CS1102
Lecture 8
Digital Media: Image and Video

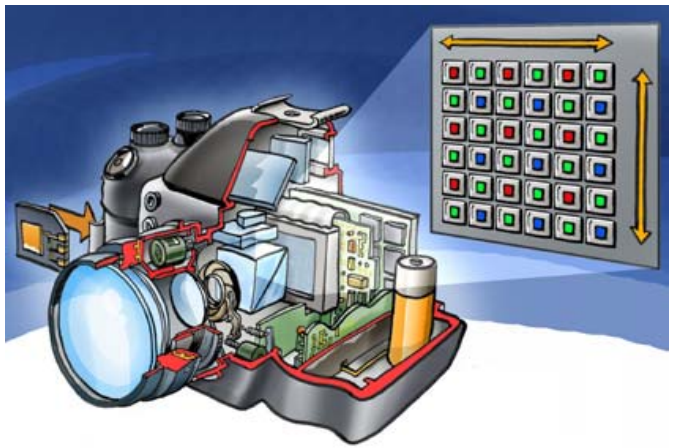
Semester B, 2021-2022
Department of Computer Science
City University of Hong Kong

Digital Image Capture

- Nowadays it is quite easy for you to take a picture with your camera or smart phone. The resulting picture is captured and stored as a **digital image**

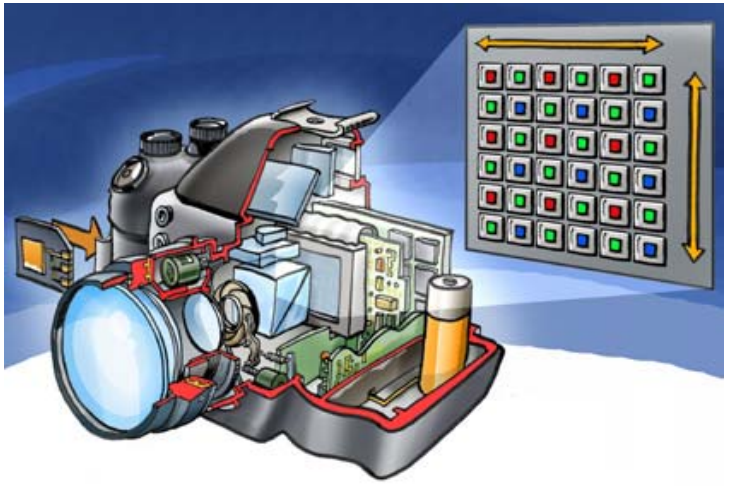
Digital Image vs Analog World

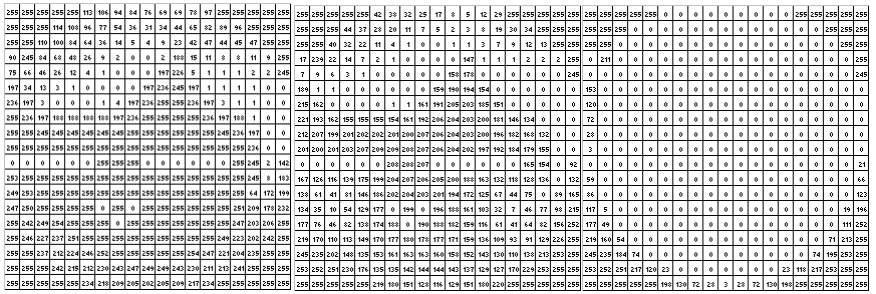
- Although a digital image appears continuous, it is a **discrete** signal instead. This means that a digital image is represented as a finite set of numbers
- The **analog-to-digital conversion** from the visual information in the analog world to the digital image is done by the image sensors which record the charges according to the brightness of the light that fall on them



Digital Image

- The **color filters** present in the image sensors help gathering the color information of the image scene
- The resulting digital image can thus be represented by the red, green, blue components

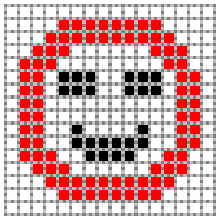


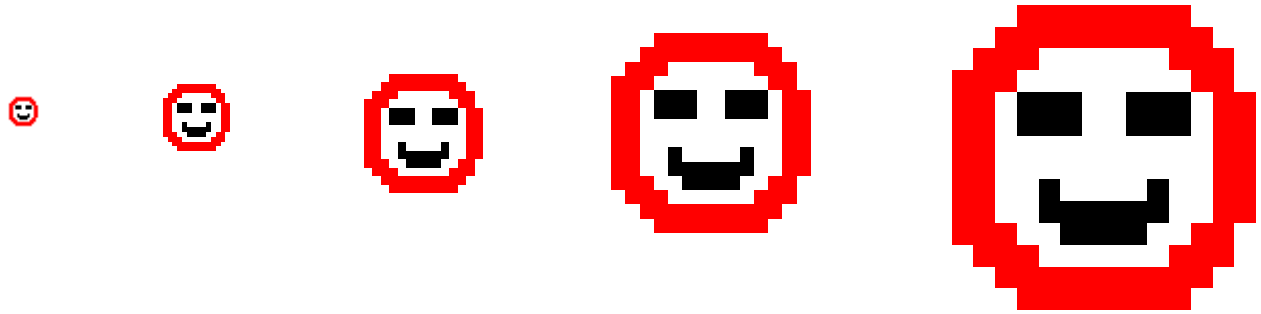


Red Green Blue

Bitmap Image

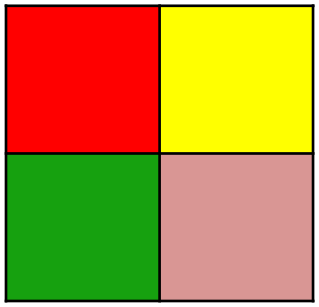
- A **bitmap image** is digitized/sampled by a grid of dots, where each dot is called a **pixel** (picture element)
  - Each pixel is assigned a color value
  - Bitmaps do not scale well; resizing bitmap image will reduce quality

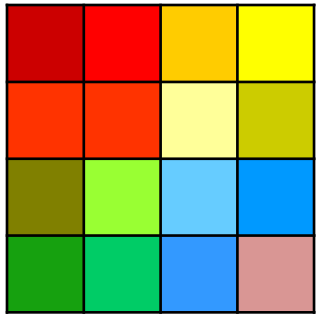


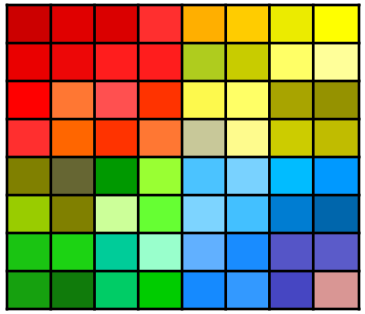


Resolution

- **Resolution** is the number of horizontal and vertical pixels
- With a higher resolution, more pixels can be used to represent the same visual scene. In other words, we are taking more samples of the light thus the image quality is better.







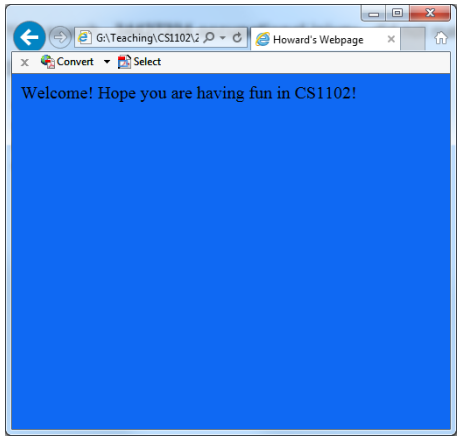
Color Depth

- **Color depth** is the number of bits used to represent color intensity
  - Determines the number of colors available for use
- **True color**
  - 24-bit is used to represent the color of each pixel, 8 bits for red, 8 bits for green, 8 bits for blue
  - Colors used in webpages are based on RGB, often written in hexadecimal values

e.g., `<body bgcolor = "#0F69F3">`

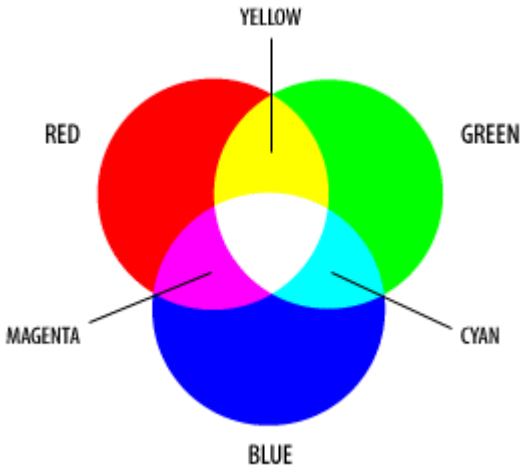
Red = $0F_{16}$, Green = 69_{16}, Blue = $F3_{16}$

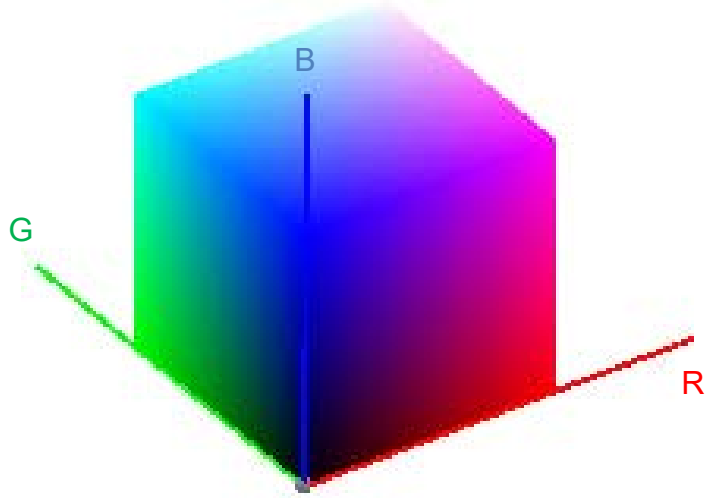
The blue component has larger value (F3) compared with red (0F) and green (69) thus the resulting color looks more blue



RGB Color Model

- Different colors can be obtained when different values of R, G, B are specified
  - E.g., R = 100, G = 100, B = 0 will result in a yellow color
    R = 255, G = 255, B = 0 will result in a brighter yellow color
    R = 255, G = 255, B = 255 will result in a white color
    R = 0, G = 0, B = 0 will result in a black color

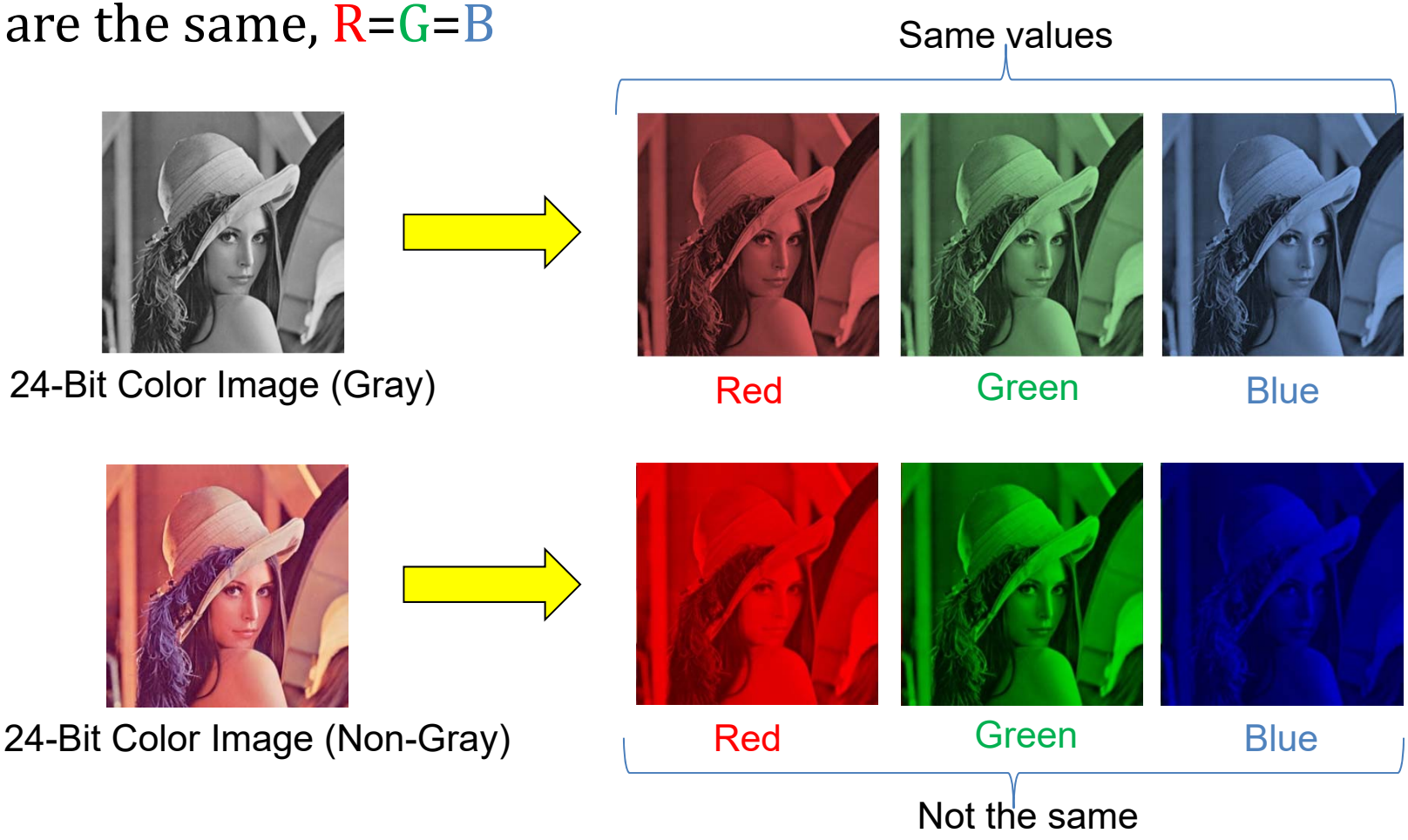




RGB Color Cube

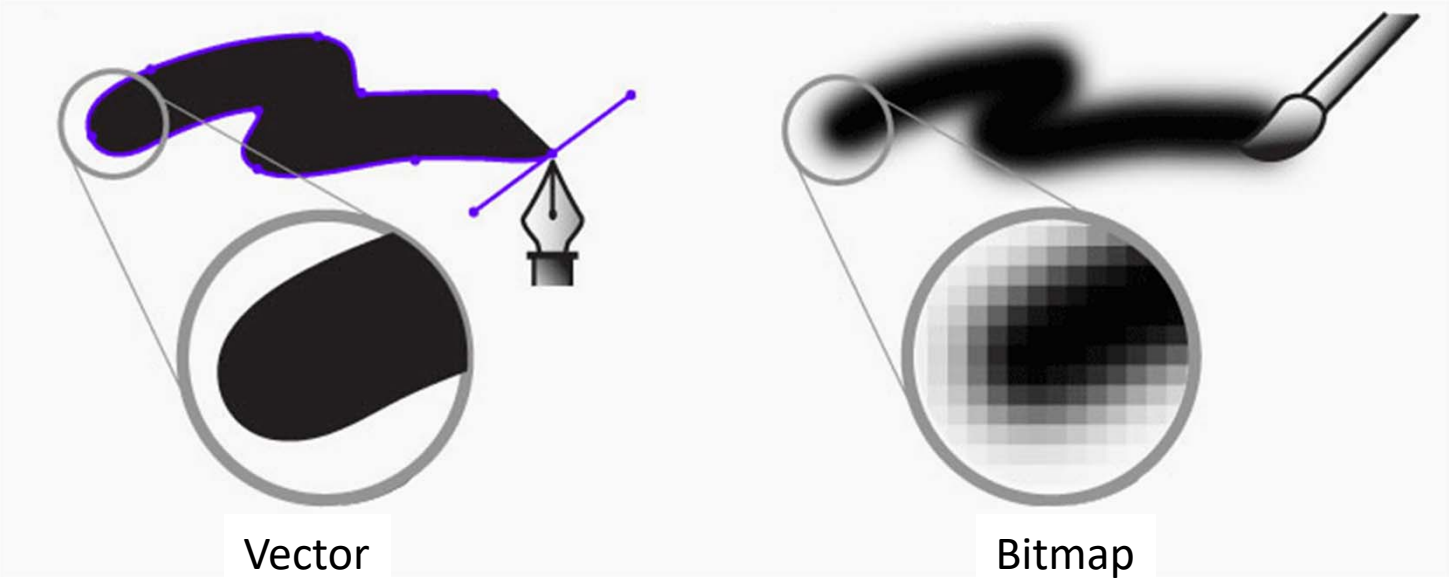
Gray Color

- The gray color is obtained when the red, green, blue values are the same, R=G=B



Vector Graphics

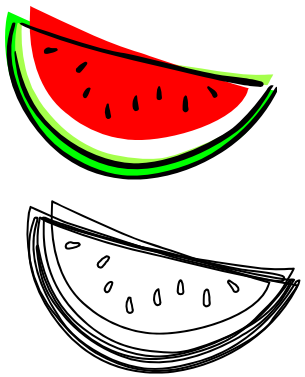
- Instead of storing the pixel color values, a **vector graphic** file contains the instructions for the computer to create the shape, size, position, and color for each object in an image
  - An object may be point, line, or other geometric objects



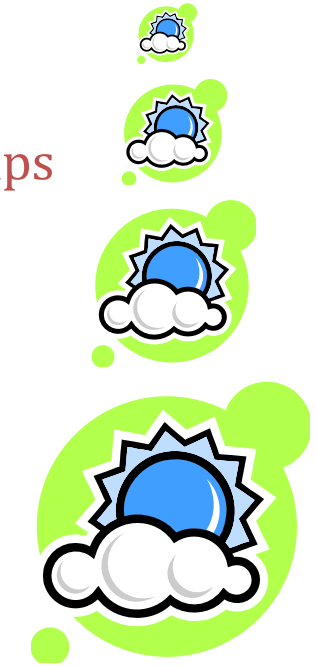
Vector Graphics

- Compared to bitmap images
  - Vector graphics resize better; the objects change proportionally and maintain their smooth edges
  - Vector graphics could require less storage space
  - It is easier to edit an object in a vector graphic
  - BUT, vector graphics usually are not as realistic as bitmaps

Bitmap



Vector



Resize better
in vector graphics

Image Manipulation Example 1

- The **brightness** of an image can be increased/decreased by adding/subtracting a constant to/from the RGB values

Original Image

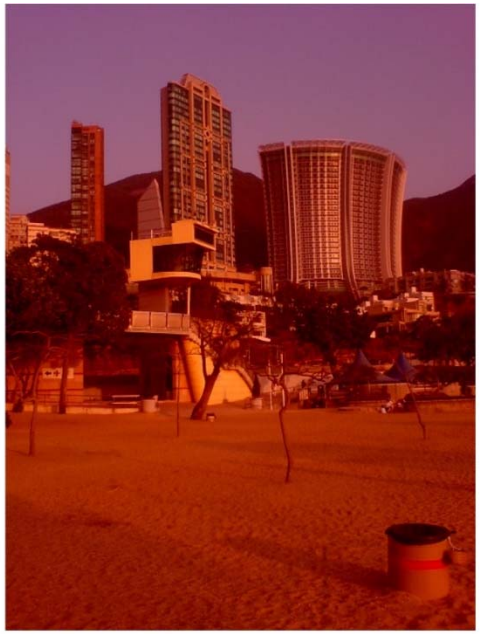


Image with
decreased brightness

Image Manipulation Example 2

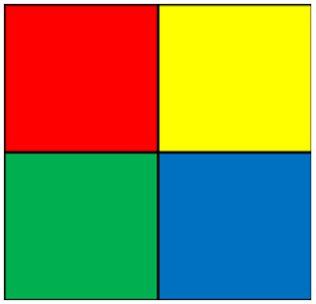
- The **negative image** can be obtained by subtracting the RGB values from a constant
  - e.g., R_{new}=255-R_{old}, G_{new}=255-G_{old}, B_{new}=255-B_{old}

Original Image

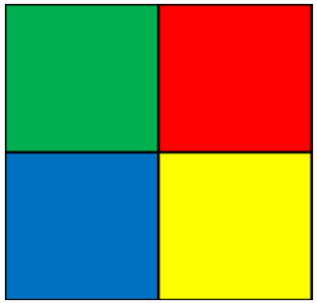
Negative Image

Image Manipulation Example 3

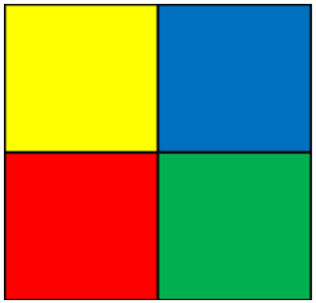
- **Rotating** an image can be achieved by rearranging the positions of the pixels accordingly



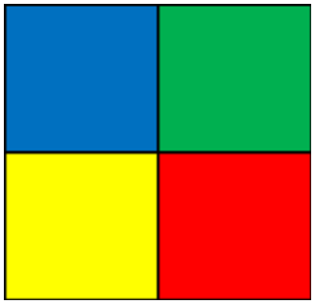
Original



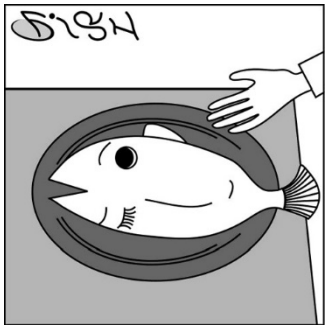
90° clockwise rotation

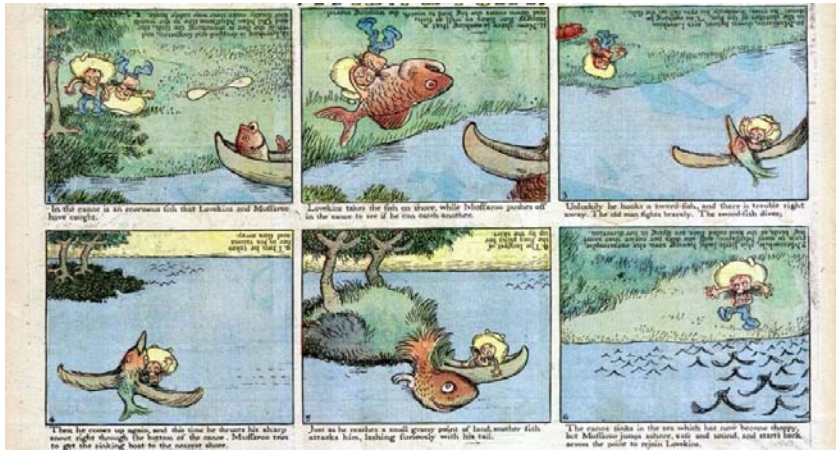


90° counter-clockwise rotation



180° rotation

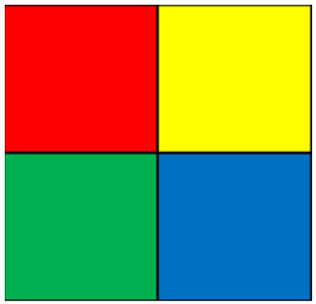




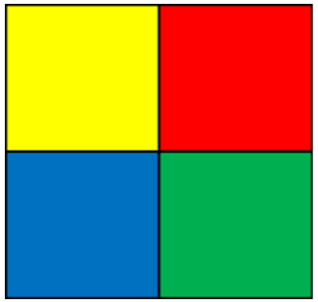
Upside-down comic strips of Gustave Verbeek

Image Manipulation Example 4

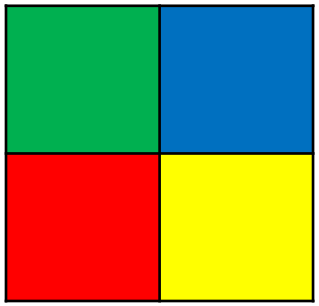
- The image can be **flipped horizontally/vertically** by reversing the rows/columns of the pixels



Original



Horizontal Flipping



Vertical Flipping

Original Image

Image After Horizontal Flipping (View from the rear mirror for the car in front)

Simultaneous Contrast

- Our perception is sensitive to luminance contrast rather than the absolute luminance values

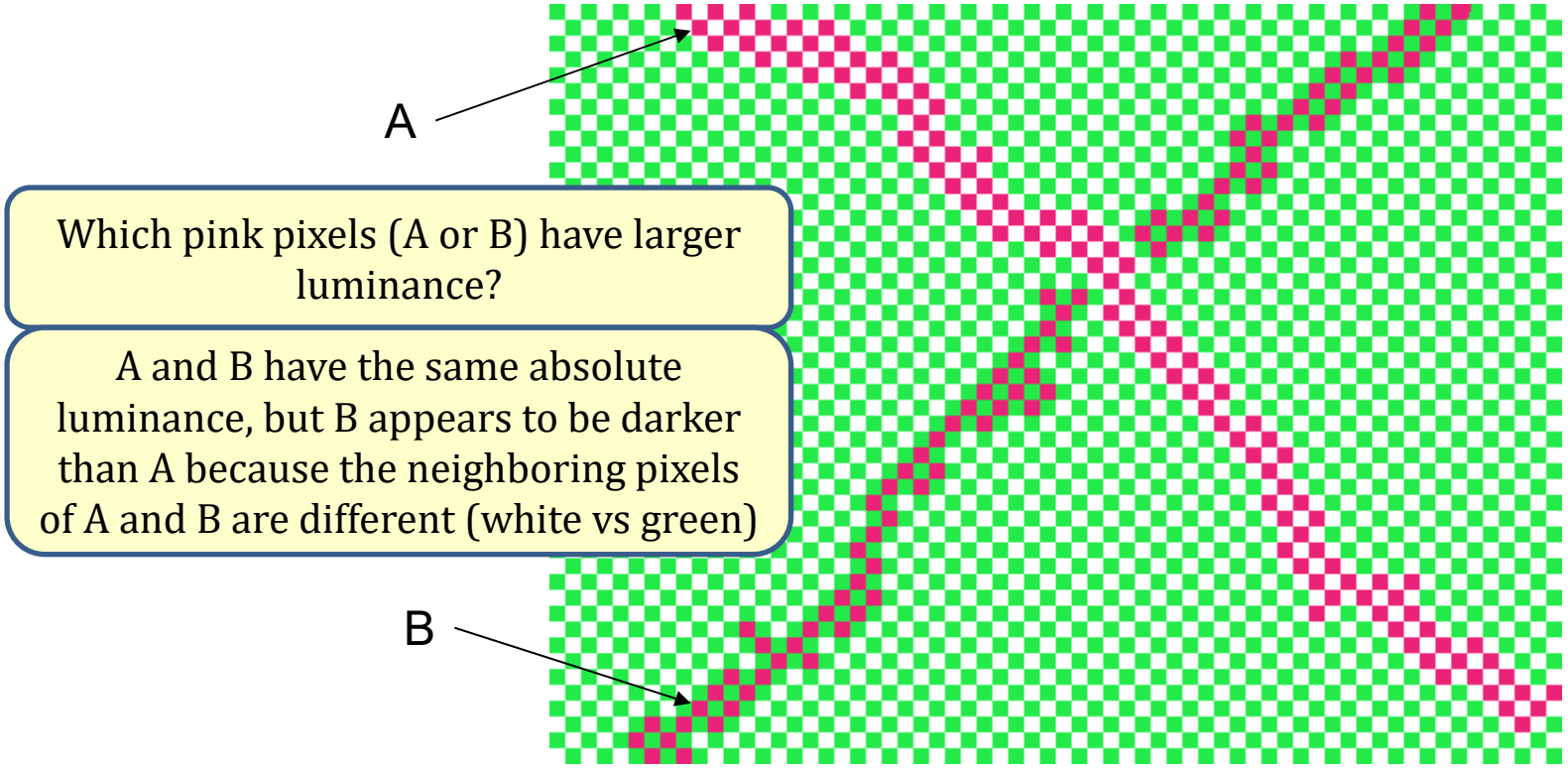


Image Compression

- How many bytes N are required to store a 24-bit bitmap image (e.g., in BMP) with resolution 1024×1024 pixels?

  N = 1024 × 1024 × 24 bits × 1 byte/8 bits = 3, 145, 728 bytes = 3MB

  Thus we need to compress images to reduce their file sizes

- Some people say that method X is better than method Y in compression because it generates a smaller file size. Is this a valid claim?

Original BMP
(365KB)

Method X
(1.65KB)

The file size is very small but can you tell who this person is?

Method Y
(29.6KB)

Need to consider the image quality in addition to the file size! We can say that method X is better than method Y if it generates a smaller file size given the same image quality

JPEG Basics

- JPEG compression is **lossy** (as opposed to lossless compression like zip), meaning that the compressed-then-decompressed image is not exactly the same as the original image
- Psychophysical experiments were used to determine what information can be lost during compression without too much effect on human perception

JPG image size: 292KB

1024×768 pixels

1024×768 pixels

JPG image size: 224KB

Which image can be compressed more (resulting in a smaller file size) with good image quality such that no artifact can be perceived by humans?

Graphics File Format

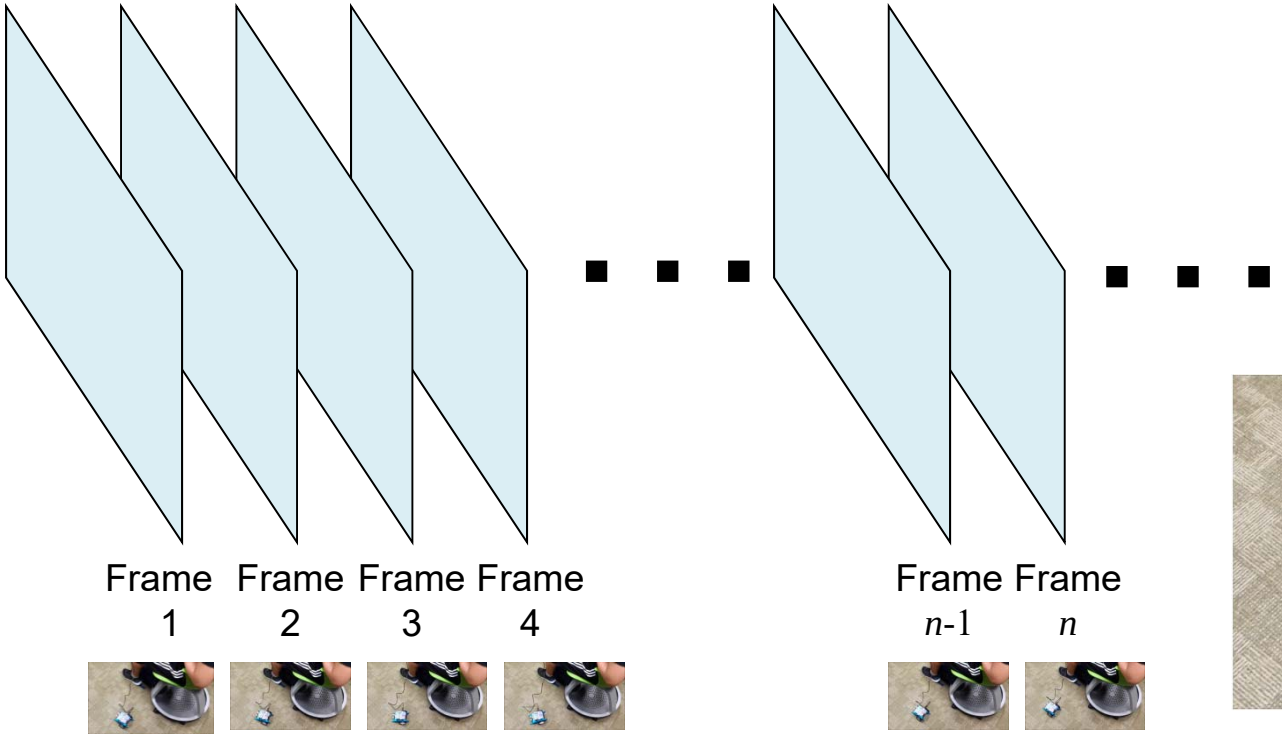
File Format	Image Type	Description
BMP	**bitmap** format	A graphics format native to Microsoft Windows. BMP is widely used on PCs for icons, buttons and other controls. The BMP file format supports up to 24-bit depth color.
TIFF (baseline)	**Lossless** compressed **bitmap**	TIFF is bitmap format defined in 1986 by Microsoft and Aldus (now part of Adobe) and widely used on both Macs and PCs for high-resolution scanned images and digital photos for desktop publishing
JPEG or JPG	**Lossy** compressed **bitmap** format	JPEG is bitmap format popularly used on the Web. It can compress TrueColor bitmap images with various compression ratio
GIF	**Lossless** compressed **bitmap**	GIF is also a bitmap format popularly used on the Web. Unlike .jpg, GIF images can only contain 256 or fewer colors. GIF format also supports transparency and animation.
PNG	**Lossless** compressed **bitmap**	PNG is a format designed to improve the GIF format, supporting 24-bit depth color and transparency. Unlike JPEG, PNG compressed bitmap data without losing any data.
WMF (Windows MetaFile)	**Vector** graphic format	The native vector graphics file format in Windows. They can also hold bitmaps and text. WMF files are made up of actual Windows drawing commands which results in an efficient format that renders illustrations very quickly.
SVG (Scalable Vector Graphics)	**Vector** graphic format	A vector graphics format from the W3C for the Web that is expressed in XML. Introduced in 2001, SVG was designed to become the standard vector format just as GIFs and JPEGs have become the standard bitmaps for the Web.

Video Applications

- TV broadcasting industry: interactivity, search and retrieval, video-on-demand, HDTV
- Videoconferencing and videophones
- Intelligent highway traffic control systems
- Medical imaging
- Surveillance
- Flight simulation

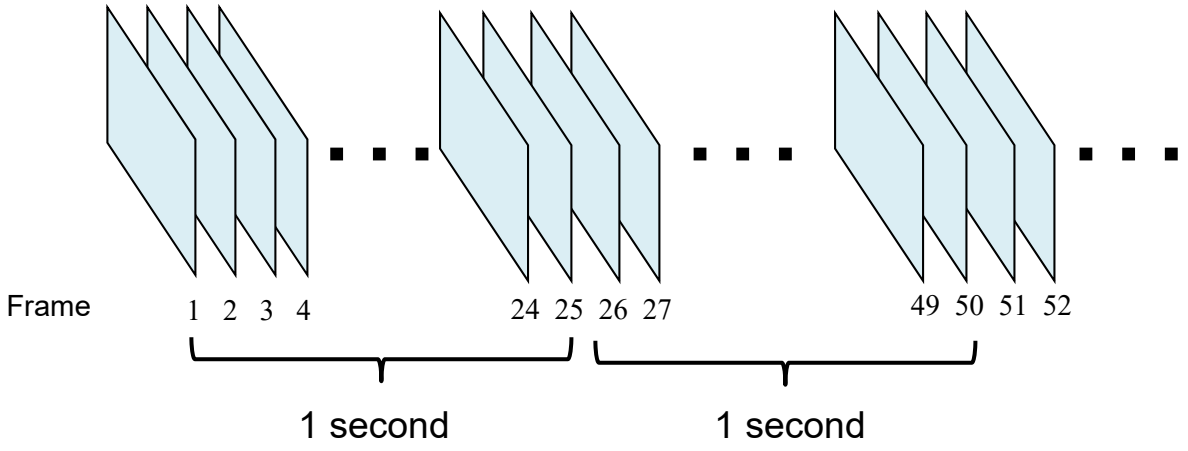
Digital Video

- A **digital video** consists of a temporal sequence of frames
  - Each frame is like an image so it is a discrete signal
  - The frames are updated in fixed time intervals



Frame Rate

- The **frame rate** is the number of frames that are displayed in 1 second
  - The video appears continuous if the frame rate is high enough



This video has a frame rate of 25 frames per second, or 25 fps

29.97 fps

10 fps

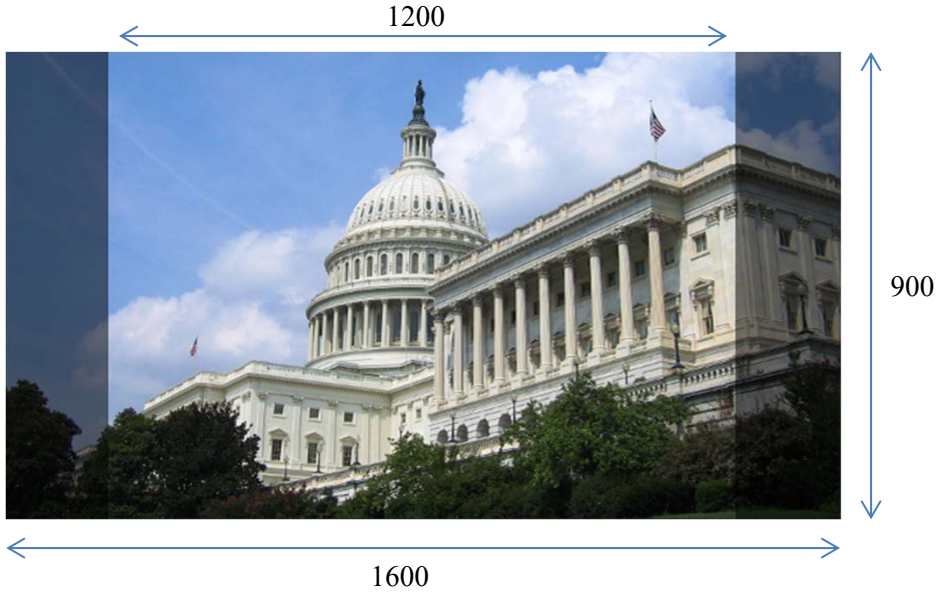
5 fps

Aspect Ratio

- The radio of the width to the height of a frame, expressed as width:height
  - Example 1: if the frame resolution is 1200×900, then

    aspect ratio = 1200:900 = 4:3
  - Example 2: if the frame resolution is 1600×900, then

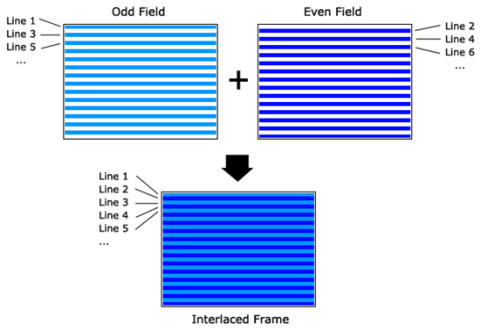
    aspect ratio = 1600:900 = 16:9



Progressive vs Interlaced Scanning

- **Progressive scanning** means that when a frame is refreshed, all the pixels are updated
- **Interlaced scanning** means that when a frame is refreshed, only half of the pixels are updated
  - The pixels on all odd-numbered lines are updated at one frame
  - The pixels on all even-numbered lines are updated at another frame
- Comparison
  - Progressive scanning results in better quality especially for scene with objects moving in high speed
  - Interlaced scanning requires less bandwidth (half) for transmitting the video signal

Video Format	Resolution
1080i, 1080p	1920×1080

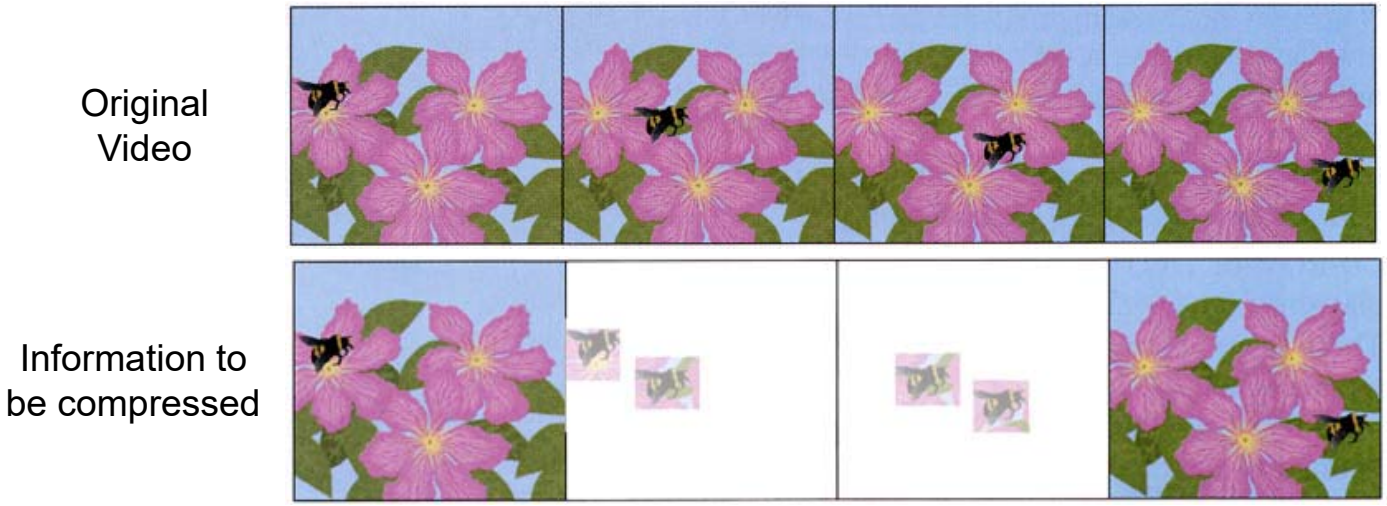



INTERLACED SCANNING


PROGRESSIVE SCANNING

Video Compression

- **Video compression** is similar to repeating image compression on each frame
- Additionally, video compression software (**video codec**) can also make use of the similarities between frames to reduce the amount of information to be encoded



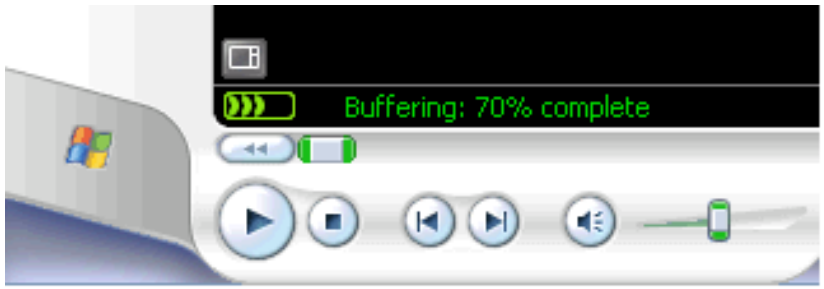
The 1st frame is compressed as an image

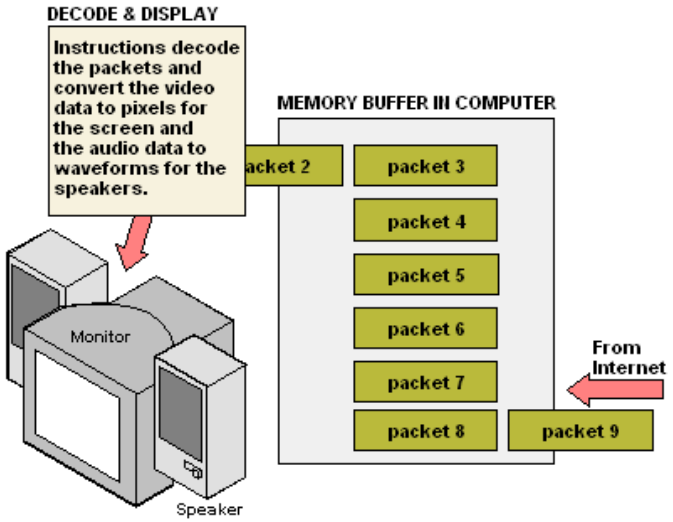
Subsequent frames can be compressed by computing the difference and only encoding the changes

After a while, the frame can be compressed as an image again to avoid too much accumulated errors from previous frames

Streaming Video

- **Streaming** is the transfer of video data in a continuous stream over the Web that allows the user to play it before the entire file is transferred
- The client side stores a few seconds of video in the memory buffer before it starts sending it to the screen and speakers. Throughout the session, it continues to receive video data ahead of time from the server.





Video File Format

Video Format	File Extension	Platform	Description
AVI (Audio Video Interleave)	.avi	PC	A common container format for storing digital clips from video cameras; used for desktop video on PC platform
QuickTime Movie	.mov	PC, Mac, Unix, Linux	One of the most popular formats for desktop and streaming Web videos, requiring Apples Quicktime Movie Player
MPEG (Moving Pictures Experts Group)	.mpg / .mpeg .mp4 / .m4v (MPEG4)	PC, Mac, Unix, Linux	Versions include MPEG1, MPEG2, and MPEG4; used for desktop video, PDA video, and streaming Web video
RealMedia	.rm	PC, Mac, Unix, Linux	Produced by RealNetworks company, a popular format for streaming Web videos
WMV (Windows Media Video)	.wmv	PC	Offers different compression options for high-quality videos; used for desktop video, PDA video, and streaming Web video
VOB (Video Object)	.vob	Standalone DVD player, PC, Mac, Linux	Industry-standard format for standalone DVD players
Flash Video	.flv	PC. Mac	Popular for Web-based video; requires Adobe Flash Player

Lesson Summary

- A digital image captures the scene as discrete signal by representing the color information as red, green, blue components
- A bitmap image consists of pixels and resolution is the number of pixels. A color image with color depth of 24-bit represents each pixel as R,G,B colors.
- Different colors can be obtained by specifying different combinations of red, green, blue values.
- A vector graphic file contains the instructions for the computer to create points, lines or other geometric objects and can be resized without much change in quality
- Both factors, file size and quality, should be considered in comparing image compression methods
- A digital video is a temporal sequence of images
- Progressive scanning updates all pixels in a frame while interlaced scanning only updates half the pixels in a frame at a time
- Image and video compressions are often lossy and are required because the raw image/video requires a large file size to store and large bandwidth to transmit
- Streaming can be used to start watching a video while it is still downloading

Reference

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- http://www.ted.photographer.org.uk/photoscience_digital.htm

[3] Wikipedia - RGB Color Model
- https://en.wikipedia.org/wiki/RGB_color_model

[4] Wikipedia - Vector Graphics
- https://en.wikipedia.org/wiki/Vector_graphics

[5] Wikipedia - Contrast Effect
- https://en.wikipedia.org/wiki/Contrast_effect

[6] JPEG Official Website
- http://jpeg.org

Reference (cont.)

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- https://techdifferences.com/difference-between-interlaced-and-progressive-scan.html

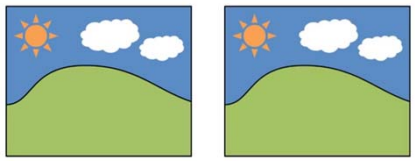
[8] MPEG Official Website

- http://mpeg.chiariglione.org/

[9] Streaming Media

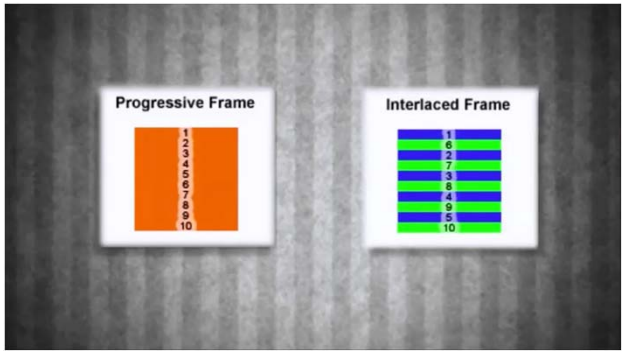
- http://www.explainthatstuff.com/streamingmedia.html

Video

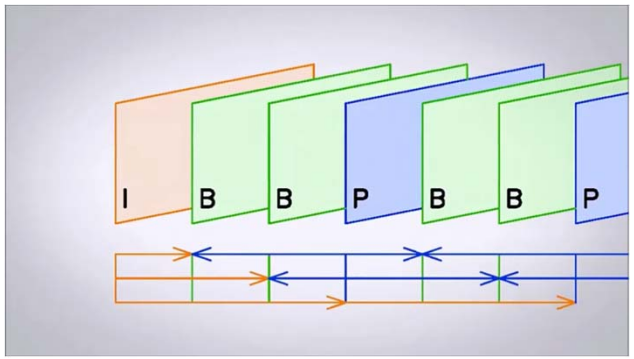


How JPEG Works? – 2:40
https://www.youtube.com/watch?v=9gPHZEXoMKc

How to Choose an Image File Format? – 6:02
https://www.youtube.com/watch?v=17oZ0pg1xLA



Interlaced and Progressive Frame Rates Explained! : FRIDAY 101 – 5:33
https://www.youtube.com/watch?v=xKMWjRllvrY



Video Compression as Fast As Possible – 4:58
https://www.youtube.com/watch?v=qbGQBT2Vwvc

Inattentional Blindness

- Do you think you see the world as they are?
- The invisible gorilla, Christopher Chabris and Daniel Simons

  http://www.theinvisiblegorilla.com/videos.html