

Multimedia Coding & Communications

1

Course Outline

- Multimedia Overview
- Component of Multimedia
 - Text – types, Unicode standard on file format
 - Image and graphics - data types, file formats, color science and color model;
 - Audio- digitization, midi, quantization and transformation of audio;
 - Video- types of video signals, analog and digital video, television broadcast standards, pc video;
 - animation- types, principals and techniques, 3D animation, camera, special effects, rendering

3-1

Course Outline

- Multimedia Overview
- Component of Multimedia
- Lossless Compression Techniques
- Lossy Compression Techniques
- Elements of Image Compression System and Standards
- Video Coding and Compressing Standards
- Audio Compression Standards
- Multimedia Communication and Retrieval
- Multimedia Architecture

2

Course Outline

Multimedia Overview

- Text – types, Unicode standard on file format
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3-2

Course Outline

- **Multimedia Overview**
- **Component of Multimedia**
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4-1

IMAGES AND GRAPHICS

5

Course Outline

Component of Multimedia

- Text – types, Unicode standard on file format
- **Image and graphics - data types, file formats, color science and color model;**
- Audio- digitization, midi, quantization and transformation of audio;
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4-2

Image and Graphics - Data Types

6-1

Image and Graphics - Data Types

- The number of file formats used in multimedia continues to proliferate.

6-2

Image and Graphics - Data Types

- The number of file formats used in multimedia continues to proliferate.
- For example, below table shows a list of some file formats used in the popular product Macromedia Director.

Image	File Import					File Export		Native
	Palette	Sound	Video	Anim.	Image	Video		
.BMP, .DIB,	.PAL	.AIFF	.AVI	.DIR	.BMP	.AVI	.DIR	
.GIF, .JPG,	.ACT	.AU	.MOV	.FLA		.MOV	.DXR	
.PICT, .PNG,		.MP3		.FLC			.EXE	
.PNT, .PSD,		.WAV		.FLI				
.TGA, .TIFF,				.GIF				
.WMF				.PPT				

6-4

Image and Graphics - Data Types

- The number of file formats used in multimedia continues to proliferate.
- For example, below table shows a list of some file formats used in the popular product Macromedia Director.

6-3

Image and Graphics - Data Types & File Formats

- GIF
- JPEG
- PNG
- TIFF
- EXIF
- GAF
- PS
- PDF

7

Image and Graphics - Popular File Formats

8-1

Image and Graphics - Popular File Formats

- **8-bit GIF:**
 - Graphics interchange format
 - One of the most important format because of its historical connection to the WWW and HTML
 - The first image type recognized by net browsers.
- **JPEG:**
 - Joint Photographic Expert Group
 - Currently the most important common file format.

~~Joint photographic expert group~~

Image and Graphics - Popular File Formats

▪ 8-bit GIF:

- Graphics interchange format
- One of the most important format because of its historical connection to the WWW and HTML
- The first image type recognized by net browsers.

8-2

Image and Graphics - Popular File Formats - GIF

~~graphic format~~

Image and Graphics - Popular File Formats - GIF

▪ GIF standard:

- We will examine GIF standard because it is so simple!
- Yet contains many common elements.

9-2

Example of 8-bit color image



320 × 200 pixels, file size:
125 KB, MIME type: image/
gif, looped, 40 frames, 6.0 s

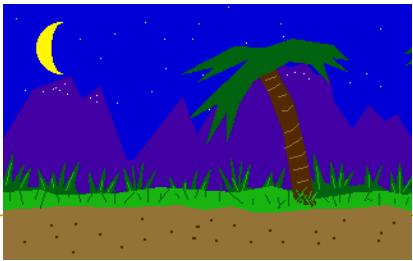


Image and Graphics - Popular File Formats - GIF

▪ ~~GIF standard:~~

- ~~▫ We will examine GIF standard because it is so simple!~~
- ~~▫ Yet contains many common elements.~~
- ~~▪ Limited to 8-bit (256) color images only, which is best suited for images with few distinctive colors (e.g., graphics or drawing) while producing acceptable color images.~~

$$\cancel{8 = 2^3}$$

9-3

Image and Graphics - Popular File Formats - GIF



Image and Graphics - Popular File Formats - GIF



- GIF standard supports **interlacing**

- Successive display of pixels in widely-spaced rows by a **4-pass display process**.

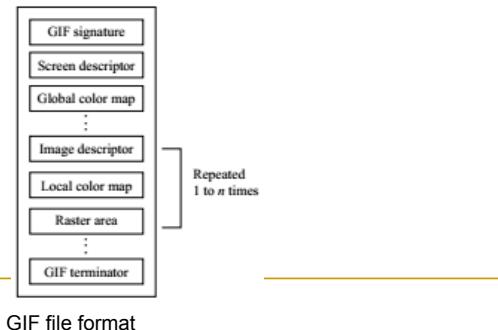


11-2

Image and Graphics - Popular File Formats - GIF

- GIF87**

- For the standard specification, the general file format of a GIF87 file is as in below figure.



12

Image and Graphics - Popular File Formats - GIF

- GIF standard supports **interlacing**

- Successive display of pixels in widely-spaced rows by a **4-pass display process**.

- GIF actually comes in two flavors:

- GIF87a**: The original specification.
 - GIF89a**:
 - The later version.
 - Supports simple animation via a Graphics Control Extension block in the data.
 - Provides simple control over delay time, a transparency index, etc.

11-3

Image and Graphics - Popular File Formats - GIF

13-1

Image and Graphics - Popular File Formats - GIF

▪ GIF Signature

- ❑ It identifies the data as a valid GIF image stream.
- ❑ It consists of the following six characters:
 - G I F 8 7 a
- ❑ The last three characters '87a' may be viewed as a version number for this particular GIF definition
- ❑ It will be used in general as a reference in documents regarding GIF that address any version dependencies.

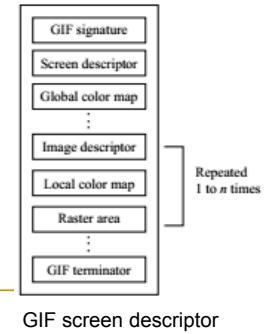
13-2

Image and Graphics - Popular File Formats - GIF

GIF screen descriptor

14-2

Image and Graphics - Popular File Formats - GIF



14-1

Image and Graphics - Popular File Formats - GIF

- **Screen Descriptor** comprises a set of attributes that belong to every image in the file.

GIF screen descriptor

14-3

Image and Graphics - Popular File Formats - GIF

- **Screen Descriptor** comprises a set of attributes that belong to every image in the file.
- It defines
 - The overall dimensions of the image space or logical screen required
 - The existence of color mapping information
 - Background screen color
 - And color depth information.

GIF screen descriptor

Vector vs Raster

Vector vs Raster

14-4

15-1

Image and Graphics - Popular File Formats - GIF

- **Screen Descriptor** comprises a set of attributes that belong to every image in the file.
- It defines
 - The overall dimensions of the image space or logical screen required
 - The existence of color mapping information
 - Background screen color
 - And color depth information.
- This information is stored in a series of 8-bit bytes.

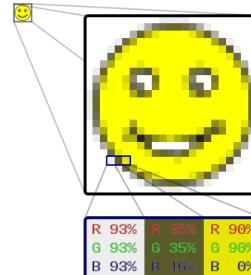
GIF screen descriptor

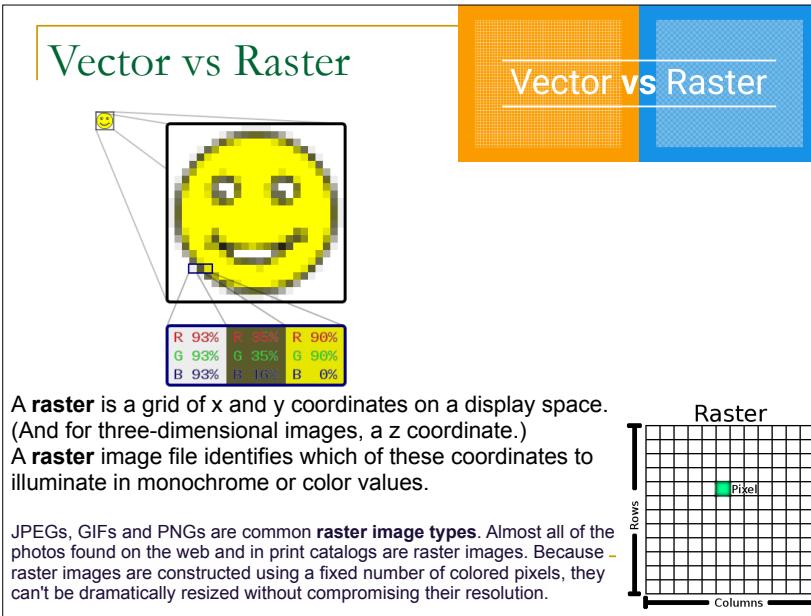
Vector vs Raster

Vector vs Raster

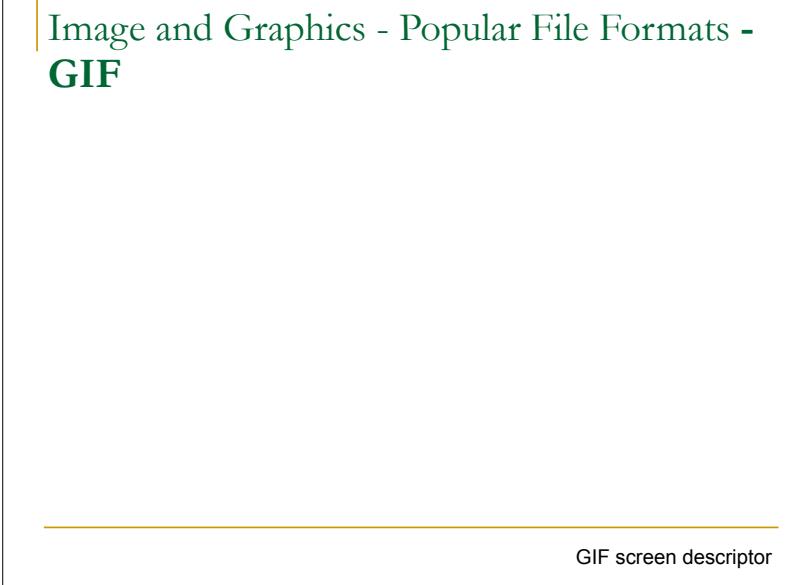
14-5

15-2

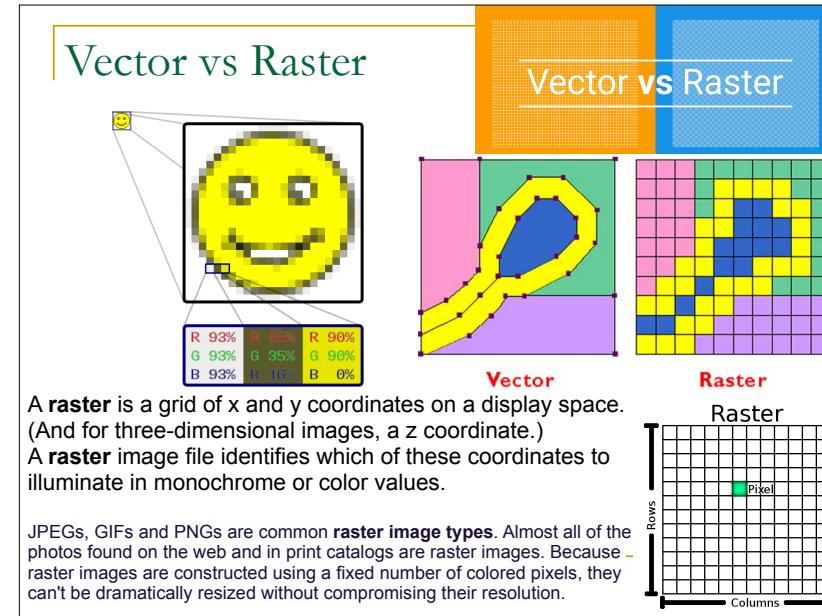




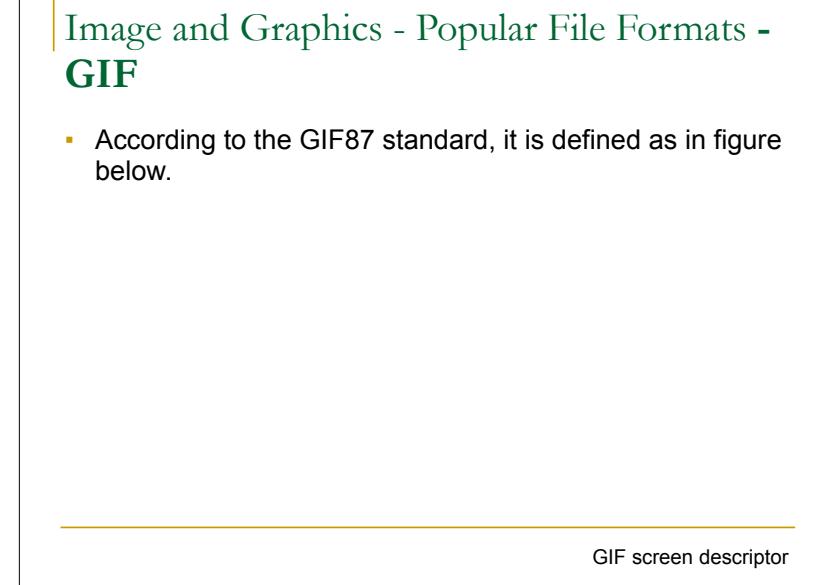
15-3



16-1



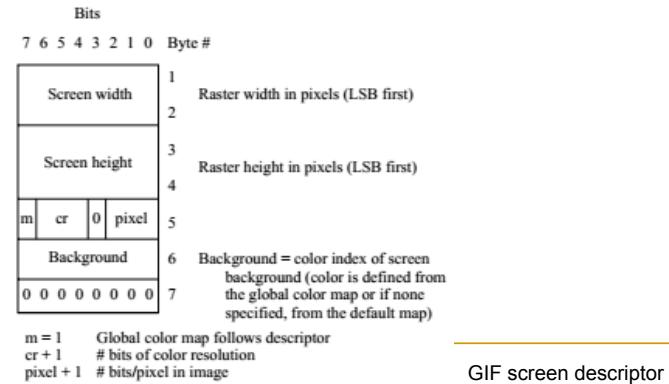
15-4



16-2

Image and Graphics - Popular File Formats - GIF

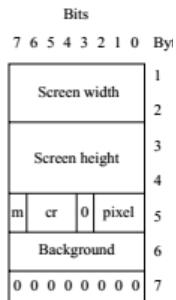
- According to the GIF87 standard, it is defined as in figure below.



16-3

Pixels

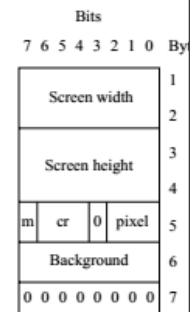
- The value of 'pixel' also defines the maximum number of colors within an image.
- The range of values for 'pixel' is 0 to 7 which represents 1 to 8 bits.
- This translates to a range of 2 (B & W) to 256 colors.
- Bit 3 of word 5 is reserved for future definition and must be zero.



18

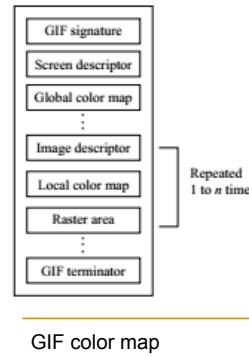
Screen Height and Width

- The logical screen width and height can both be larger than the physical display.
- How images larger than the physical display are handled is implementation dependent and can take advantage of hardware characteristics.
- Otherwise images can be clipped to the edges of the display.



17

Image and Graphics - Popular File Formats - GIF



19-1

Image and Graphics - Popular File Formats - GIF

GIF color map

19-2

Image and Graphics - Popular File Formats - GIF

- **Global Color Map** is set up in a very simple fashion as shown in below figure.

Bits	Byte #	Value
7 6 5 4 3 2 1 0	1	Red value for color index 0
	2	Green value for color index 0
	3	Blue value for color index 0
	4	Red value for color index 1
	5	Green value for color index 1
	6	Blue value for color index 1
	:	(continues for remaining colors)

GIF color map

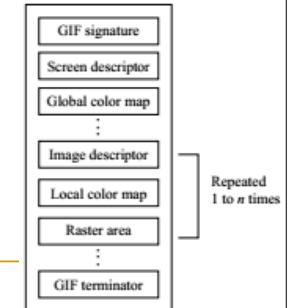
19-4

Image and Graphics - Popular File Formats - GIF

- **Global Color Map** is set up in a very simple fashion as shown in below figure.

GIF color map

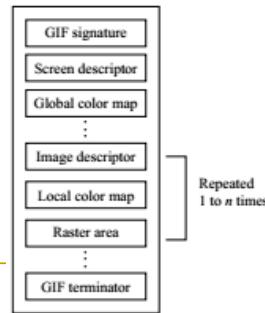
19-3



20-1

■ The Global Color Map

- ❑ It is optional but recommended for images where accurate color rendition is desired.
- ❑ The existence of this color map is indicated in the 'M' field of byte 5 of the Screen Descriptor.
- ❑ A color map can also be associated with each image in a GIF file.

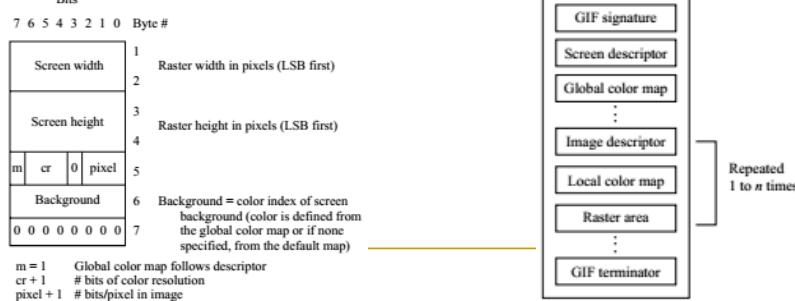


20-2

■ The Global Color Map

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- ❑ The existence of this color map is indicated in the 'M' field of byte 5 of the Screen Descriptor.
- ❑ A color map can also be associated with each image in a GIF file.

■ In the individual Image Descriptors, the 'M' flag

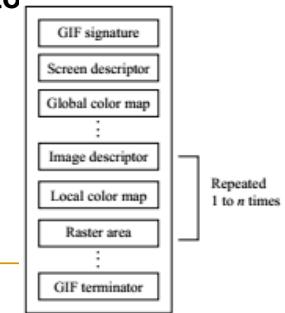


20-4

■ The Global Color Map

- ❑ It is optional but recommended for images where accurate color rendition is desired.
- ❑ The existence of this color map is indicated in the 'M' field of byte 5 of the Screen Descriptor.
- ❑ A color map can also be associated with each image in a GIF file.

■ In the individual Image Descriptors, the 'M' flag will normally be zero.

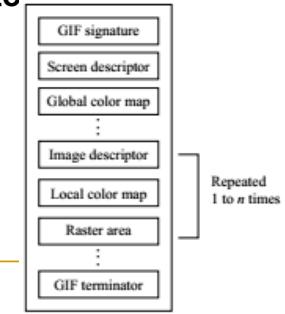


20-3

■ The Global Color Map

- ❑ It is optional but recommended for images where accurate color rendition is desired.
- ❑ The existence of this color map is indicated in the 'M' field of byte 5 of the Screen Descriptor.
- ❑ A color map can also be associated with each image in a GIF file.

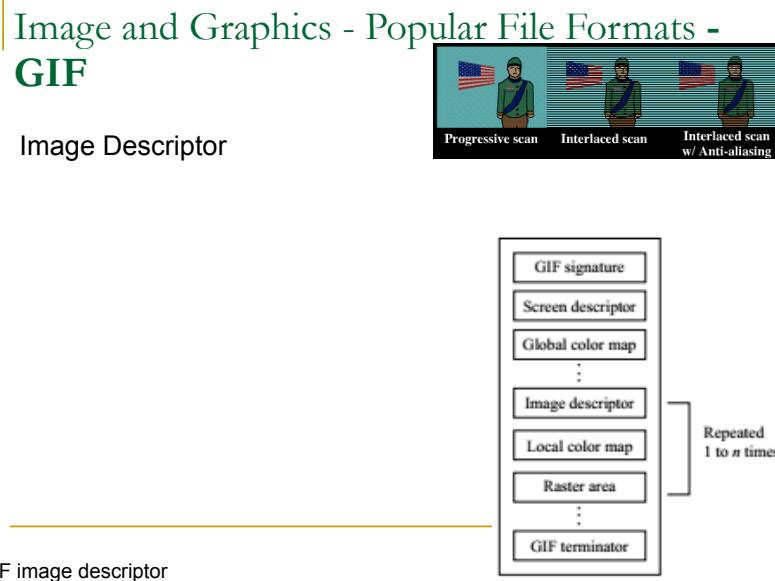
■ In the individual Image Descriptors, the 'M' flag will normally be zero.



20-5

- **The Global Color Map**
 - It is optional but recommended for images where accurate color rendition is desired.
 - The existence of this color map is indicated in the 'M' field of byte 5 of the Screen Descriptor.
 - A color map can also be associated with each image in a GIF file.
- **In the individual Image Descriptors the 'M' flag will normally be zero.**

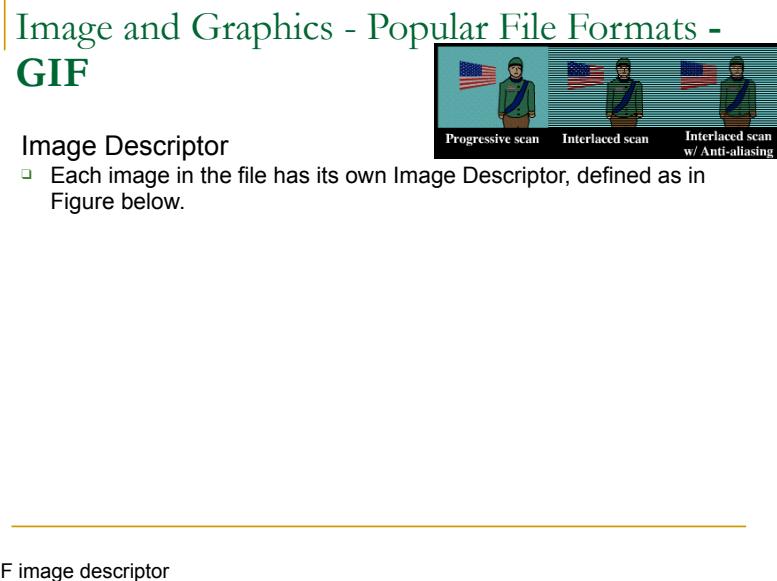
20-6



21-1

- **The Global Color Map**
 - It is optional but recommended for images where accurate color rendition is desired.
 - The existence of this color map is indicated in the 'M' field of byte 5 of the Screen Descriptor.
 - A color map can also be associated with each image in a GIF file.
- **In the individual Image Descriptors the 'M' flag will normally be zero.**
- **If the Global Color Map is present, its definition immediately follows the Screen Descriptor.**

20-7



21-2

Image and Graphics - Popular File Formats - GIF



▪ Image Descriptor

- Each image in the file has its own Image Descriptor, defined as in Figure below.

Bits	Byte #	
7 6 5 4 3 2 1 0		
0 0 1 0 1 1 0 0	1	Image separator character (comma)
	2	Start of image in pixels from the left side of the screen (LSB first)
	3	Start of image in pixels from the top of the screen (LSB first)
	4	Width of the image in pixels (LSB first)
	5	Height of the image in pixels (LSB first)
m i 0 0 0 pixel	6	Width of the image in pixels (LSB first)
	7	Height of the image in pixels (LSB first)
	8	Image formatted in Sequential order
	9	Image formatted in Interlaced order
	10	pixel + 1 # bits per pixel for this image

GIF image descriptor

21-3

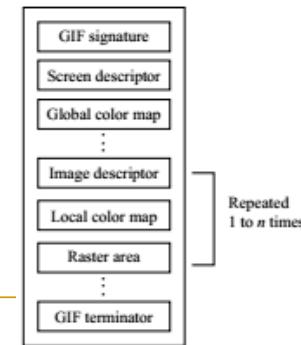
Image and Graphics - Popular File Formats - GIF

▪ Raster Area

22-2

Image and Graphics - Popular File Formats - GIF

▪ Raster Area



22-1

Image and Graphics - Popular File Formats - GIF

▪ Raster Area

- The format of the actual image is defined as the series of pixel color index values that make up the image.

22-3

Image and Graphics - Popular File Formats - GIF

▪ Raster Area

- The format of the actual image is defined as the series of pixel color index values that make up the image.
- The pixels are stored left to right sequentially for an image row.

22-4

Image and Graphics - Popular File Formats - GIF

▪ Raster Area

- The format of the actual image is defined as the series of pixel color index values that make up the image.
- The pixels are stored left to right sequentially for an image row.
- By default each image row is written sequentially, top to bottom.
- In the case that the Interlace or 'I' bit is set in byte 10 of the Image Descriptor then the row order of the image display follows a four-pass process in which the image is filled in by widely spaced rows.

22-6

Image and Graphics - Popular File Formats - GIF

▪ Raster Area

- The format of the actual image is defined as the series of pixel color index values that make up the image.
- The pixels are stored left to right sequentially for an image row.
- By default each image row is written sequentially, top to bottom.

22-5

Image and Graphics - Popular File Formats - GIF

▪ Raster Area

23-1

Image and Graphics - Popular File Formats - GIF

▪ Raster Area

- The first pass writes every 8th row, starting with the top row of the image window.

23-2

Image and Graphics - Popular File Formats - GIF

▪ Raster Area

- The first pass writes every 8th row, starting with the top row of the image window.
- The second pass writes every 8th row starting at the fifth row from the top.
- The third pass writes every 4th row starting at the third row from the top.

23-4

Image and Graphics - Popular File Formats - GIF

▪ Raster Area

- The first pass writes every 8th row, starting with the top row of the image window.
- The second pass writes every 8th row starting at the fifth row from the top.

23-3

Image and Graphics - Popular File Formats - GIF

▪ Raster Area

- The first pass writes every 8th row, starting with the top row of the image window.
- The second pass writes every 8th row starting at the fifth row from the top.
- The third pass writes every 4th row starting at the third row from the top.
- The fourth pass completes the image, writing every other row, starting at the second row from the top.

23-5

Image and Graphics - Popular File Formats - GIF

24-1

Image and Graphics - Popular File Formats - GIF

- GIF 4 - pass interlace display row order.

row	Pass 1	Pass 2	Pass 3	Pass 4	Result
0	*1a*				*1a*
1				*4a*	*4a*
2			*3a*		*3a*
3				*4b*	*4b*
4		*2a*			*2a*
5				*4c*	*4c*
6			*3b*		*3b*
7				*4d*	*4d*
8	*1b*				*1b*
9				*4e*	*4e*
10			*3c*		*3c*
11				*4f*	*4f*
12		*2b*			*2b*
:					

24-3

Image and Graphics - Popular File Formats - GIF

- GIF 4 - pass interlace display row order.

24-2

Interlaced vs Sequential GIF



Interlaced Image



Interlaced image vs Sequential Image

25

Interlaced vs Sequential GIF

- Progressively rendered GIF files, called interlaced GIFs, use a protocol that is simpler and somewhat more crude than that of PNG or JPEG files, but are almost universally viewable by applications capable of displaying GIF images.
- An interlaced GIF doesn't display its scanline linearly from top to bottom, but instead reorders it so the content of the GIF becomes clear even before it finishes loading.
- For example, the GIF viewer may display lines at the top of the image, then in the middle, then at the end, and will continue to fill in the blanks until the image is completely loaded.
- Many web browsers will use the lines that have been loaded to fill in the empty lines, making it appear as though the image is coming into focus.
- Interlaced GIFs are often larger than normal GIFs, though the difference is usually slight.

26

Interlaced vs Progressive

- The first three numbers refer to the number of lines on a sensor or screen.
- The second five numbers refer to number of frames per second a video-image is recorded or played back.
- The letters i and p, as the tutorial title hints at, stand for *interlaced* and *progressive*, the main ways video images are created.
- These three technologies—number of lines, number of frames per second, and the way the images are recorded and displayed—are big factors in determining the resolution and quality of your video image.

28

Interlaced vs Progressive

- You've likely seen numbers like
 - 1080p, 1080i, 720p and
 - 24p, 25p 30p, 60p and 60ion televisions and cameras, often on a shiny silver or gold decal.
You might know these numbers are vaguely about video quality, but the exact meanings of these numbers are understandably murky.

27

Interlaced vs Progressive

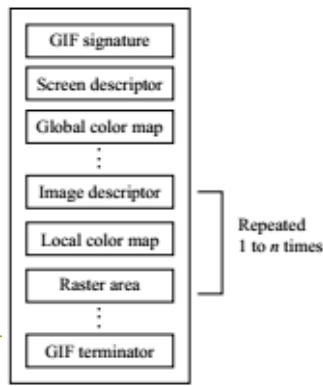
- These are the two choices (i or p) for recording and displaying video footage, each with their strengths and weaknesses.



Interlaced image with progressive display

29

Image and Graphics - Popular File Formats - GIF



30-1

Image and Graphics - Popular File Formats - GIF

- **GIF Terminator**
 - In order to provide a synchronization for the termination of a GIF image file, a GIF decoder will process the end of GIF mode when the character 0x3B hex or ';' is found after an image has been processed.
 - By convention the decoding software will pause and wait for an action indicating that the user is ready to continue.
 - This may be a carriage return entered at the keyboard or a mouse click.
 - For interactive applications this user action must be passed on to the host as a carriage return character so that the host application can continue.
 - The decoding software will then typically leave graphics mode and resume any previous process.

30-3

Image and Graphics - Popular File Formats - GIF

30-2

Image and Graphics - Popular File Formats - GIF



Example of 8-bit color image

31-1

Image and Graphics - Popular File Formats - GIF

- We can investigate how the file header works in practice by having a look at a particular GIF image. Below figure is an 8-bit color GIF image, in UNIX, issue the command:

Example of 8-bit color image



31-2

Image and Graphics - Popular File Formats - GIF

- We can investigate how the file header works in practice by having a look at a particular GIF image. Below figure is an 8-bit color GIF image, in UNIX, issue the command:

```
od -c forestfire.gif | head -2
```

and we see the first 32 bytes interpreted as characters:

Example of 8-bit color image



31-4

Image and Graphics - Popular File Formats - GIF

- We can investigate how the file header works in practice by having a look at a particular GIF image. Below figure is an 8-bit color GIF image, in UNIX, issue the command:
`od -c forestfire.gif | head -2`

Example of 8-bit color image



31-3

Image and Graphics - Popular File Formats - GIF

- We can investigate how the file header works in practice by having a look at a particular GIF image. Below figure is an 8-bit color GIF image, in UNIX, issue the command:

```
od -c forestfire.gif | head -2
```

and we see the first 32 bytes interpreted as characters:

```
G I F 8 7 a \208 \2 \188 \1 \247 \0 \0 \6 \3 \5 J \132 \24 | ) \7 \198 \195 \ \128 U  
\27 \196 \166 & T
```

Example of 8-bit color image



31-5

Image and Graphics - Popular File Formats - **GIF**

32-1

Image and Graphics - Popular File Formats - **GIF**

- To decipher the remainder of the file header (after "GIF87a"), we use hexadecimal:

```
od -x forestfire.gif | head -2
```

32-3

Image and Graphics - Popular File Formats - **GIF**

- To decipher the remainder of the file header (after "GIF87a"), we use hexadecimal:

32-2

Image and Graphics - Popular File Formats - **GIF**

- To decipher the remainder of the file header (after "GIF87a"), we use hexadecimal:

```
od -x forestfire.gif | head -2
```

with the result

32-4

Image and Graphics - Popular File Formats - GIF

- To decipher the remainder of the file header (after "GIF87a"), we use hexadecimal:

```
od -x forestfire.gif | head -2
```

with the result

```
4749 4638 3761 d002 bc01 f700 0006 0305 ae84 187c  
2907 c6c3 5c80 551b c4a6 2654
```

32-5

Image and Graphics - Popular File Formats - JPEG

34-1

Image and Graphics - Data Types & File Formats

- GIF
- JPEG
- PNG
- TIFF
- EXIF
- GAF
- PS
- PDF

33

Image and Graphics - Popular File Formats - JPEG

- JPEG:** The most important current standard for image compression.

34-2

Image and Graphics - Popular File Formats - JPEG

- **JPEG:** The most important current standard for image compression.
- The human vision system has some specific limitations and JPEG takes advantage of these to achieve high rates of compression.

34-3

Image and Graphics - Popular File Formats - JPEG



JPEG image with low quality specified by user.

Figure shows on **forestfire** image with a quality factor Q=10%.

35

Image and Graphics - Popular File Formats - JPEG

- **JPEG:** The most important current standard for image compression.
- The human vision system has some specific limitations and JPEG takes advantage of these to achieve high rates of compression.
- JPEG allows the user to set a desired level of quality, or compression ratio (input divided by output).

34-4

Image and Graphics - Popular File Formats - JPEG

36-1

Image and Graphics - Popular File Formats - JPEG

- As an example, Figure shows on **forestfire** (as in the last slide) image with a quality factor Q=10%.
 - The **quality factor (Q factor)** is a number that determines the degree of loss in the **compression process**.
 - This image is a mere 1.5% of the original size.
 - In comparison, a JPEG image with Q=75% yields an image size 5.6% of the original,
 - whereas a GIF version of this image compresses down to 23.0% of uncompressed image size.

36-2

Image and Graphics - Popular File Formats - PNG

38-1

Image and Graphics - Data Types & File Formats

- GIF
- JPEG
- PNG
- TIFF
- EXIF
- GAF
- PS
- PDF

37

Image and Graphics - Popular File Formats - PNG

- **PNG format:** standing for **Portable Network Graphics**

38-2

Image and Graphics - Popular File Formats - **PNG**

- **PNG format:** standing for **Portable Network Graphics**
- Meant to supersede the GIF standard, and extends it in important ways.

38-3

Image and Graphics - Data Types & File Formats

- GIF
- JPEG
- PNG
- TIFF
- EXIF
- GAF
- PS
- PDF

39

Image and Graphics - Popular File Formats - **PNG**

- **PNG format:** standing for **Portable Network Graphics**
- Meant to supersede the GIF standard, and extends it in important ways.
- Special features of PNG files include:
 1. Support for up to 48 bits of color information – a large increase.
 2. Files may contain
 1. **gamma-correction information** for correct display of color images,
 2. As well as **alpha-channel information** for such uses as control of transparency.
 3. The display progressively displays pixels in a 2-dimensional fashion by showing a few pixels at a time over seven passes through each 8×8 block of an image.

38-4

Image and Graphics - Popular File Formats - **TIFF**

40-1

Image and Graphics - Popular File Formats - TIFF

- Stands for **Tagged Image File Format**.

40-2

Image and Graphics - Data Types & File Formats

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41

Image and Graphics - Popular File Formats - TIFF

- Stands for **Tagged Image File Format**.
- The support for attachment of additional information (referred to as "tags") provides a great deal of flexibility.
 1. The most important tag is a format signifier: what type of compression etc. is in use in the stored image.
 2. TIFF can store many different types of image: 1-bit, grayscale, 8-bit color, 24-bit RGB, etc.
 3. TIFF was originally a lossless format but now a new JPEG tag allows one to opt for JPEG compression.
 4. The TIFF format was developed by the Aldus Corporation in the 1980's and was later supported by Microsoft.

40-3

Image and Graphics - Popular File Formats - EXIF

42-1

Image and Graphics - Popular File Formats - EXIF

- Exchange Image File

Cam W^o

42-2

Image and Graphics - Popular File Formats - EXIF

Image and Graphics - Popular File Formats - EXIF

- Exchange Image File
- It is an image format for digital cameras:
 1. Compressed EXIF files use the baseline JPEG format.
 2. A variety of tags (many more than in TIFF) are available to facilitate higher quality printing
 3. since information about the camera and picture-taking conditions (flash, exposure, light source, white balance, type of scene, etc.) can be stored and used by printers for possible color correction algorithms.

42-3

Image and Graphics - Popular File Formats - EXIF

- Exchange Image File
- 1. The EXIF standard also includes specification of file format for audio that accompanies digital images.
- 2. As well, it also supports tags for information needed for conversion to FlashPix
- 3. FlashPix is initially developed by Kodak.

43-1

43-2

Image and Graphics - Data Types & File Formats

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44

Image and Graphics - Popular File Formats – Graphics Animation Files

- A few dominant formats aimed at storing graphics animations (i.e., series of drawings or graphic illustrations) as opposed to video (i.e., series of images).

45-2

Image and Graphics - Popular File Formats – **Graphics Animation Files**

- A few dominant formats aimed at storing graphics animations (i.e., series of drawings or graphic illustrations) as opposed to video (i.e., series of images).
- **Difference:** animations are considerably less demanding of resources than video files.
 1. FLC is an animation or moving picture file format;
 2. It was originally created by Animation Pro.
 3. Another format, FLI, is similar to FLC.
 4. GL produces somewhat better quality moving pictures.
 5. GL animations can also usually handle larger file sizes.
 6. Many older formats: such as DL or Amiga IFF files, Apple Quicktime files, as well as animated GIF89 files.

45-3

Image and Graphics - Data Types & File Formats

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- PS
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46

Image and Graphics - Popular File Formats – PS

- **Postscript** is an important language for typesetting, and many high-end printers have a Postscript interpreter built into them.

47-2

Image and Graphics - Popular File Formats – PS

47-1

Image and Graphics - Popular File Formats – PS

- **Postscript** is an important language for typesetting, and many high-end printers have a Postscript interpreter built into them.
- **Postscript** is a vector-based picture language, rather than pixel-based

47-3

Image and Graphics - Popular File Formats – PS

- Postscript** is an important language for typesetting, and many high-end printers have a Postscript interpreter built into them.
- Postscript is a **vector-based** picture language, rather than **pixel-based**
 - The key difference between pixel and vector based graphics is how the image is structured.
 - Pixel based graphics are made up from lots of tiny **physical squares** (or 'pixels')
 - whereas vector graphics are mapped out using mathematical equations which calculate where the edges of the shapes sit in relation to one another.

47-4

Image and Graphics - Popular File Formats – PS

- As an example;
 - fonts are always created using vectors so that the colours can be changed efficiently and the symbol can be easily scaled up to any size without losing quality.
 - In contrast, digital photographs are always made up of pixels, which allows for a much more efficient blending of the colours as each physical pixel block can be coloured individually

48-2

Image and Graphics - Popular File Formats – PS

48-1

Image and Graphics - Popular File Formats – PS

- As an example;
 - fonts are always created using vectors so that the colours can be changed efficiently and the symbol can be easily scaled up to any size without losing quality.
 - In contrast, digital photographs are always made up of pixels, which allows for a much more efficient blending of the colours as each physical pixel block can be coloured individually
- Page element definitions are essentially in terms of vectors.
 1. Postscript includes text as well as vector/structured graphics.
 2. GL bit-mapped images can be included in output files.
 3. Encapsulated Postscript files add some additional information for inclusion of Postscript files in another document.
 4. Postscript page description language itself does not provide compression; in fact, Postscript files are just stored as ASCII

48-3

Image and Graphics - Data Types & File Formats

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49

Image and Graphics – Color Scheme and Model

- Binary Image
 - 1-bit Image
- Gray Image
 - 8-bit Image
- Color Image
 - 24-bit Image
 - 8-bit Image



51

Image and Graphics - Popular File Formats –PDF

- Another text + figures language has begun to supersede (or at least parallel) Postscript
- Adobe Systems Inc. includes LZW compression in its Portable Document Format (**PDF**) file format.
 - PDF files that do not include images have about the same compression ratio, 2:1 or 3:1, as do files compressed with other LZW-based compression tools.

50

Image and Graphics – 1 bit Images



Monochrome 1-bit Lena image.

52-1

Image and Graphics – 1 bit Images

- Each pixel is stored as a single bit (0 or 1), so also referred to as **binary image**.



Monochrome 1-bit Lena image.

52-2

Image and Graphics – 1 bit Images

- Each pixel is stored as a single bit (0 or 1), so also referred to as **binary image**.
- Such an image is also called a 1-bit **monochrome** image since it contains no color.
- This figure shows a 1-bit monochrome image called "Lena" by multimedia scientists



Monochrome 1-bit Lena image.

52-4

Image and Graphics – 1 bit Images

- Each pixel is stored as a single bit (0 or 1), so also referred to as **binary image**.
- Such an image is also called a 1-bit **monochrome** image since it contains no color.



Monochrome 1-bit Lena image.

52-3

Image and Graphics – Color Scheme and Model

- Binary Image**
 - 1-bit Image
- Gray Image**
 - 8-bit Image
- Color Image**
 - 24-bit Image
 - 8-bit Image

53

Image and Graphics – 8-bit Gray-level Images

54-1

Image and Graphics – 8-bit Gray-level Images

- Each pixel has a gray-value between 0 and 255.
- Each pixel is represented by a single byte; e.g., a dark pixel might have a value of 10, and a bright one might be 230.
 - **Bitmap:** The two-dimensional array of pixel values that represents the graphics/image data.
 - **Image resolution** refers to the number of pixels in a digital image (higher resolution always yields better quality).
 - Fairly high resolution for such an image might be $1,600 \times 1,200$, whereas lower resolution might be 640×480 .

Image and Graphics – 8-bit Gray-level Images

- Each pixel has a gray-value between 0 and 255.

54-2

Image and Graphics – 8-bit Gray-level Images



54-3

55

Image and Graphics – 8-bit Gray-level Images

56-1

Image and Graphics – 8-bit Gray-level Images

- 8-bit image can be thought of as a set of 1-bit **bit-planes**,
 - where each plane consists of a 1-bit representation of the image at higher and higher levels of "elevation":
 - a bit is turned on if the image pixel has a nonzero value that is at or above that bit level.
- **Frame buffer:** Hardware used to store bitmap.
 - **Video card** (actually a *graphics card*) is used for this purpose.
 - The resolution of the video card does not have to match the desired resolution of the image
 - but if not enough video card memory is available then the data has to be shifted around in RAM for display.

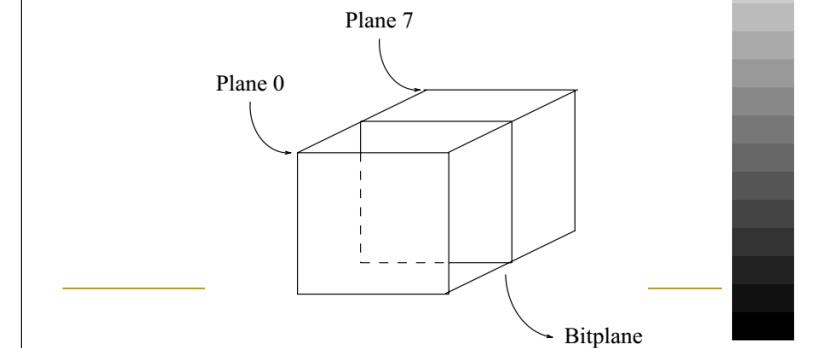
Image and Graphics – 8-bit Gray-level Images

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 - where each plane consists of a 1-bit representation of the image at higher and higher levels of "elevation":
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56-2

Image and Graphics – 8-bit Gray-level Images

- Below figure displays the concept of bit-planes graphically.
- Bit-planes for 8-bit grayscale image



56-3

57

Multimedia Presentation

58-1

Multimedia Presentation

- Each pixel is usually stored as a byte (a value between 0 to 255)
- So a 640×480 grayscale image requires 300 kB of storage ($640 \times 480 = 307,200$).

58-3

Multimedia Presentation

- Each pixel is usually stored as a byte (a value between 0 to 255)

58-2

Multimedia Presentation

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- So a 640×480 grayscale image requires 300 kB of storage ($640 \times 480 = 307,200$).
- Next figure shows the same Lena image again, but this time in grayscale.

58-4

Multimedia Presentation

- Each pixel is usually stored as a byte (a value between 0 to 255)
- So a 640×480 grayscale image requires 300 kB of storage ($640 \times 480 = 307,200$).
- Next figure shows the same Lena image again, but this time in grayscale.
- When an image is printed, the basic strategy of **dithering** is used
 - which trades intensity resolution for spatial resolution to provide ability to print multi-level images on 2-level (1-bit) printers.

58-5

Image and Graphics – Color Scheme and Model

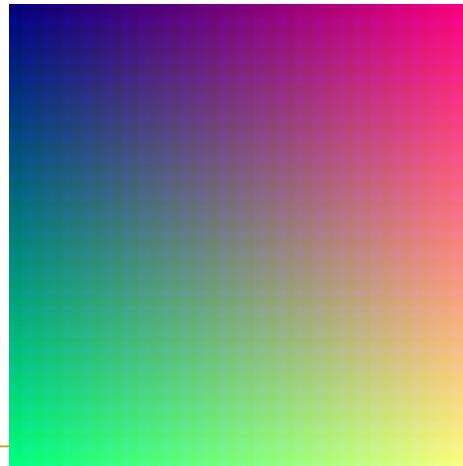
- **Binary Image**
 - 1-bit Image
- **Gray Image**
 - 8-bit Image
- **Color Image**
 - 24-bit Image
 - 8-bit Image

60

Grayscale image of Lena



59



61

Image and Graphics – Color Images

- The most common data types for graphics and image file formats
 - 24-bit color
 - 8-bit color
- Some formats are restricted to particular hardware/operating system platforms, while others are “cross-platform” formats.
- Even if some formats are not cross-platform, there are conversion applications that will recognize and translate formats from one system to another.

62

Image and Graphics – 24-bit Color Images

- In a color 24-bit image, each pixel is represented by three bytes, usually representing RGB.
 - This format supports $256 \times 256 \times 256$ possible combined colors, or a total of 16,777,216 possible colors.
 - However such flexibility does result in a storage penalty:
 - A 640×480 24-bit color image would require 921.6 kB of storage without any compression.

64

Image and Graphics – Color Images

- Most image formats incorporate some variation of a **compression** technique due to the large storage size of image files.
 - Compression techniques can be classified into either
 - **Lossless**
 - **Lossy**

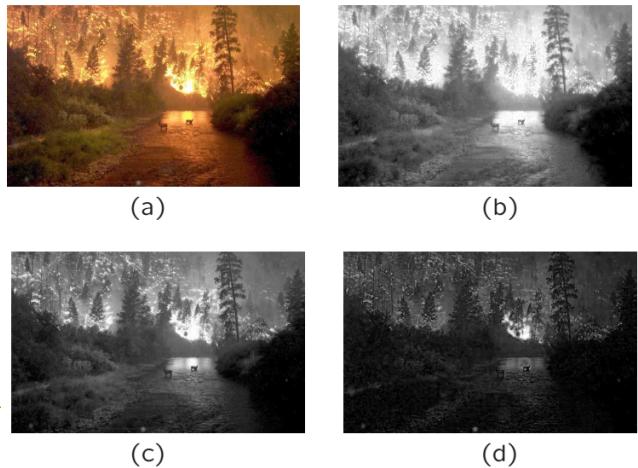
63

Image and Graphics – 24-bit Color Images

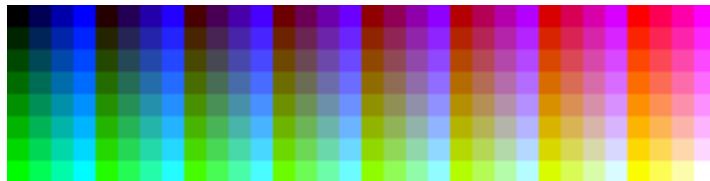
- An important point: many 24-bit color images are actually stored as 32-bit images, with the extra byte of data for each pixel used to store an *alpha* value representing special effect information (e.g., transparency).
- Next figure shows the image **forestfire.bmp.**, a 24-bit image in Microsoft Windows BMP format.
- Also shown are the grayscale images for just the Red, Green, and Blue channels, for this image.

65

High-resolution color and separate R, G, B color channel images. (a): Example of 24-bit color image "forestfire.bmp". (b, c, d): R, G, and B color channels for this image



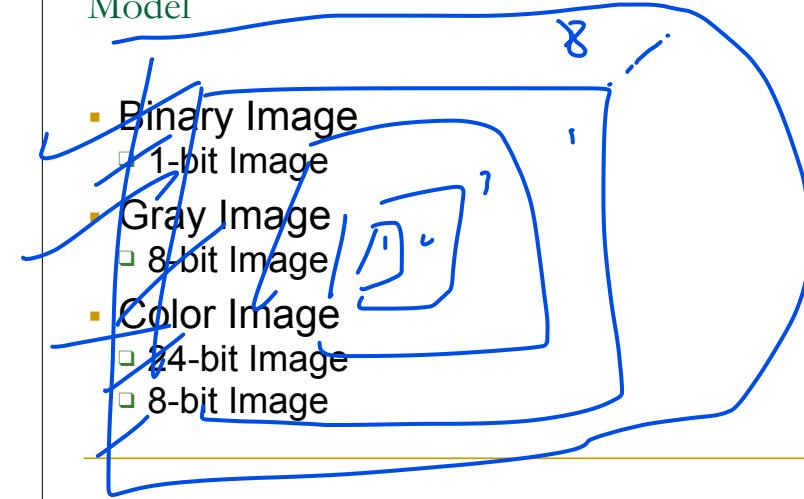
66



68

Image and Graphics – Color Scheme and Model

- **Binary Image**
 - 1-bit Image
- **Gray Image**
 - 8-bit Image
- **Color Image**
 - 24-bit Image
 - 8-bit Image



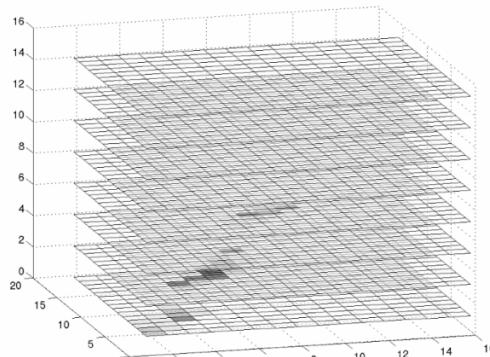
67

Image and Graphics – 8-bit Color Images

- Many systems can make use of 8 bits of color information (the so-called "256 colors") in producing a screen image.
- Such image files use the concept of a **lookup table** to store color information.
 - Basically, the image stores not color, but instead just a set of bytes, each of which is actually an index into a table with 3-byte values that specify the color for a pixel with that lookup table index.
- Next figure shows a 3D histogram of the RGB values of the pixels in "forestfire.bmp".
- And then, 8-bit image in GIF format of the "forestfire.bmp".

69

3-dimensional histogram of RGB colors in "forestfire.bmp"



70

COLOR LOOK-UP TABLE
(LUTS)

72

Example of 8-bit color image.

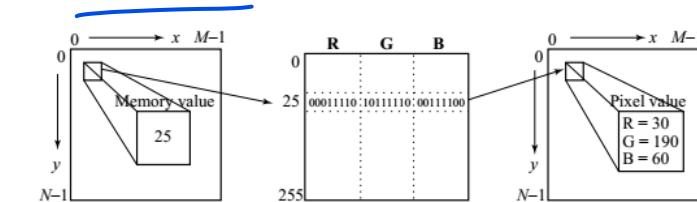
- Note the great savings in space for 8-bit images, over 24-bit ones: a 640×480 8-bit color image only requires 300 kB of storage, compared to 921.6 kB for a color image (again, without any compression applied).



71

Color look-up Table (LUTs)

- The idea used in 8-bit color images is to store only the index, or code value, for each pixel. Then, e.g., if a pixel stores the value 25, the meaning is to go to row 25 in a color look-up table (LUT).

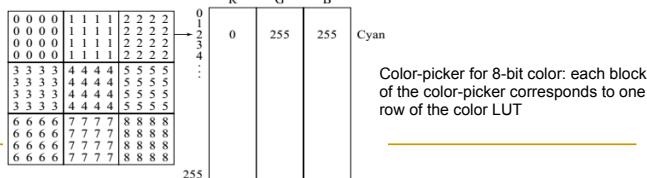


Color LUT for 8-bit color images.

73

Color look-up Table (LUTs)

- A **Color-picker** consists of an array of fairly large blocks of color (or a semi-continuous range of colors) such that a mouse-click will select the color indicated.
 - In reality, a color-picker displays the palette colors associated with index values from 0 to 255.
 - Below figure displays the concept of a color-picker: if the user selects the color block with index value 2, then the color meant is cyan, with RGB values (0; 255; 255).



74

Color look-up Table (LUTs)

How to devise a color look-up table

- The most straightforward way to make 8-bit look-up color out of 24-bit color would be to divide the RGB cube into equal slices in each dimension.
 - (a) The centers of each of the resulting cubes would serve as the entries in the color LUT, while simply scaling the RGB ranges 0..255 into the appropriate ranges would generate the 8-bit codes.
 - (b) Since humans are more sensitive to R and G than to B, we could shrink the R range and G range 0..255 into the 3-bit range 0..7 and shrink the B range down to the 2-bit range 0..3, thus making up a total of 8 bits.
 - (c) To shrink R and G, we could simply divide the R or G byte value by $(256/8)=32$ and then truncate. Then each pixel in the image gets replaced by its 8-bit index and the color LUT serves to generate 24-bit color.

76

Color look-up Table (LUTs)

- A very simple animation process is possible via simply changing the color table: this is called **color cycling** or **palette animation**.
- Figure (a) shows a 24-bit color image of "Lena", and Figure (b) shows the same image reduced to only 5 bits via dithering. A detail of the left eye is shown in Figure (c).



Figure (a): 24-bit color image "lena.bmp". (b): Version with color dithering. (c): Detail of dithered version.

75

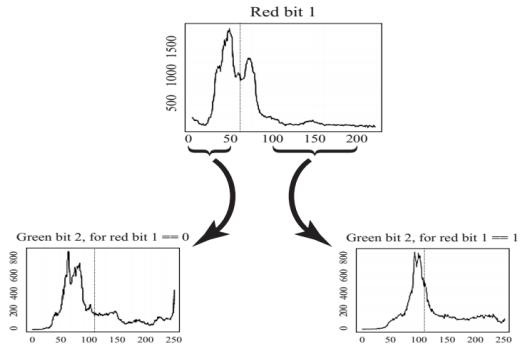
Color look-up Table (LUTs)

Median-cut algorithm:

- A simple alternate solution that does a better job for this color reduction problem.
 - (a) The idea is to sort the R byte values and find their median; then values smaller than the median are labelled with a "0" bit and values larger than the median are labelled with a "1" bit.
 - (b) This type of scheme will indeed concentrate bits where they most need to differentiate between high populations of close colors.
 - (c) One can most easily visualize finding the median by using a histogram showing counts at position 0..255.
 - (d) Fig. 3.11 shows a histogram of the R byte values for the forestfire.bmp image along with the median of these values, shown as a vertical line.

77

Color look-up Table (LUTs)



Histogram of R bytes for the 24-bit color image "forestfire.bmp" results in a "0" bit or "1" bit label for every pixel. For the second bit of the color table index being built, we take R values less than the R median and label just those pixels as "0" or "1" according as their G value is less than or greater than the median of the G value, just for the "0" Red bit pixels. Continuing over R, G, B for 8 bits gives a color LUT 8-bit index

78

IMAGE AND GRAPHICS - DITHERING

80

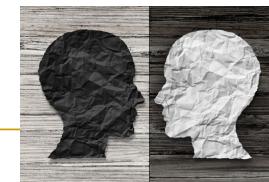
LUT Video Example

- <https://www.youtube.com/watch?v=XgL1Z7tsBz8>

79

Image and Graphics - Dithering

- Full-color photographs may contain an almost infinite range of color values.
- **Dithering** is the most common means of reducing the color range of images down to the 256 (or fewer) colors seen in 8-bit GIF images.
- **Dithering** is the process of **juxtaposing** pixels of two colors to create the illusion that a third color is present.
- **Juxtaposition** (or side by side, or parallel) is an act or instance of placing two elements close together or side by side.



81

Image and Graphics - Dithering

- Dithering is used to calculate patterns of dots such that values from 0 to 255 correspond to patterns that are more and more filled at darker pixel values, for printing on a 1-bit printer.
- The main strategy is to replace a pixel value by a larger pattern, say 2×2 or 4×4 , such that the number of printed dots approximates the varying-sized disks of ink used in analog, in halftone printing (e.g., for newspaper photos).

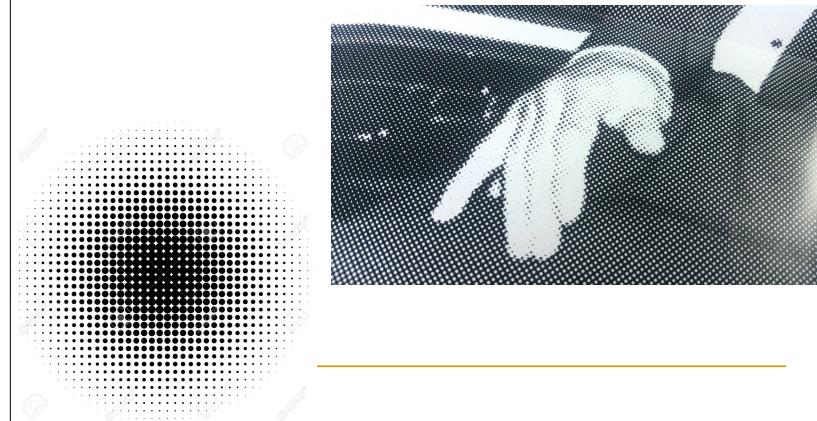
82

Image and Graphics – Halftone printing

- Half-tone printing is an analog process that uses smaller or larger filled circles of black ink to represent shading, for newspaper printing.
- For example, if we use a 2×2 dither matrix
 - we can first re-map image values in 0..255 into the new range 0..4 by (integer) dividing by 256/5. Then, e.g., if the pixel value is 0 we print nothing, in a 2×2 area of printer output. But if the pixel value is 4 we print all four dots.
- The rule is:
 - If the intensity is > the dither matrix entry then print an on dot at that entry location: replace each pixel by an $n \times n$ matrix of dots.

84

Image and Graphics – Halftone printing



83

Image and Graphics - Dithering

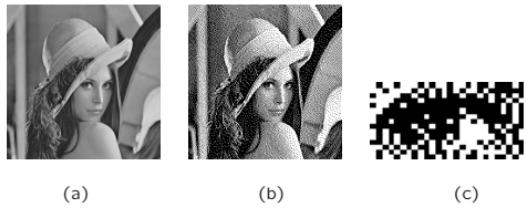
- Note that the image size may be much larger, for a dithered image, since replacing each pixel by a 4×4 array of dots, makes an image 16 times as large.
- A clever trick can get around this problem. Suppose we wish to use a larger, 4×4 dither matrix, such as

$$\begin{pmatrix} 0 & 8 & 2 & 10 \\ 12 & 4 & 14 & 6 \\ 3 & 11 & 1 & 9 \\ 15 & 7 & 13 & 5 \end{pmatrix}$$

85

Image and Graphics - Dithering

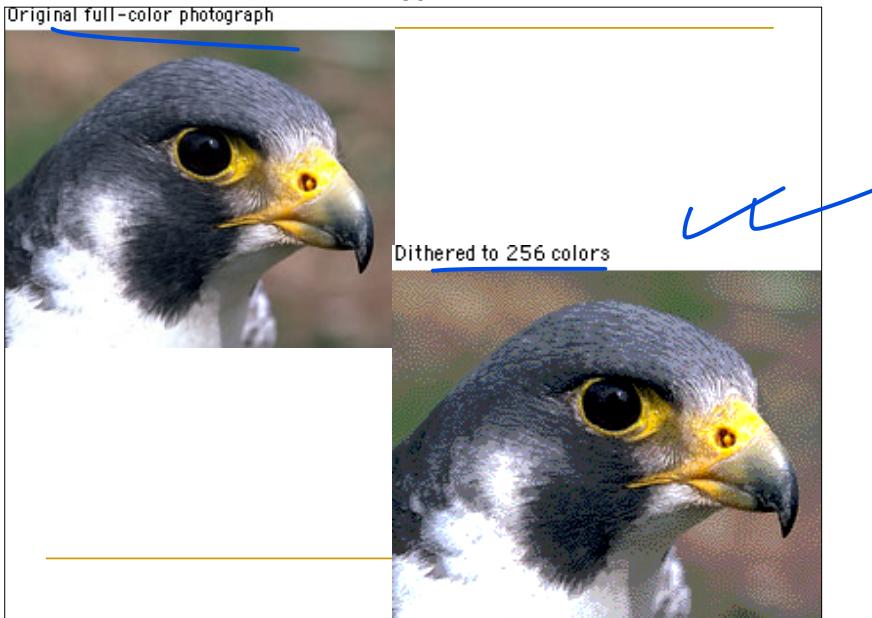
- An **ordered dither** consists of turning on the printer output bit for a pixel if the intensity level is greater than the particular matrix element just at that pixel position.
- Figure (a) shows a grayscale image of "Lena". The ordered dither version is shown as Figure (b), with a detail of Lena's right eye in Figure (c).



Dithering of grayscale images.

(a): 8-bit grey image lenagray.bmp". (b): Dithered version of the image. (c): Detail of dithered version

86



88

Image and Graphics - Dithering

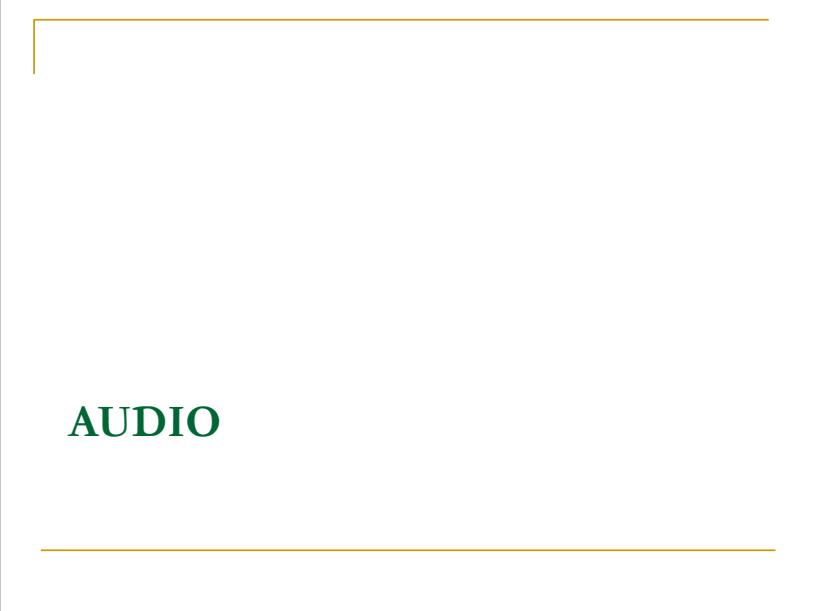
- An algorithm for ordered dither, with $n \times n$ dither matrix, is as follows:

```
BEGIN
    for  $x = 0$  to  $x_{max}$           // columns
        for  $y = 0$  to  $y_{max}$       // rows
             $i = x \text{ mod } n$ 
             $j = y \text{ mod } n$ 
            //  $I(x, y)$  is the input,  $O(x, y)$  is the output,
            //  $D$  is the dither matrix.
            if  $I(x, y) > D(i, j)$ 
                 $O(x, y) = 1;$ 
            else
                 $O(x, y) = 0;$ 
    END
```

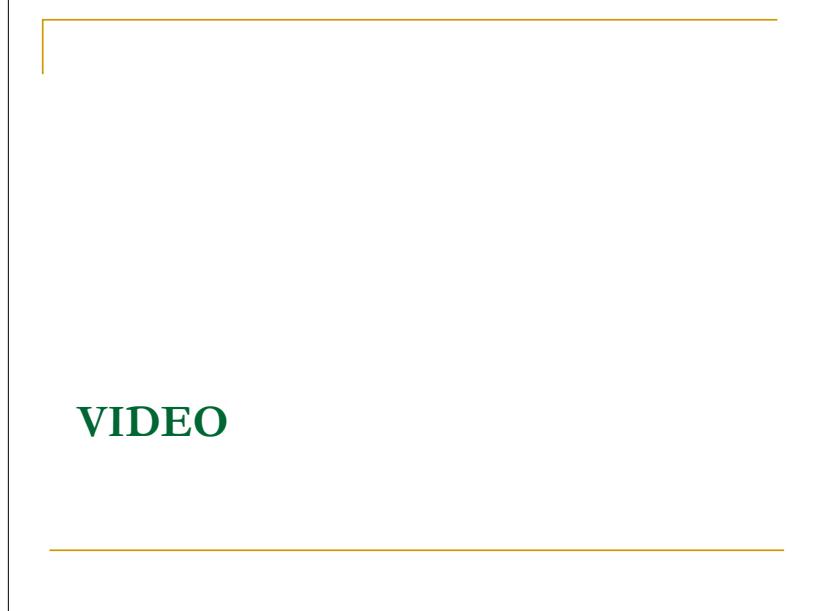
87



89



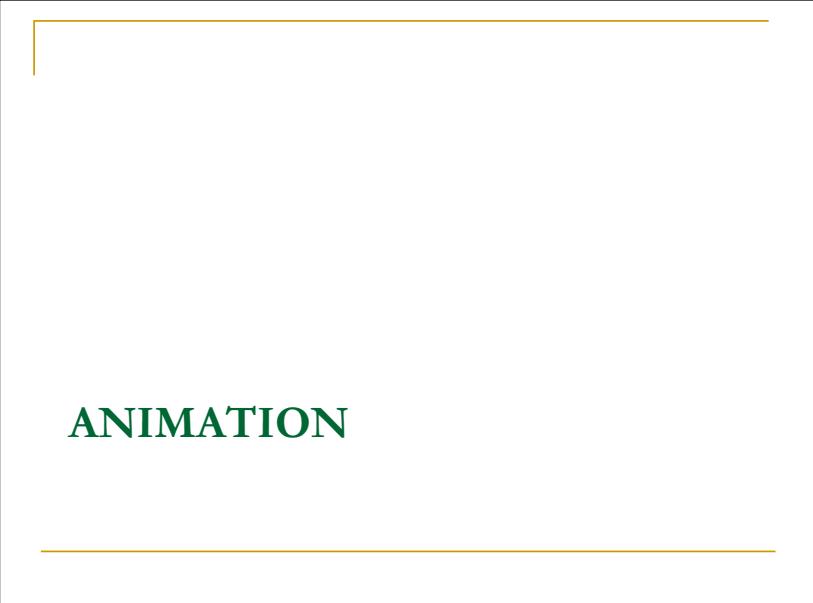
AUDIO



VIDEO

90

91



ANIMATION

92