
    - NesterDC can be used for the Sega Dreamcast.
- Pixels
  - The basic unit of a computer image. A single dot of color
  - Resolution
    - The number of pixels in an image, or on a display, such as a monitor, television, or projector.
    - Usually written as Width x Height
  - Common screen resolutions
    - 640x480: VGA computers, US television
    - 800x600: SVGA computers, European television
    - 1024x768: SVGA computers
  - NES resolution
    - 248x240 visible
    - From the programmer's perspective, the NES has a resolution of 256x256, but it chops off 8 pixels on each side, and 16 pixels on the bottom.
- Television
  - NTSC (North America), NTSC-J (Japan)
    - "National Television Standards Committee"
    - 29.97 fps (frames per second), interlaced
    - 640x480 resolution
  - PAL (Europe)
    - "Phase Alternating Line"
    - 25 fps interlaced
    - 800x600 resolution
  - Most displays, including televisions, are drawn one pixel at a time, starting from the upper left corner. The electorn beam inside the display draws one row at a time, then moves down to draw the next row, like written English.

- Interlaced displays, such as televisions (but not computers), will draw every second row, then go back to fill in the skipped rows. Each scan of the screen (which draws half the lines) is called a field, and there are two interlaced fields per frame. An interlaced display at 30 frames per second will therefore display 60 fields per second. In standard video, the two fields in a frame occur at slightly different times, 1/60 of a second apart.
- RF (Radio Frequency), RCA, S-Video
  - RF is a method of connecting older game consoles or VCRs to a television. The video and audio signals are transmitted together, normally on channel 3 or 4, just like television stations broadcasting over airwaves or through cable.
  - RCA connectors are a method of connecting devices to a television that generally yields a better image than RF. The video and each audio channel have their own "phono plug" that carries signal from the device to the television. By convention, video uses a yellow plug, left audio white, and right audio red.
  - S-Video connectors transmit higher quality video than RCA by separating the brightness and hue components of a video image. The connector itself looks similar to a mouse or keyboard connector from a computer. Audio is usually still transmitted over RCA cables.
- Color Space
  - CMYK
    - Cyan, Magenta, Yellow, Black
    - A method of subtractive color mixing used in printing magazines and newspapers. The four colors are the inks used in the process. Mixing the inks in varying amounts can create any color in the spectrum.
  - YUV
    - Also called Y'CbCr and YPbPr
    - A method of representing color used by televisions and standard video. Y is the luminance (brightness) of the color, and U and V represent components of the chrominance (hue) of the color.
  - RGB
    - Red, Green, Blue
    - Additive light mixing used in computer monitors and the web. Mixing varying amounts of red, green, and blue light can create any color in the spectrum. Usually, each of these components is represented as a floating point number between 0 and 1, or as an integer from 0 to 255.
- Graphics Memory (technical)
  - Memory is an array. Computer memory is a list of bytes, very similar to a file on disk. The arrangement of data within this array can determine its use. Graphics cards have a section of memory dedicated to holding image data.
  - A screen buffer is a section of graphics memory that allows a program to modify an image as desired before it is displayed on screen.

- ☐ Double Buffering is a method that uses a screen buffer to prevent flickering during games. Often, the game has two "pages", or screen buffers. One buffer is shown on screen while the other is updated with the next frame. When the new frame is ready, the pages are flipped, and the game player doesn't see any artifacts that would otherwise occur while calculating the new frame. Usually, this flip is done in between refreshes of the monitor or television, to prevent "tearing", which is the result of swapping pages in the middle of a screen redraw. The visual result of tearing is that the top portion of the screen shows the previous frame, and the bottom portion shows the new frame.
- ☐ 16-bit RGB. In 16-bit displays, 16 bits (2 bytes) of data are used for each pixel on the screen to define the color. 5 bits of color information are used for Red, 6 bits for Green, and 5 bits for Blue. Because the human eye is most sensitive to green, the extra bit is used to allow twice as much detail for that hue. The 5 bits for red or blue allow 32 different brightness levels to be defined, and the 6 bits for green allow 64 brightness levels.
- ☐ 24-bit RGB. Most modern 2d displays use 24-bit color. This allows 8 bits of color information (256 brightness levels) each for the red, green, and blue components of each pixel's color.
- ☐ 32-bit RGBA. Modern 3d displays, and some 2d displays, add an "Alpha" channel to the color, and 8 bits of information are used for each of the four channels in the color. The alpha channel defines the opacity of a color, where 0 is completely transparent, and 255 is completely opaque. This extra opacity information is useful for 3d games, or in layered graphical applications such as Photoshop.
- ☐ Color planes are screen buffers that hold the information for one color component of an entire image. Some computers, for example, have a plane (screen buffer) containing all the red data for the image, a plane for blue data, and a plane for green. Combining these three planes together will create a full-color image for display on the monitor.
- ☐ Bit planes, very similar to color planes, are used by the Nintendo for its color information. Colors in the NES are defined by 2 bits. Each small portion of graphics memory (8x8 pixels) is stored as a plane containing the first bit of color for each pixel, and then a second plane containing the second bit of color for each pixel.
- ▼ ☐ Color Palettes
  - ☐ On systems with limited graphics memory (such as the NES), color palettes can be used to save memory. For example, in a system with a 16-color palette, only 16 colors at a time are available for display. However, each of these 16 colors can generally be set to any color of the spectrum. This allows each pixel's color to be defined by 4 bits of data (16 colors), instead of 24 (16 million colors). This has obvious drawbacks for visual quality, which is why modern systems have gobs of graphics memory.
  - ☐ Color index is a number used to tell which color of a palette a pixel should have. Generally, indices begin at 0. So in a 16-color palette, the first color would have index 0, and the last would have index 15.
  - ▼ ☐ Bit Depth is the number of bits of color available for each pixel. This may refer to either 16/24/32 bit RGB displays, or to indexed palette displays. The bit depth determines how many colors may be in an indexed palette.
    - ☐ 1-bit: 2 colors (usually black and white)
    - ☐ 2-bit: 4 colors (NES sprites and background)
    - ☐ 4-bit: 16 colors
    - ☐ 6-bit: 64 colors (NES global palette)

- 8-bit: 256 colors (VGA displays)
- Rather than being able to set each palette index to any color of the spectrum, the NES has a global palette, which contains the only colors displayable on the NES. The palette contains 64 colors; however, some of the blacks should not be used because of ill effects they may have on some televisions.

▼ Photoshop
- A popular graphics application for personal computers.
- Artists use this to create or edit graphics for many uses.
- We will be able to use this application for NES graphics as well.

▼ 2d Game Graphics
  ▼ Image planes
  - Most game systems have at least two image planes, similar to screen buffers. One plane is used to store the background image. This image is made up of many small pieces of an image, which are copied multiple times in various locations on the screen to create background scenery.
  - In most 2d game systems, such as the NES, the background image may only contain aligned squares of image data, which are copied from other aligned squares of image data.
  - The foreground image plane generally holds characters, enemies, powerups, and other items that may need to move anywhere on the screen.
  ▼ Pattern table, Background tiles
  - The NES pattern table is a region of graphics memory from which background tiles and sprites are copied to the screen. Each of the two pattern tables is split into 256 graphics regions (8x8 pixels each) called tiles. Similarly, the background image plane is split into many 8x8 pixel tiles. Any tile from the pattern table may be copied into any one of these background tiles. The source and destination tiles must always lie on the 8x8 pixel boundaries, however. They may not be placed willy-nilly all over the screen. Sprites, however, may take their images from any tile in the pattern table and place the image anywhere on the screen. A sprite's destination location does not have any boundary alignment requirements.
  - The NES may have two active pattern tables at a time. One must be used for the background, and one must be used for the foreground. It is not required, however, that the foreground and background use different pattern tables.
  - Sprites are images that can be placed anywhere on the screen. These are often used for main characters, enemies, and other game elements that move individually.
  - Sprite Animation is a technique used to create a sense of movement that doesn't actually exist in the game. Imagine we have a sprite that is an image of a man with his hand in the air and to the right. We also have an image of him with the same hand directly above, and a third image with the hand above and to the left. Now, if we show the first image, and then a few frames later replace it with the second image in the same location, then the third, then the second again, we have a short animation. By repeating this image loop (first, second, third, second), we have created an animation of the man waving. This is often used in games for characters running, rolling, jumping, throwing, or performing various other movements.

- ☐ Most 2d game systems allow Sprite Flipping. This allows us to create a sprite of a character facing to the right, and if the game requires that the character run to the left, then we can simply tell the game to flip the image around. The same image reversed will look like the character facing left. Of course, if our character has a distinguishing asymmetrical characteristic, such as an eyepatch over one eye, then flipping the sprite will put the patch over the over the other eye. But most games don't bother with addressing such issues.
- ▼☐ Scrolling and Parallax Scrolling
  - ☐ The NES has enough graphics memory to store more than one screen of background image data. This allows the game to have usually two screens of the world drawn and ready. As the player moves through the world, the NES simply has to slide the viewable area along the background buffer, to create the appearance of moving through the world. As the player approaches the edge of the buffer, off-screen portions are updated so that they will be ready when they must be shown on screen.
  - ☐ Parallax Scrolling is a technique that is usually not handled by the NES, but is handled well by later game systems, such as the SNES and the Sega Genesis. Usually for this technique, multiple background image planes are used. One of these background planes would hold normal level graphics for the world. The other plane, shown behind the first, would display far-off landscape, such as a mountain. As can be demonstrated by looking out your car window while riding in the passenger seat (not while driving!), objects that are closer appear to move faster than farther away objects as you pass by them. By scrolling the two background planes at different rates, you can create this same effect in a game.
- ▼☐ NES Color Palettes
  - ☐ 64 Colors in the system palette
  - ☐ 16 Colors in the background palette
  - ☐ 16 Colors in the foreground palette
  - ☐ The background and foreground image planes of the NES may each have their own palette of 16 colors. Each of these colors is taken from the global system palette.
- ▼☐ NES Sub Palettes
  - ☐ The background and foreground palettes are split into sub palettes of 4 colors. This allows graphics data to use half as much memory, by allocating 2 bits of color for each pixel, instead of 4 bits. Whenever a sprite or background tile is placed on the screen, a sub palette is associated with it, to tell which set of four colors to use when drawing that piece of the image. Aside from certain restrictions on the background, any sprite or background tile may use any of its four available sub palettes, regardless of what other sub palettes are used by other sprites or tiles.
  - ☐ The first entry in each background sub palette is the same primary background color. This primary background color is usually used for the sky color, but it can also be used as the transparent color, in the rare event that you may wish to draw a sprite "behind" the background.
  - ☐ The first entry in each foreground sub palette is transparent. When a sprite is drawn on the screen, the background image will show through any sprite pixel whose color index is 0.
  - ☐ The game is allowed to change the palettes and sub palettes during play, and sprites and tiles may change which sub palette they use for drawing.

- A total of 25 unique colors may be shown on screen at any time. 3 unique colors per sub palette, with 4 sub palettes each for background and foreground. The 25th color is the global background color.

- NES Sprites
  - Sprites may be 8x8 or 8x16 pixels. However, only one size may be active at a time. To draw an 8x8 image while in 8x16 mode, a sprite must be defined to include blank space. Often, characters are drawn larger than these sizes, such as 16x16 or 16x32. To accomplish this, multiple sprites may be drawn next to each other.
  - May be flipped horizontally or vertically.
  - Each sprite may have 3 colors, plus transparency, due to the sub palette limitations. However, you may cleverly draw multiple sprites on top of each other, to create the appearance of a single sprite with more colors.
  - Usually used for main character, enemies, Tetris pieces, and any other moving objects.
  - The NES has a limit of 64 sprites on screen at once.
  - There is a hardware limit of 8 sprites per television scan line. If the game tries to draw more than 8 sprites in a single row, then the overlapping portions of any sprite past the 8th simply will not be drawn. This creates a problem in many games where in some situations an enemy will disappear.
  - Be aware that some emulators allow more than 8 sprites per scan line. A game that looks good in these emulators may not look correct in more accurate ones.

- Assignment 1 Graphics
  - Draw text as tiles on the background layer
  - Why lowercase letters didn't work
    - The pattern table font I provided with the assignment only contained upper case letters. Any lowercase letters that the assignment tried to print would simply reference a blank tile. Many people found that a name such as "Bob Rost" would only show up as "B   R".
  - Why might you not want mixed case?
    - Only one pattern table at a time may be used for the background. If you wish to have both text and graphics on screen at the same time, then both need to be in your pattern table. More characters for the text means fewer tiles left for the graphics.
  - How can we make the text move?
    - Since the text is drawn on the background, we can simply scroll the background.
    - By changing the vertical and horizontal scroll values each frame, you can create various effects, such as scrolling or bouncing text.