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Multimedia

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Few words about me...



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Recommended Reading / Watching

- Prezentare curs, Exemple seminar:
 - <https://github.com/liviucotfas/ase-multimedia>
 - <http://online.ase.ro>

Further Reading / Watching

- Cursuri Microsoft Virtual Academy - mva.microsoft.com
 - Free
- Cursuri PluralSight - www.pluralsight.com
 - Free trial
 - Free access (limited period) through Microsoft DreamSpark

Definiție, Caracteristici, Concepte

Definiție

- **Multimedia** este din punct de vedere informatic :
 - orice combinație de **text, imagine, video, sunet și animație**
 - accesibilă utilizatorului prin intermediul sistemului de calcul.
- **Dezvoltarea multimedia** a devenit posibilă ca urmare a Revoluției Digitale, prin intermediul :
 - conversiei analog-digital;
 - compresiei datelor.

Factori declanșatori

- **Revoluția digitală** reprezintă schimbarea de la tehnologia mecanică și electronică analogică la electronica digitală care a început la sfârșitul anilor 1950 până la sfârșitul anilor 1970, odată cu adoptarea și proliferarea computerelor digitale și păstrarea înregistrărilor în format digital.

Conversia analog - digital

- Resursele utilizate trebuie convertite în format digital pentru:
 - stocare
 - Procesare
 - includere în aplicații
- Resursele sunt convertite în format analog la redare

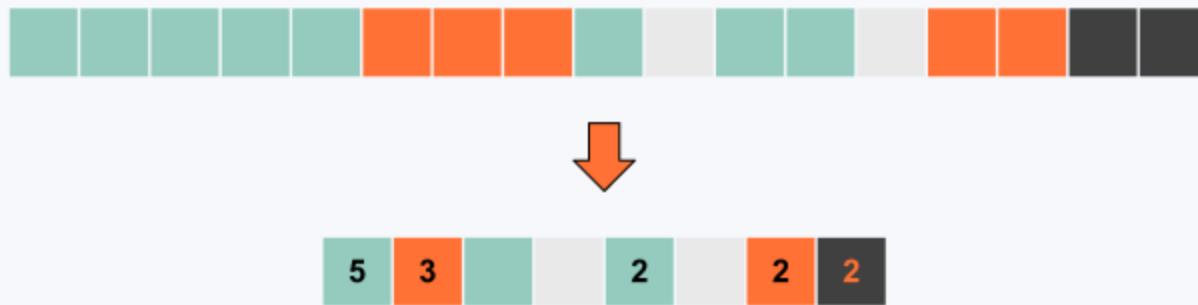
Compresia

- Există două categorii majore de algoritmi de compresie :
 - Compresie lossless (fără pierderi)
 - Compresie lossy (cu pierderi)
- Algoritmii de compresie utilizați în multimedia sunt de obicei **asimetrici** – timpul de compresie este mai mare decât timpul de decompresie.

Compresia lossless

- utilizează o codificare mai eficientă pentru a reduce dimensiunea fișierului, păstrând în același timp toate datele originale. Când fișierul este decompresionat, acesta va fi identic cu originalul.
- Run Length Encoding - RLE
 - una dintre strategiile mai simple pentru a realiza compresia lossless
 - poate fi folosit pentru a comprima fișiere de imagine bitmap(ex: format *pcx). Imaginele bitmap pot deveni cu ușurință foarte mari, deoarece fiecare pixel este reprezentat cu o serie de biți care oferă informații despre culoarea sa. RLE generează un cod pentru a „semnaliza” începutul unei linii de pixeli de aceeași culoare. Informațiile despre culoare sunt apoi înregistrate o singură dată pentru fiecare pixel. De fapt, RLE spune computerului să repete o culoare pentru un anumit număr de pixeli adjacenți, mai degrabă decât să repete aceleași informații pentru fiecare pixel de mai multe ori. Fișierul comprimat RLE va fi mai mic, dar va păstra toate datele originale ale imaginii – este "lossless".

Run Length Encoding - RLE



Compresia Lossy

- numărul de biți din fișierul original este redus și unele date se pierd. Compresia Lossy nu este o opțiune pentru fișierele constând din text și numere, aşa-numitele informații *alphanumerice*. În cazul acestora pierderea unei singure litere sau număr ar putea modifica cu ușurință semnificația datelor
- este adesea posibil să se mențină imagini sau sunete de înaltă calitate cu mai puține date decât era prezent inițial (util în special pentru multimedia)
- exploatează limitele perceptiei umane

Compresia Lossy

- Example:
 - JPEG – imagini;
 - MPEG – sunet și video.
- compresie MP3:
 - analizează fișierul audio și elimină date care nu sunt critice pentru o redare de înaltă calitate;
 - elimină frecvențele care nu pot fi percepute de auzul uman. De asemenea, poate evalua două sunete care rulează în același timp și poate elimina sunetul mai puțin perceptibil. Aceste tipuri de date pot fi eliminate fără impact semnificativ asupra calității;
 - poate reduce cu un factor de 10 cantitatea de date necesară pentru a reprezenta înregistrările audio digitale, la o calitate similară cu cea a sunetului original necomprimat pentru majoritatea ascultătorilor.

Aplicații Multimedia

- Caracteristici:
- componentele sunt accesibile prin intermediu unui sistem de calcul;
- datele utilizate sunt în format digital (NU analogic);
- elementele sistemului sunt integrate într-o interfață unitară;
- grad ridicat de interacțiune cu utilizatorul.

Abordări pentru construirea de aplicații multimedia

- **Multimedia authoring – high-level**
 - includ componente preprogramate ce permit recunoașterea mai multor formate de resurse multimedia, instrumente pentru generarea animațiilor, pentru implementarea conceptelor de hypertext, hypermedia;
 - accentul cade pe scenariul de derulare a aplicației și pe sincronizarea resurselor;
 - bazat pe concepte precum axa timpului / carte / diagrame de flux;
 - Exemple: Flash, PowerPoint.
- **Multimedia programming – low-level**
 - accentul se pune pe procesarea directă a resurselor prin intermediul unui limbaj de programare precum C, C# sau Java și a unor biblioteci specializate.

Classification of multimedia applications

- Mai multe criterii de clasificare bazate pe :
 - domeniu: economie, educație, publicitate, medicină, industrie, divertisment, sisteme de navigație și informații, comunicări;
 - interactivitate: interactiv, static;
 - localizarea componentelor: local, la distanță (video-streaming, distant learning).

Precondiții hardware / software

Precondiții hardware

- Echipamente hardware pentru achiziție / procesare:
 - Imagine;
 - Sunet;
 - Video.

Dispozitive periferice - Imagine

- Scanner
 - transformă informația luminoasă în informație electrică, iar ulterior aceasta este convertită și salvată sub formă digitală.
 - tipuri: flatbed / rotativ
 - operație: o lumină trece peste text sau imagine, iar lumina se reflectă înapoi pe un senzor **CCD** (charge-coupled device). Un senzor CCD este un dispozitiv electronic care captează semnauul analogic. Semnalul analogic este apoi convertit într-un semnal digital de către un alt dispozitiv numit **ADC** (analog-to-digital converter) și transferat prin intermediul unei interfețe (în general USB) către RAM.
 - Recunoașterea optică a caracterelor (OCR) este procesul de conversie a textului tipărit într-un fișier digital care poate fi editat într-un procesor de text.

Dispozitive periferice - Imagine

- scanner

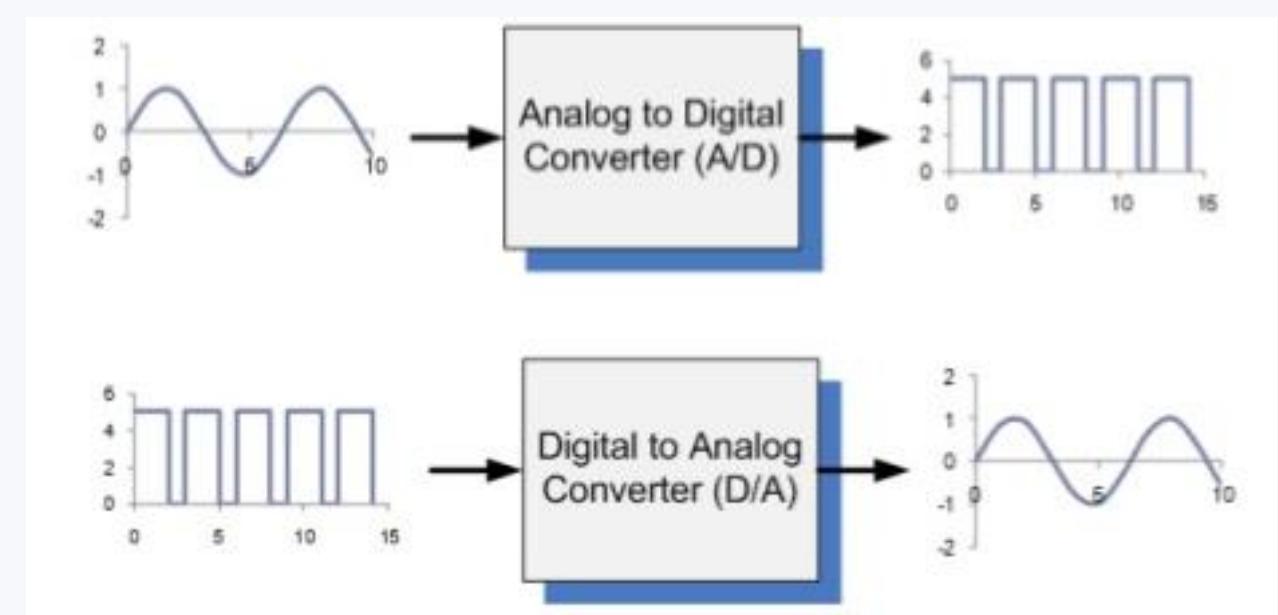
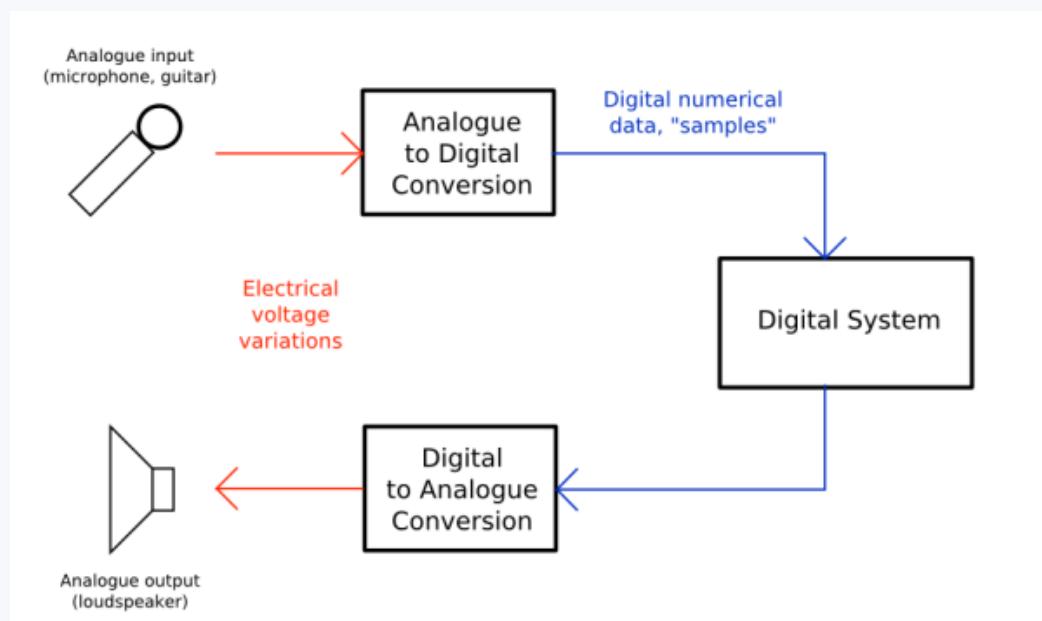


Dispozitive periferice - Imagine

- Camere foto
 - Când declanșatorul camerei este deschis pentru a captura o imagine, lumina trece prin obiectivul camerei. Imaginea este focalizată pe un CCD, care generează un semnal analogic.
 - Semnalul analogic este convertit în formă digitală de un ADC și apoi trimis la un procesor de semnal digital (DSP) chip care ajustează calitatea imaginii și o stochează în memoria încorporată a camerei sau pe un card de memorie.

Dispozitive periferice - Sunet

- Placă de suzentă
- convertește semnalul analogic de la microfon la o reprezentare digitală;
- convertește reprezentarea digitală într-o reprezentare analogică care poate fi redată de difuzoare.



Dispozitive periferice - Video

- Placă video
- Cameră video digitală

Precondiții software

- **Drive** - program de computer care operează sau controlează un anumit tip de dispozitiv care este atașat la un computer. Un driver oferă o interfață software pentru dispozitivele hardware, permitând sistemelor de operare și alte programe de computer să acceseze funcțiile hardware fără a fi nevoie să știe detalii precise despre hardware-ul utilizat.
- **Extensii ale sistemului de operare:**
 - biblioteci specializate pentru controlul resurselor multimedia;
 - instrumente de bază pentru redarea conținutului (ex: Groove Music).
- **Software specializat**

Software specializat

- Există două tipuri majore de software pentru dezvoltare multimedia:
 - **Media-specific** applications sunt folosite pentru a crea și edita elementele media individuale (text, grafică, sunet, video, animație) care alcătuiesc un produs multimedia.
 - **Authoring** applications conțin instrumente software pentru integrarea componentelor media și furnizarea unei interfețe cu utilizatorul.

Grafică

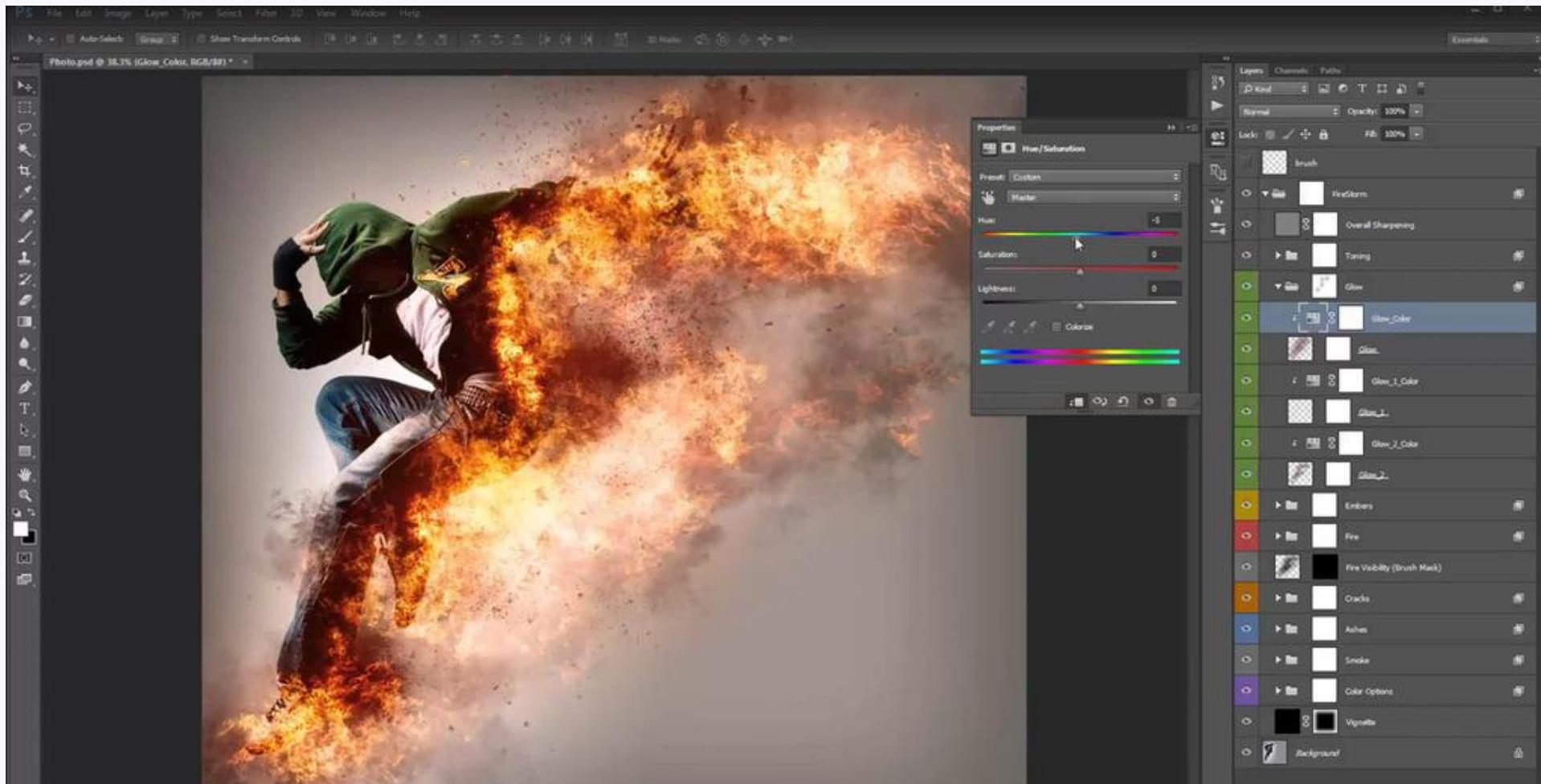
- Achiziția și prelucrarea de imagini 2D sau 3D.
- Categorii:
 - prelucrare imagini raster;
 - prelucrare imagini vectoriale;
 - lucru cu imagini 3D.

Aplicații prelucrare imagini raster

- conțin seturi de instrumente pentru a crea obiecte grafice, precum și instrumente de editare pentru fotografii digitale sau imagini scanate
- oferă o gamă largă de caracteristici, cum ar fi filtre (blur, emboss, pixelate), setări de reglare a imaginii (redimensionare, luminozitate, rotație) și efecte (umbră, gradient overlay).
- asigurarea unui control asupra elementelor individuale ale imaginii este posibilă folosind straturi (en: layers) și setări de mască. Instrumentele de tip text sunt utilizate pentru a genera text grafic cu modele, forme și efecte 3D.

Aplicații prelucrare imagini raster

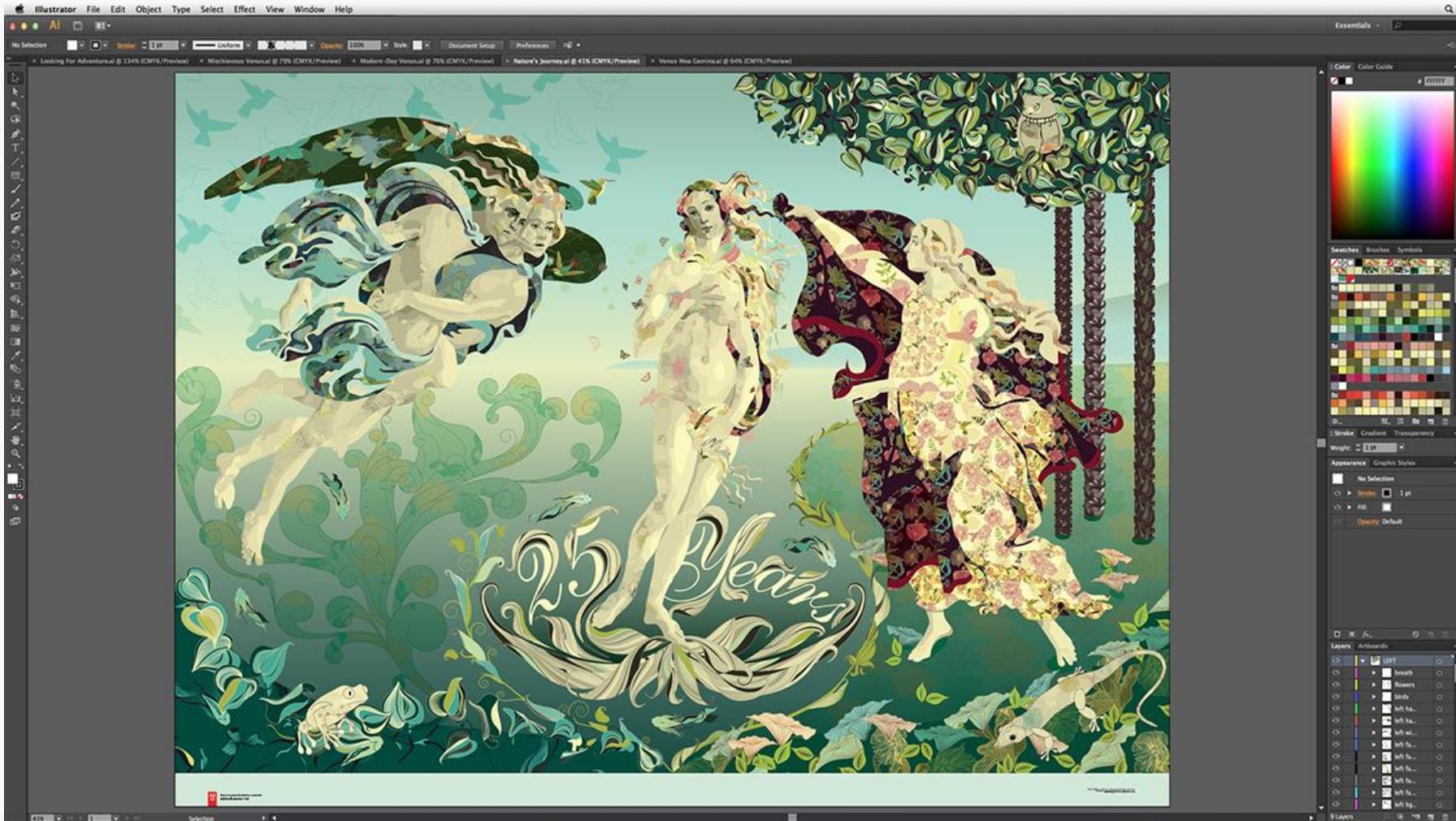
- Example: Photoshop (Adobe), Gimp (open source)



Aplicații prelucrare imagini vectoriale

- conține un set distinct de instrumente pentru crearea de forme de bază, cum ar fi ovale, dreptunghiuri, curbe Bezier și poligoane generate utilizând formule matematice.
- formele pot fi grupate, umplute și redimensionate pentru a produce imagini complexe.
- astfel de aplicații pot fi folosite pentru a crea obiecte grafice care pot fi redimensionate cu ușurință pentru proiecte multimedia diverse.
- Example: Illustrator (Adobe), Draw (Corel), Inkscape (open source)

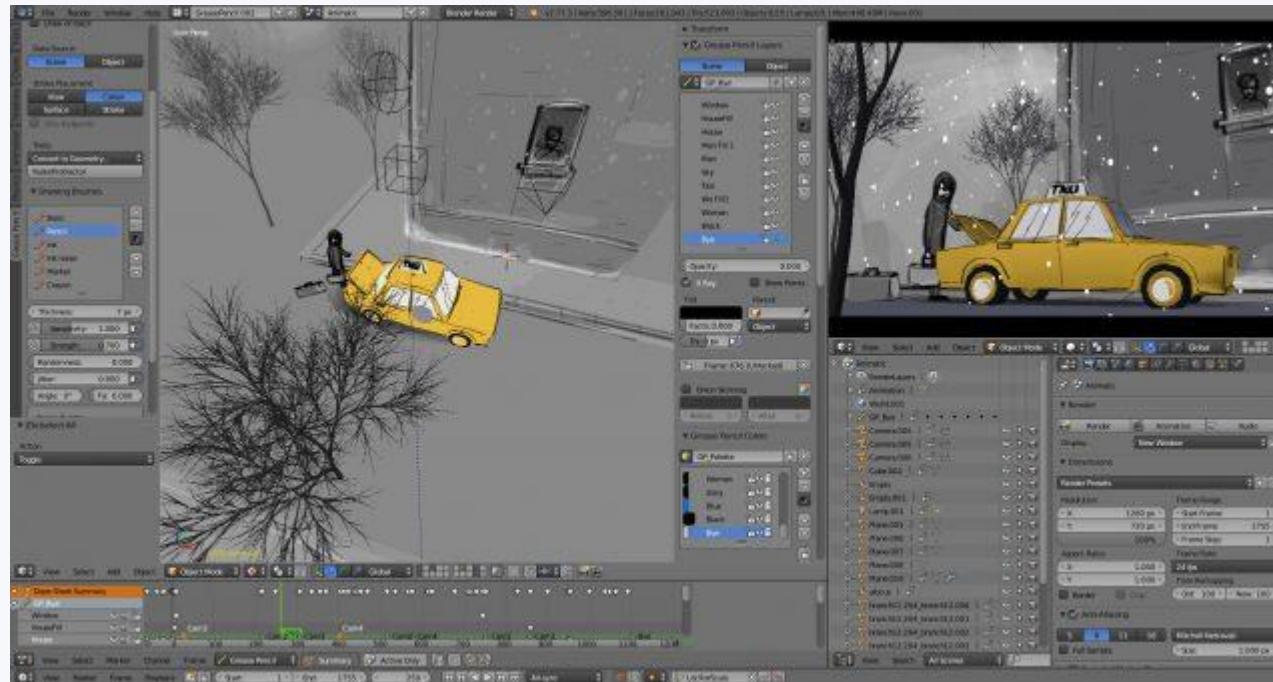
Aplicații prelucrare imagini vectoriale



Aplicații prelucrare imagini 3D

- folosit pentru a modela obiecte 3D, a defini suprafete, a compune scene și a exporta imaginea rezultată;
- În etapa de modelare (en: *modeling*), se creează forma obiectului; în etapa ulterioară, de definire a suprafetei (en: *surface definition*), se aplică culoarea și textura; în etapa de construire a scenei (en: *scene composition*), obiectele sunt aranjate în cadru, iluminate, se adaugă fundalul și efectele speciale. Ultima etapă, este reandarea (en: *rendering*). Randarea creează o imagine pornind de la o scenă 3D. Rendering is both processor intensive and time consuming because the software must calculate how the image should appear based on the object's position, surface materials, lighting, and specific render options.
- Example: Blender (open source)

Aplicații prelucrare imagini 3D



Sunet

- Există două tipuri majore de aplicații de sunet pentru dezvoltarea multimedia:
 - *sunet eşantionat* (en: *sampled*);
 - *sunet sintetizat* (en: *synthesized*).
- Example: Audition (Adobe)

Sunet eşantionat

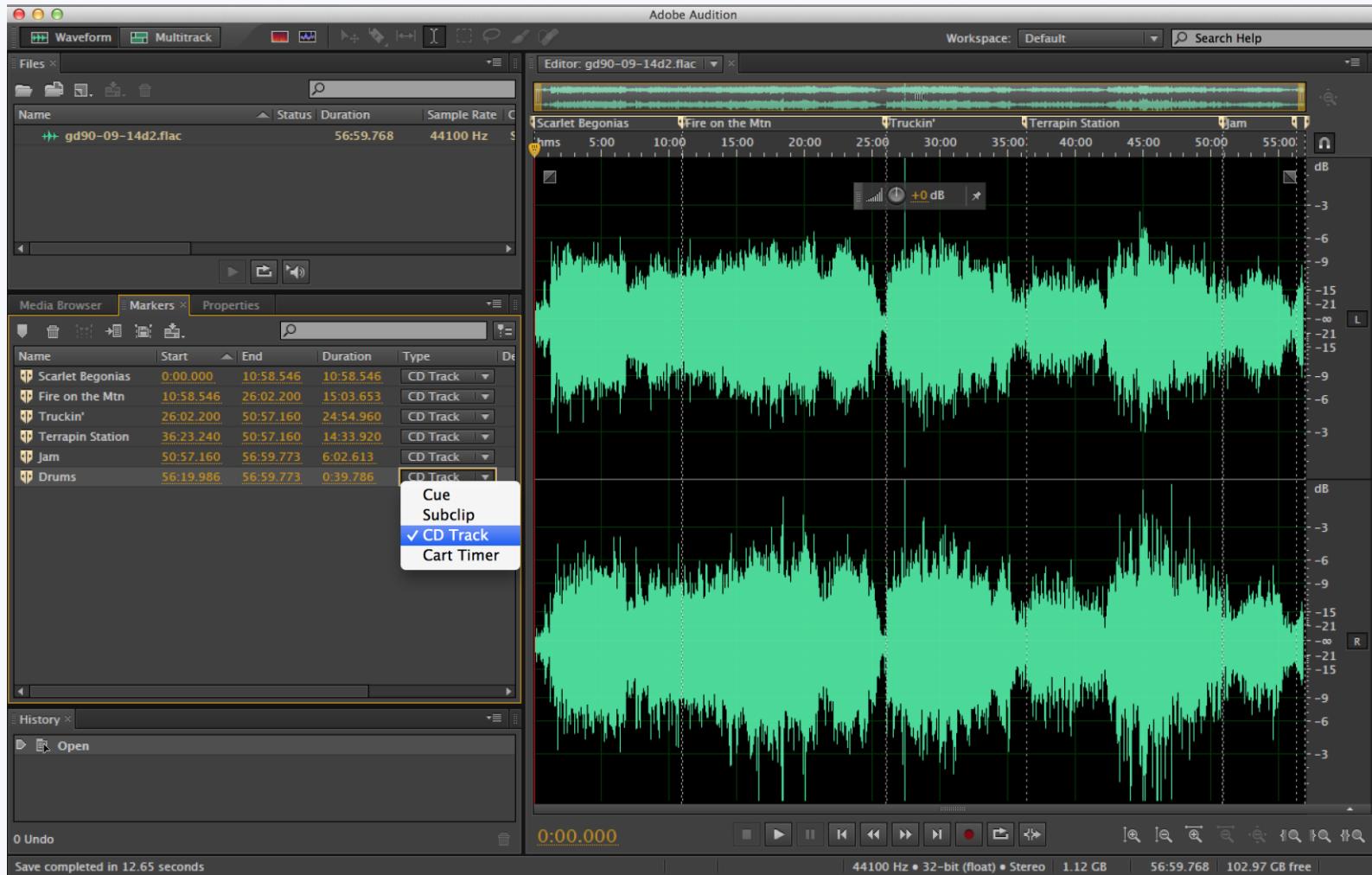
- sunetele eşantionate sunt reprezentări digitale ale surselor de sunet analogice captureate de la microfoane sau alte dispozitive.
- sunetele eşantionate pot fi editate într-o mare varietate de moduri, cum ar fi tăierea pentru a șterge porțiunile goale, îmbinarea pentru a combina segmente de sunet, setarea fade-in și fade-out, reglarea volumului și adăugarea de efecte speciale, cum ar fi ecouri sau inversări de sunet

Sunet sintetizat

- aplicațiile de sunet sintetizat folosesc comenzi digitale pentru a genera sunete. Aceste comenzi pot fi capturate de la un instrument MIDI, cum ar fi o tastatură electronică sau create cu un program specializat.

Software specializat

Sunet



Video

- un mediu pentru a combina videoclipuri sursă, pentru a sincroniza clipurile cu o piesă sonoră, pentru a adăuga efecte speciale și pentru a salva rezultatul ca un videoclip digital.
- un proiect video începe prin încărcarea resurselor utilizate într-o fereastră de proiect. Resursele pot consta în imagini, animații, sunete, fișiere video.
- aplicațiile video oferă instrumente pentru a muta și insera clipuri pe o axă a timpului, pentru a tăia clipul și a defini tranziții între piese. Aplicațiile de editare video definesc, de asemenea, dimensiunea redării și rata de afișare a cadrelor. Când proiectul video este finalizat, aplicația oferă setări pentru salvarea acestuia utilizând diferite scheme de compresie..

Software specializat

Video

- Example: Premiere (Adobe)



Animație

- Folosit pentru a crea și edita secvențe animate. **Animația** este tehnica utilizării unei serii de imagini statice afișate rapid pentru a crea iluzia de mișcare.
- Fiecare cadru reprezintă o singură instanță a secvenței animate. Instrumentele tipice de animație controlează calea unui obiect, forma obiectului și modificările de culoare pe secvența de cadre.
- Obiectele sunt plasate pe o axă a timpului în care efectele pot fi aplicate pentru a se estompa, transforma, roti, răsturna sau schimba ritmul. Mai multe obiecte pot fi stratificate pentru a interacționa între ele pentru a crea animații mai complexe.

Software specializat

Animație

- Example: Director (Adobe), Flash (Adobe), Animate (Adobe)

Software pentru dezvoltare multimedia

- consists of programs specifically designed to facilitate the creation of multimedia products.
- they are used to assemble media elements, synchronize content, design the user interface, and provide user interactivity.

Authoring Software

- Categories based on the metaphor they use to organize media element:
 - card-based metaphor;
 - timeline;
 - flow diagram.

Card-based metaphor

- elements are arranged much as they might be on index cards or the pages of a book.
- such applications are easy to use and are ideal for products such as information kiosks, lectures, and tutorials that do not require precise synchronization of individual media elements.
- Examples: **PowerPoint**, ToolBook

Timeline

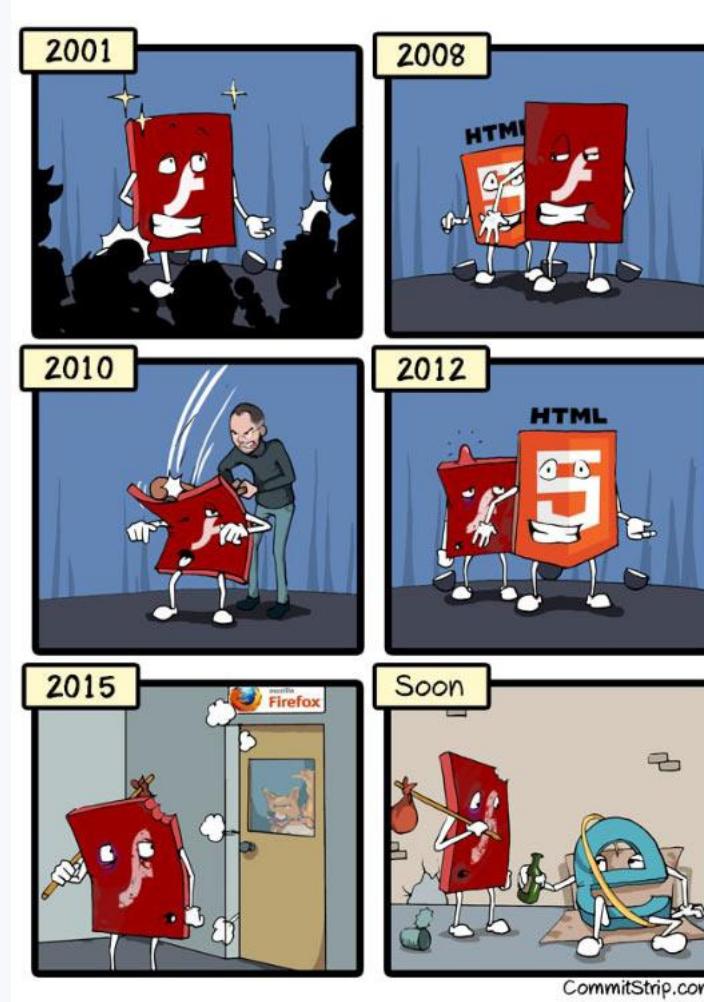
- use a *timeline* of separate frames much like a motion picture film;
- such applications provide the precise control needed for advanced animations;
- Examples: Director (Adobe), Flash (Adobe), Animate(Adobe).

Authoring Software

Adobe Flash



The Evolution Of Flash



Flow diagram

- use *icons* arranged on flow lines to quickly develop a wide range of multimedia products including advanced tutorials, product demonstrations, and simulations. Icons can represent both content (images, text, animations, video) and a wide range of interactions (play, stop, go to, calculate, etc.).
- example: Authorware

Web Multimedia

Web Multimedia

- HTML5 provides a greatly improved support for web multimedia, by including elements such as audio, video, canvas
- supported multimedia elements:
 - text
 - images
 - animations
 - raster graphics
 - vector graphics
 - 3D graphics
 - audio
 - video

HTML5 Games



http://www.cuttherope.net/basic_standalone/game.html

HTML5 Videos

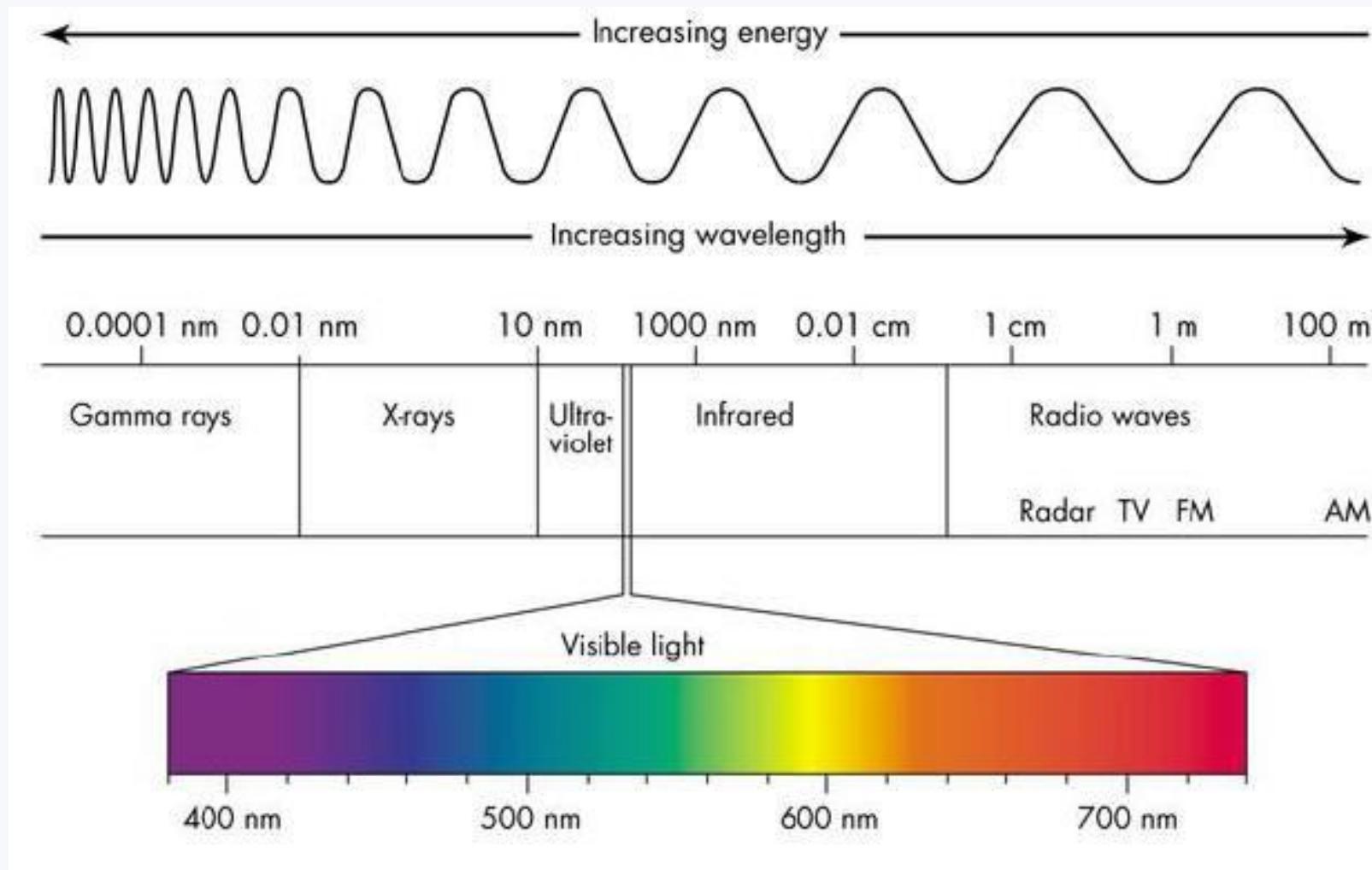


Images

Digital Images

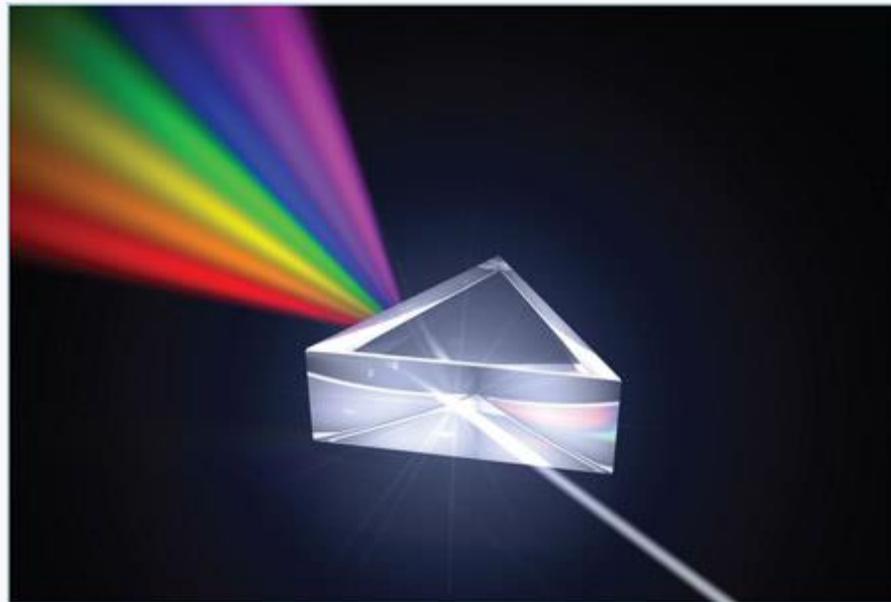
- An **image** is a two- or three-dimensional representation of a person, animal, object, or scene in the natural world [1].
- A **digital image** is a numeric representation of a two-dimensional image.

Visible light



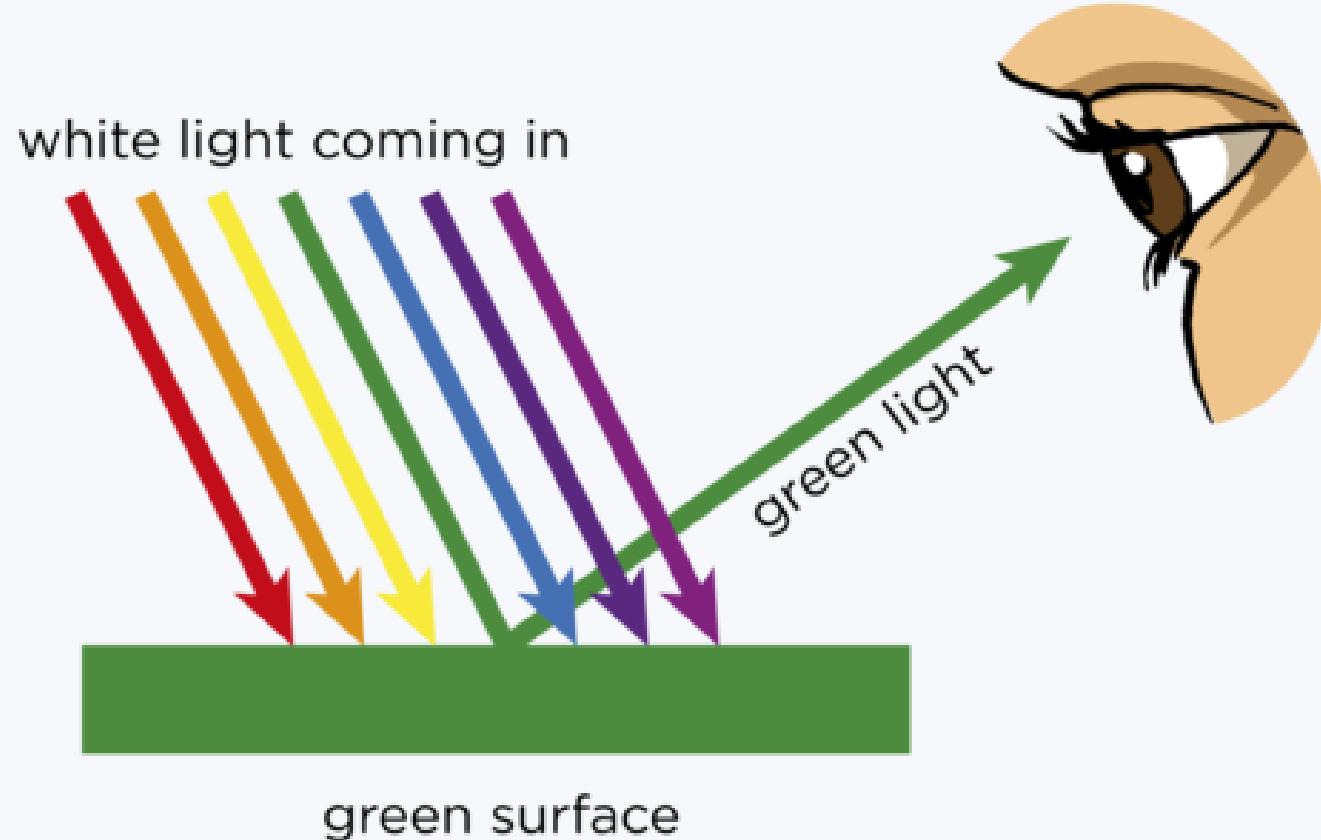
Color Space

- we refer to natural sunlight as white light because it appears to the human eye to be colorless.
- it's possible to separate white light into a dazzling display of various colors using a prism. As light travels through a prism, it's refracted (bent), causing the beam of white light to break apart into its component color wavelengths



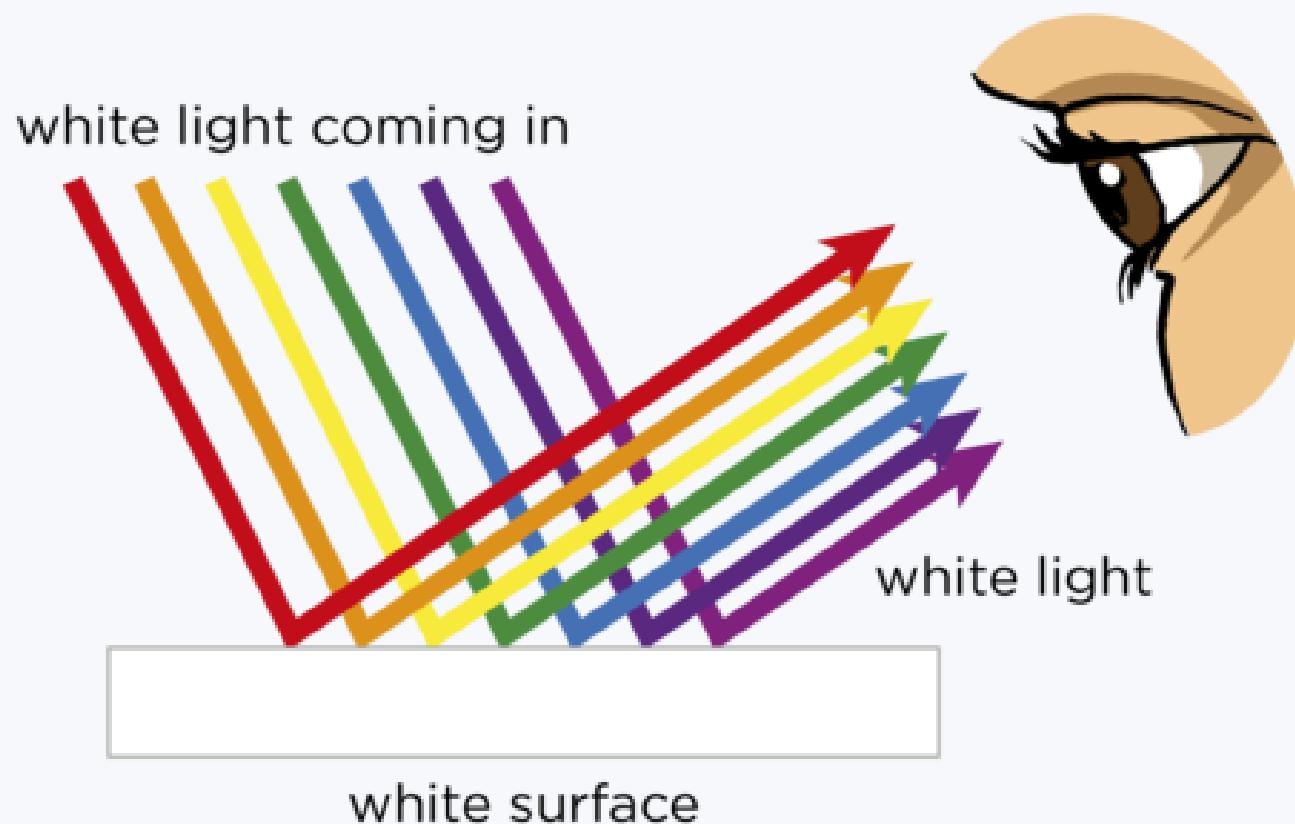
The primary and secondary colors of white light become visible when refracted by a glass prism.

Color Space



The green leaf absorbs all the colors except green which it reflects back into our eyes.

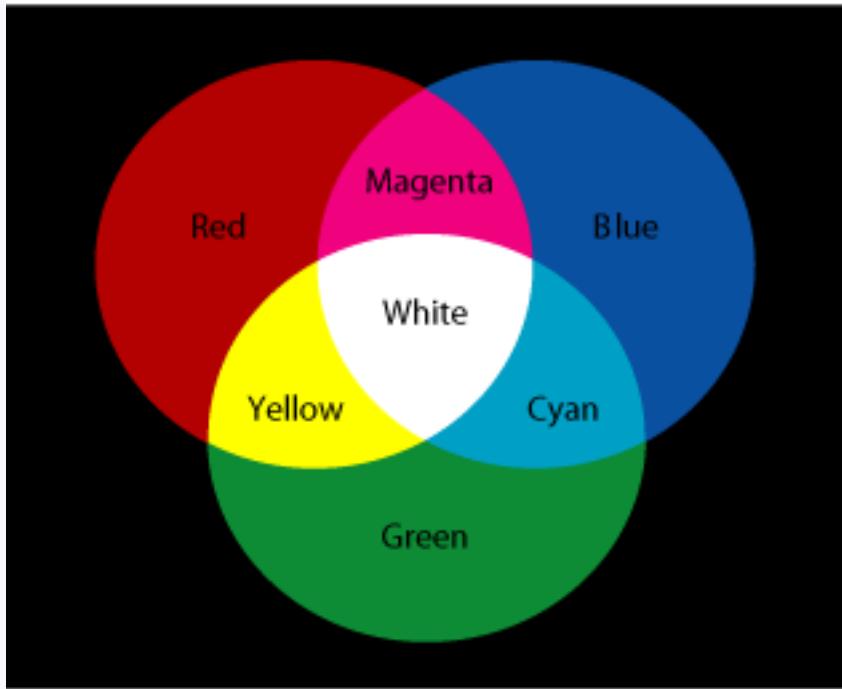
Color Space



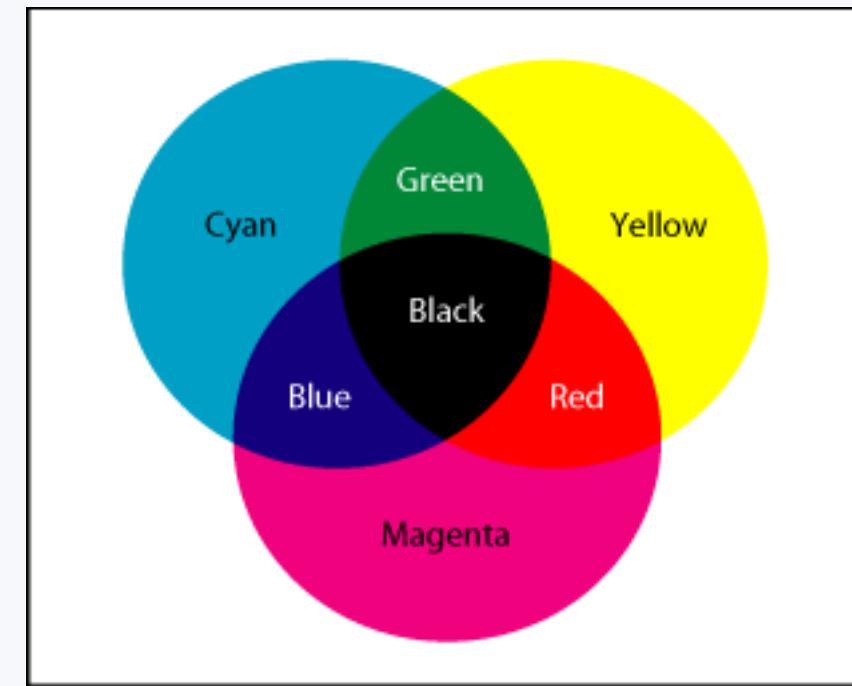
Color Space

- Although we can get black paint as a pigment, black is not a color of light. Black is the result of the complete absorption of light.

Color Systems



Additive Model (RGB)



Subtractive Model (CMYK)

Additive Model

- Additive color is color created by mixing a number of different light colors.
- Shades of **red**, **green**, and **blue** are the most common primary colors used in additive color system.
- Additive color mixing begins with **black** and ends with white; as more color is added, the result is lighter and tends to **white**.
- The combination of **two** of the standard **three** additive primary colors in equal proportions produces an additive secondary color - **cyan**, **magenta** or **yellow**.

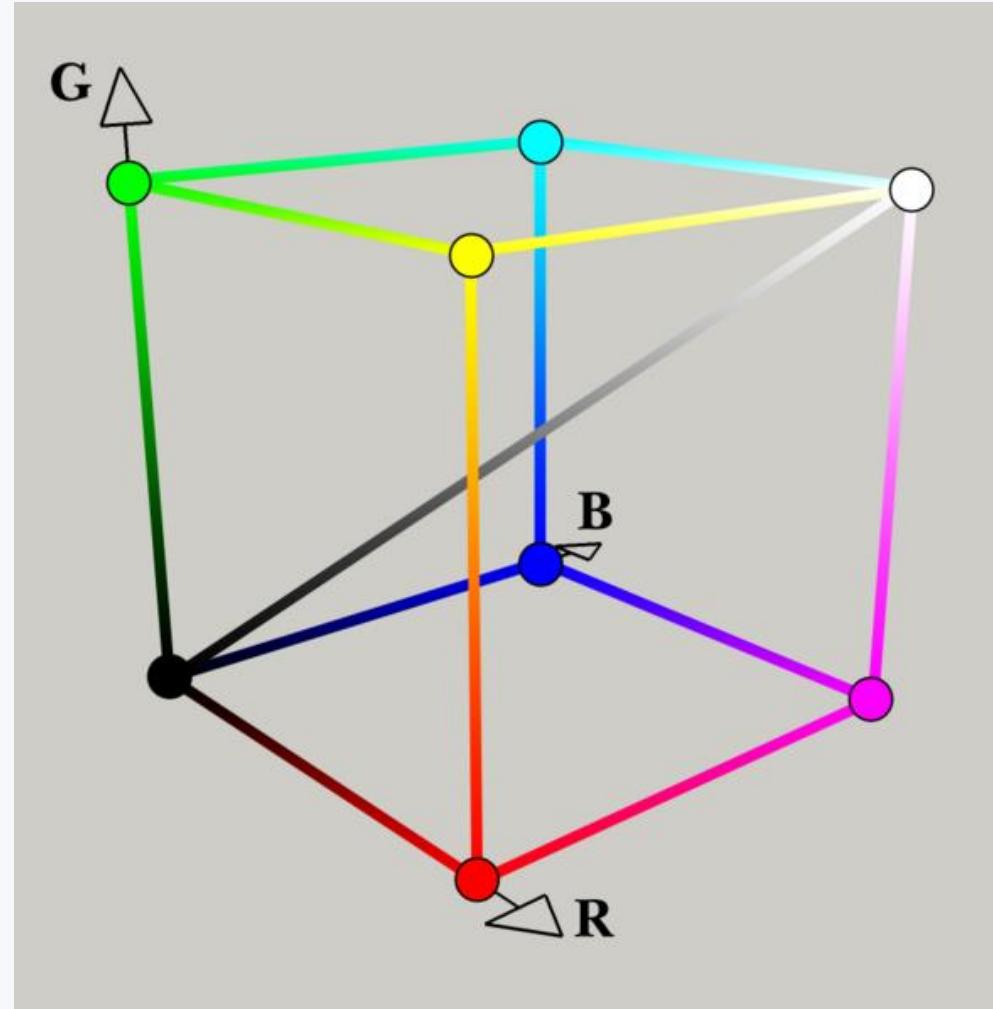
RGB Color Model (or Mode)

- the primary colors of light are **red**, **green**, and **blue** (RGB).
- by adjusting the intensity of each, you can produce **all the colors** in the visible light spectrum. You get **white** if you add all the colors equally and **black** by removing all color entirely from the mix.
- If we were to look at a monitor such as an LCD (liquid crystal display) under a microscope, we would see that each pixel really displays only the three primary colors of light.

RGB Color Model (or Mode)

- In additive color mixing, red and green make yellow. If you fill a graphic with intense yellow in Photoshop, the pixels really display stripes of intense red and green, with no blue.
- The individual points of color are tiny, so our brains add the colors together into yellow.

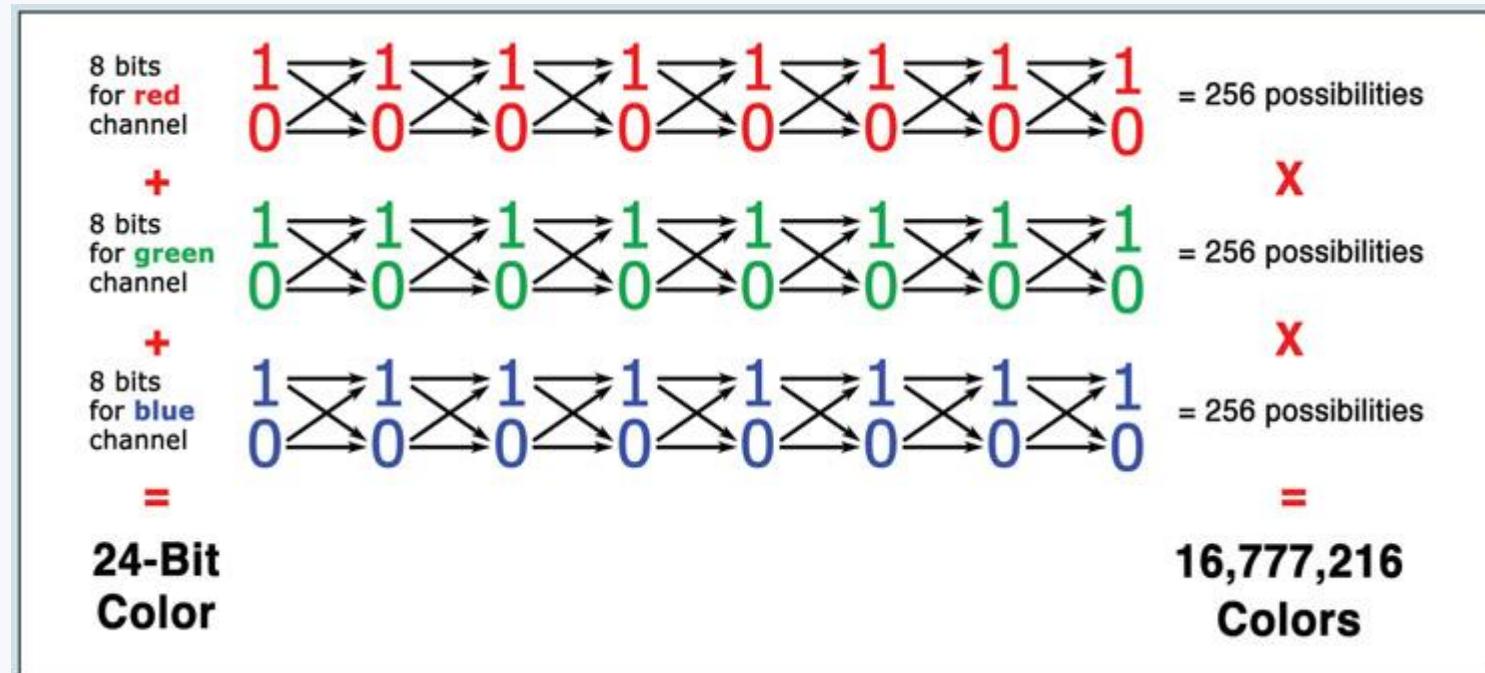
RGB Color Model (or Mode)



Adobe Photoshop – RGB Color



RGB Color Model (or Mode)



The possible color combinations for any pixel in an eight-bit graphic (or a 24-bit display).

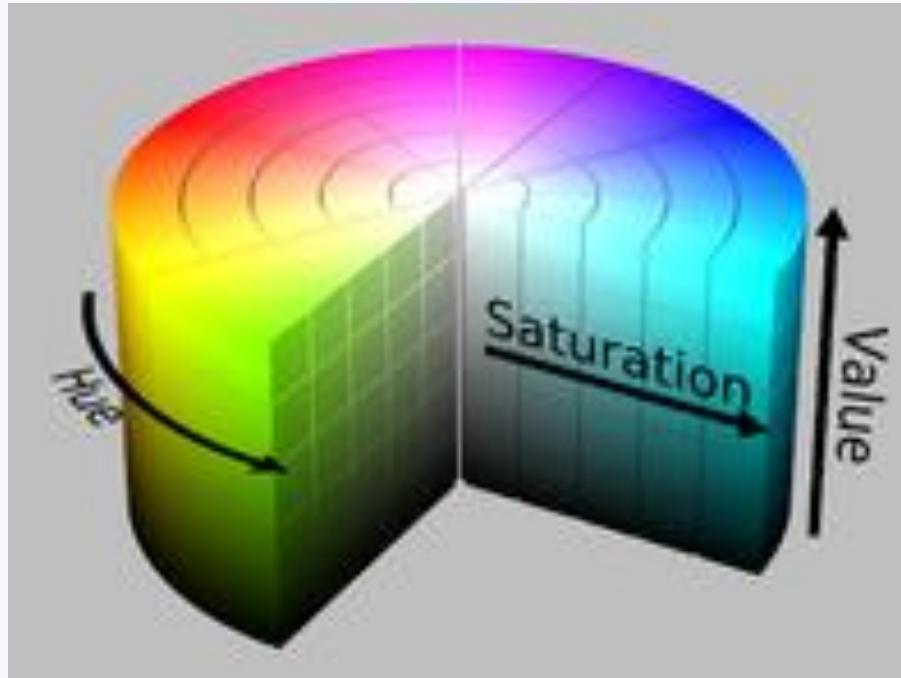
RGB Color Model (or Mode)

- 256 possibilities for each color channel.
- 256 possibilities for red \times 256 for green \times 256 for blue - **16.8 million** possible combinations / colors.

HSB - Hue, Saturation and Brightness Color Model

- Also known as **HSV** (Hue, Saturation and Value):
- Together with **HSL** (Hue, Saturation and Lightness) are the most common cylindrical-coordinate representations of points in an RGB color model.
- The two representations rearrange the geometry of RGB in an attempt to be more intuitive and perceptually relevant than the cartesian (cube) representation.

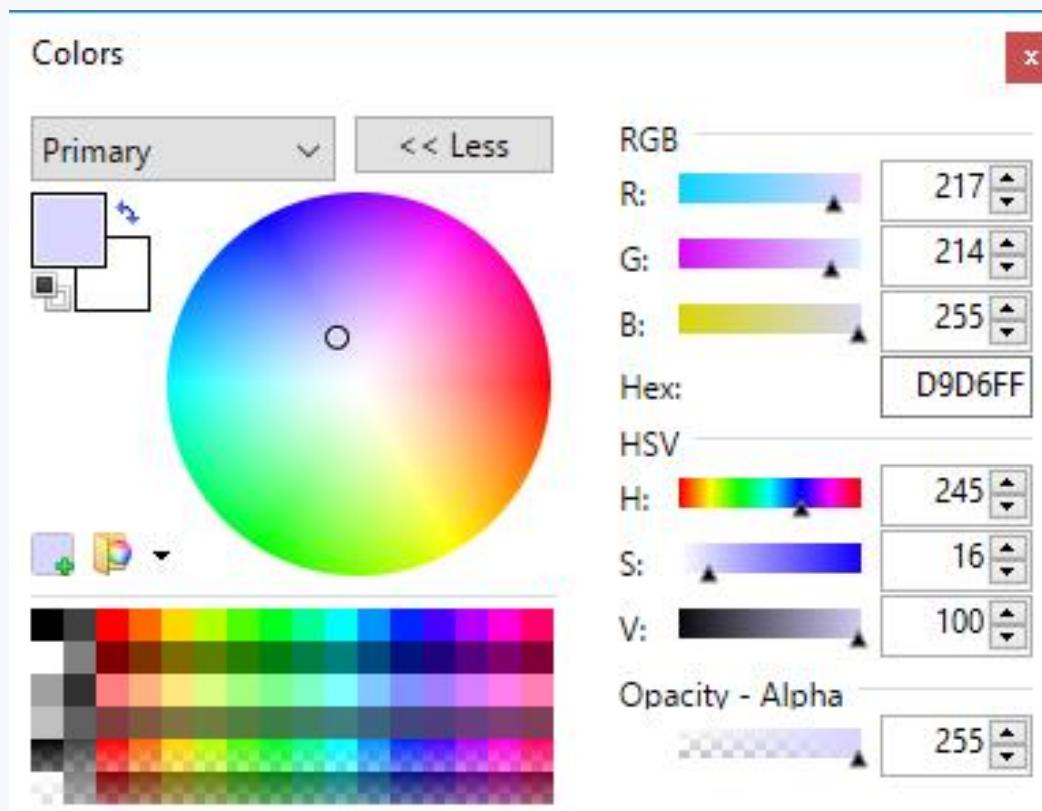
HSB - Hue, Saturation and Brightness Color Model



- Red - 0^0
- Green - 120^0
- Blue - 240^0

HSB - Hue, Saturation and Brightness Color Model

- HSL and HSV are used primarily in color pickers, in image editing software, and less commonly in image analysis and computer vision.



Color Picker in Paint.NET:
<http://www.getpaint.net/index.html>

Subtractive Color System

- When we mix colors using paint, or through the printing process, we are using the **subtractive** color method [1].
- A **subtractive color** model explains the mixing of a limited set of dyes, inks, paint pigments or natural colorants to create a wider range of colors, each the result of partially or completely subtracting (that is, absorbing) some wavelengths of light and not others [1]
- Subtractive color mixing means that one begins with white and ends with black; as one adds color, the result gets darker and tends to black [2].

[1] https://en.wikipedia.org/wiki/Subtractive_color

[2] http://www.worqx.com/color/color_systems.htm

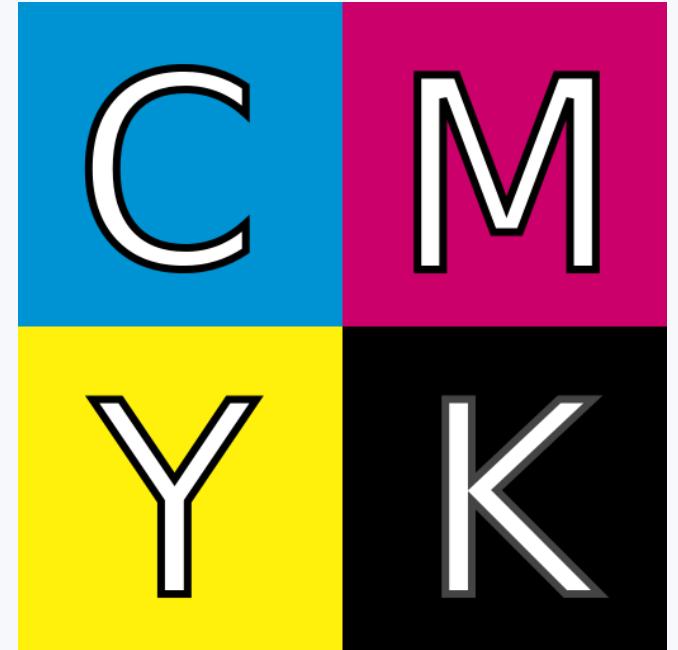
Subtractive Color System

- The color that a surface displays depends on which parts of the visible spectrum are not absorbed and therefore remain visible [1].

[1] https://en.wikipedia.org/wiki/Subtractive_color

CMYK Color Model (or Mode)

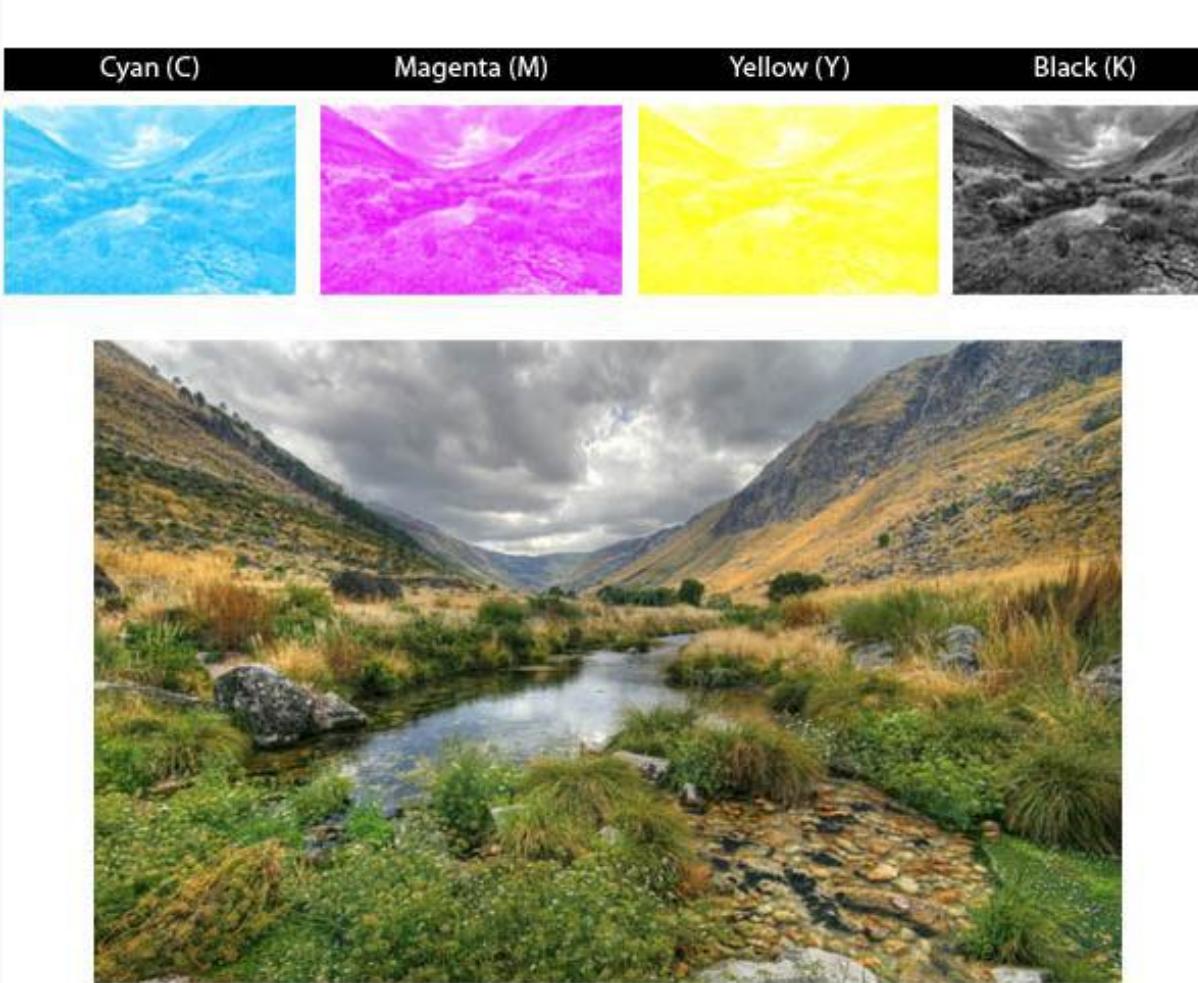
- The CMYK color model (process color, four color) is a subtractive color model, used in color printing, and is also used to describe the printing process itself [1].
- CMYK refers to the four inks used in some color printing: cyan, magenta, yellow and key (black) [1].
- Though it varies by print house, press operator, press manufacturer, and press run, ink is typically applied in the order of the abbreviation [1].



CMY Color Model (or Mode)

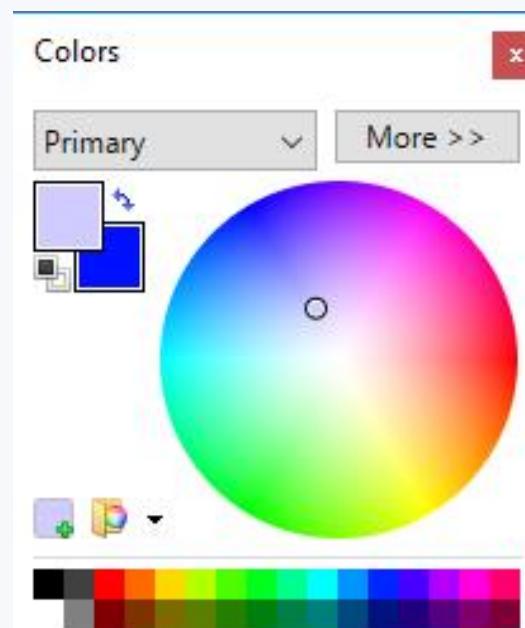


CMYK Color Model (or Mode)



Color Wheel

- A **color wheel** (also referred to as a color circle) is a visual representation of colors arranged according to their **chromatic relationship**. Begin a color wheel by positioning **primary** hues equidistant from one another, then create a bridge between primaries using **secondary** and **tertiary colors** [1].



Color Picker in Paint.NET:
<http://www.getpaint.net/index.html>

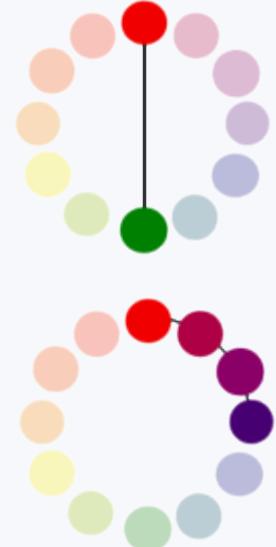
Color Wheel

- **Primary Colors:** Colors at their basic essence; those colors that cannot be created by mixing others [1].
- **Secondary Colors:** Those colors achieved by a mixture of two primaries [1].
- **Tertiary Colors:** Those colors achieved by a mixture of primary and secondary hues [1].



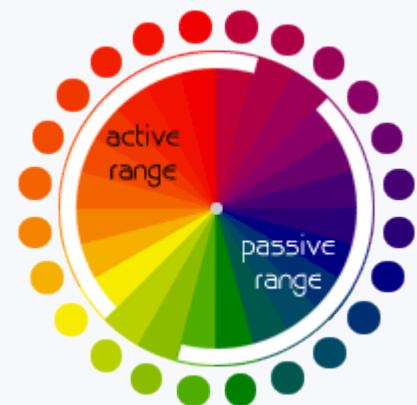
Color Wheel

- **Complementary Colors:** Those colors located opposite each other on a color wheel [1].
- **Analogous Colors:** Those colors located close together on a color wheel [1].



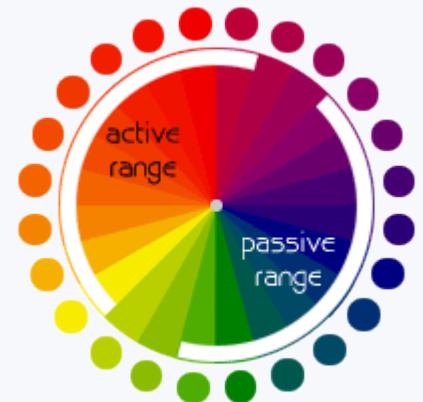
Active & Passive Colors

- The color wheel can be divided into ranges that are visually:
 - Active colors - will appear to advance when placed against passive hues.
 - Passive colors - appear to recede when positioned against active hues.
- Advancing hues are most often thought to have less visual weight than the receding hues.
- Most often warm, saturated, light value hues are "active" and visually advance.



Active & Passive Colors

- Cool, low saturated, dark value hues are "passive" and visually recede.
- Tints or hues with a low saturation appear lighter than shades or highly saturated colors.
- Some colors remain visually neutral or indifferent.



Complementary Colors

- When fully saturated complements are brought together, interesting effects are noticeable. This may be a desirable illusion, or a problem if creating visuals that are to be read.



Does this text have
highlighted edges?

- Notice the illusion of highlighted edges and raised text. This may occur when opposing colors are brought together.

2-D Computer Graphics

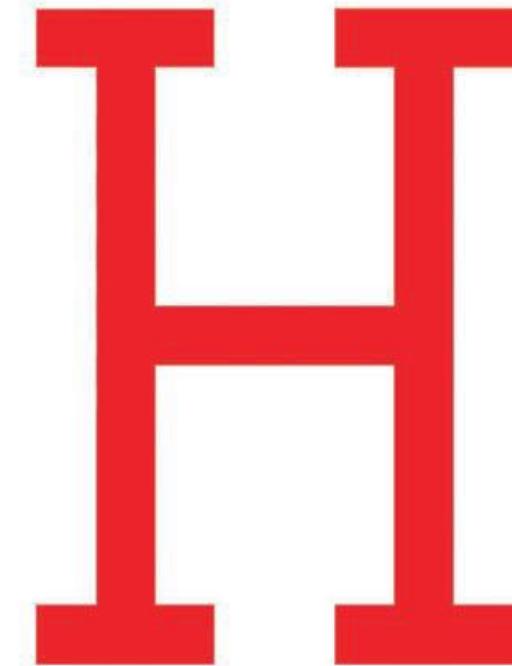
- Computers create either 2-D (width and height) or 3-D images (width, height, and depth).
- There are two main types of 2-D computer graphics:
 - **bitmapped** approach - particularly well suited for images with fine detail, such as paintings or photographs. Also called **raster graphics**.
 - **vector** drawing - used for graphic designs ranging from simple drawings and logos to sophisticated artistic creations.

Raster Graphics

Raster Graphics

- a **raster graphics** image is formed by dividing the area of an image into a rectangular matrix of rows and columns comprised of pixels [1].
- A **pixel**, short for picture element, is a square (or occasionally rectangular) area of light representing a single point in a raster image [2].

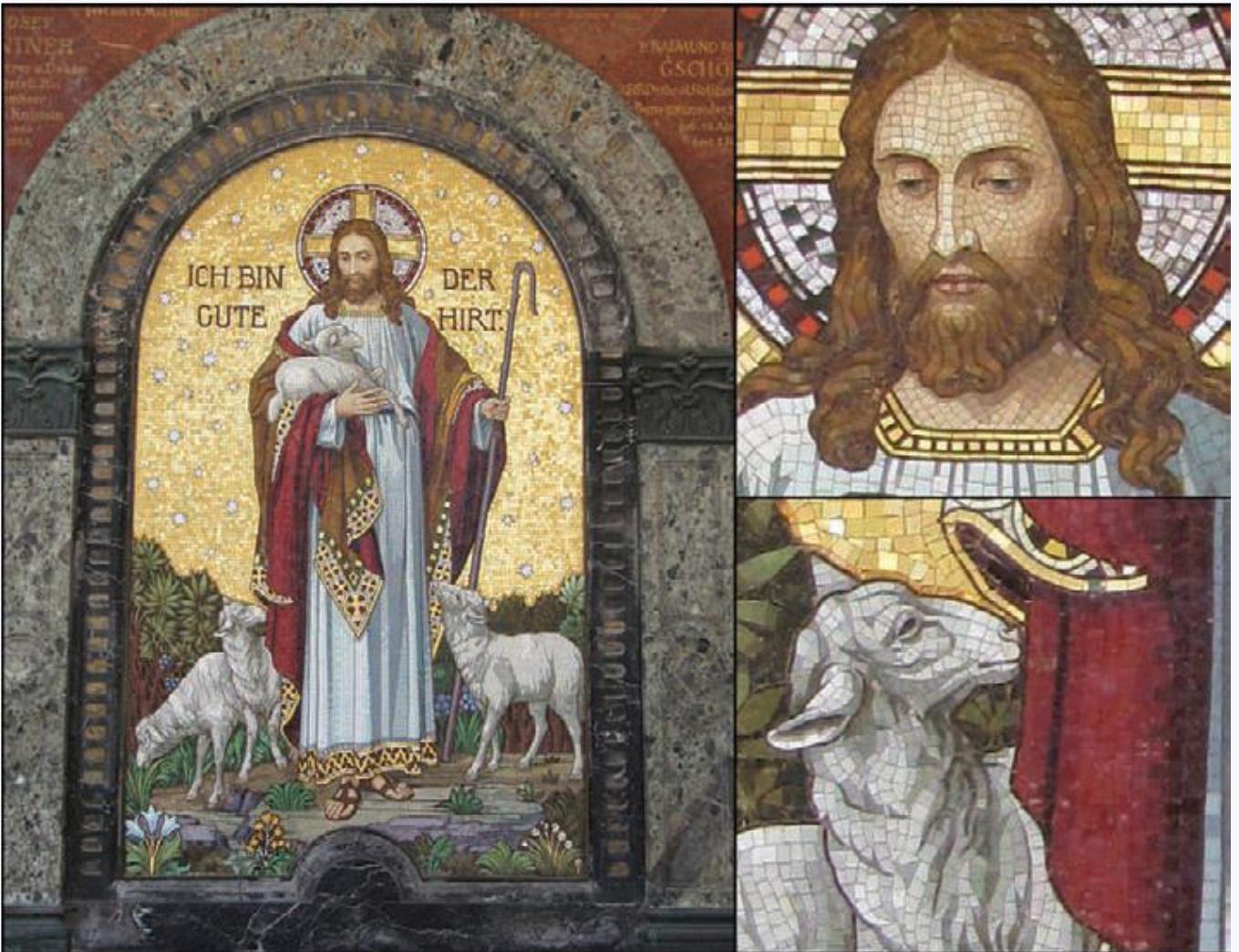
0	0	0	0	0	0	0	0	0	0	0
0	1	1	1	1	0	0	1	1	1	0
0	0	1	0	0	0	0	1	0	0	0
0	0	1	0	0	0	0	1	0	0	0
0	0	1	0	0	0	0	1	0	0	0
0	0	1	0	0	0	0	1	0	0	0
0	0	1	0	0	0	0	1	0	0	0
0	0	1	1	1	1	1	1	0	0	0
0	0	1	0	0	0	0	1	0	0	0
0	0	1	0	0	0	0	1	0	0	0
0	1	1	1	1	0	0	1	1	1	0
0	0	0	0	0	0	0	0	0	0	0



Raster Graphics

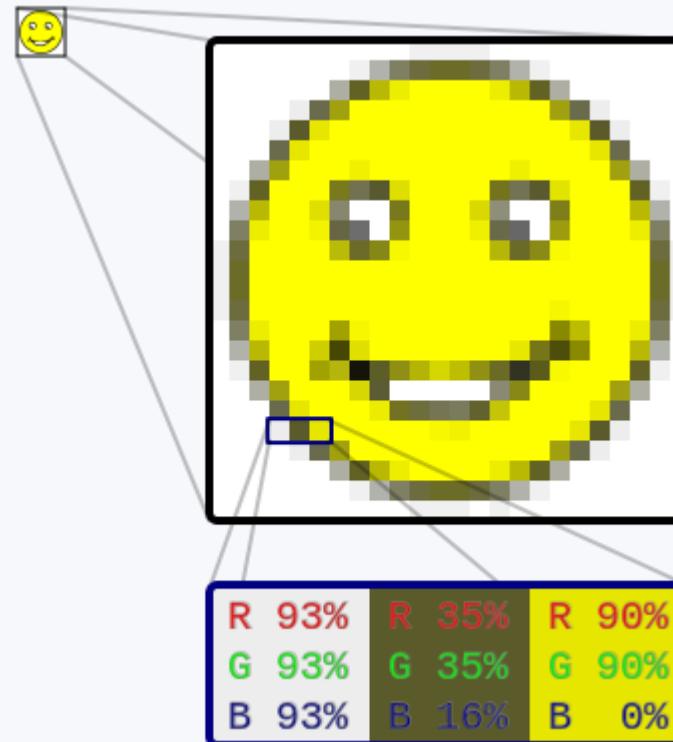
- Every pixel in a raster image is exactly the same size and contains a single color value that's typically stored as a 24-bit string of binary data.
- The total number of pixels in a raster image is fixed. In order to make a raster image physically larger, more pixels have to be added to the raster matrix.
- Likewise, pixels need to be discarded when making a raster image smaller. The width and height of a raster image is determined by how many pixels each row and column contains.

Raster Graphics Mosaic



From a distance, the individual tiles forming the image are barely perceptible to the naked eye. Up close, however, we can see that many small pieces of visual information went into forming this 19th-century mosaic of Christ, the good shepherd. This technique of using tiny bits of colored material to form a composite visual impression dates back to about 3,000 bc.

Raster Graphics



When enlarged, individual pixels appear as squares. Zooming in further, they can be analyzed, with their colors constructed by adding the values for red, green and blue.

Formats

- **BMP** (Microsoft Windows Bitmap) - ***.bmp**
 - also known as bitmap image file or device independent bitmap (DIB) file format or simply a bitmap
- either uncompressed or compressed using RLE (**lossless compression format**)
- monochrome or color (various color depths are supported)

Characteristics

- **Resolution**
 - describes the image quality of a raster image and directly relates to the size and quantity of the pixels the image contains.
- **Pixel Dimensions**
 - describe the size of a raster image, expressed as the number of pixels along the x-axis (width) by the number of pixels along the y-axis (height).
 - ex: 800 px * 600 px
- **Pixel Count**
 - Pixel count is the total number of pixels in a raster matrix. To determine the pixel count, multiply the horizontal and vertical pixel dimensions.
 - ex: a 30 * 18 pixel image has a pixel count of 540 pixels.

Characteristics

- **Pixel Density**
 - We express the pixel density or resolution of a raster image in pixels per inch (ppi)—this is pixels per linear inch (across or down), not square inch.
 - Most television and computer monitors have a display resolution of either 72 or 96 ppi.
 - The resolution determines the maximum size of an image you print. In order to produce a high-quality print of any size, digital photographs need a pixel density of at least 300 ppi—that's 90,000 pixels in a square inch!

Characteristics

- **Color-Depth (Color Resolution)**

- measure of the number of different colors that can be represented by an individual pixel. The number of bits assigned to each pixel, or bit depth, determines color resolution.
- 8-bits (256 colors), 24 bits (16.8 million colors)
- A drawing using 16 distinct colors, for example, would only require 4 bits per pixel. Using a code with greater bit depth produces a larger file with no increase in quality.

Advantages and Disadvantages

- Advantages:
 - great when creating rich and detailed images. Every pixel in a raster image can be a different color therefore complex images with any kind of color changes and variations can be created.

Advantages and Disadvantages

- Disadvantages:
 - the files are often **quite large** because they contain all the information for every single pixel of the image.
 - cannot be scaled up in size very well. If enlarged, a raster image will look grainy and distorted because raster images are created with a finite number of pixels. When you increase the size of a raster image, the image increases in size however, because there are no longer enough pixels to fill in this larger space, gaps are created between the pixels in the image. The photo editing software will try to fill these gaps the best they can however, the resulting image is often blurry.
 - no information is provided regarding the shapes that make up the image.

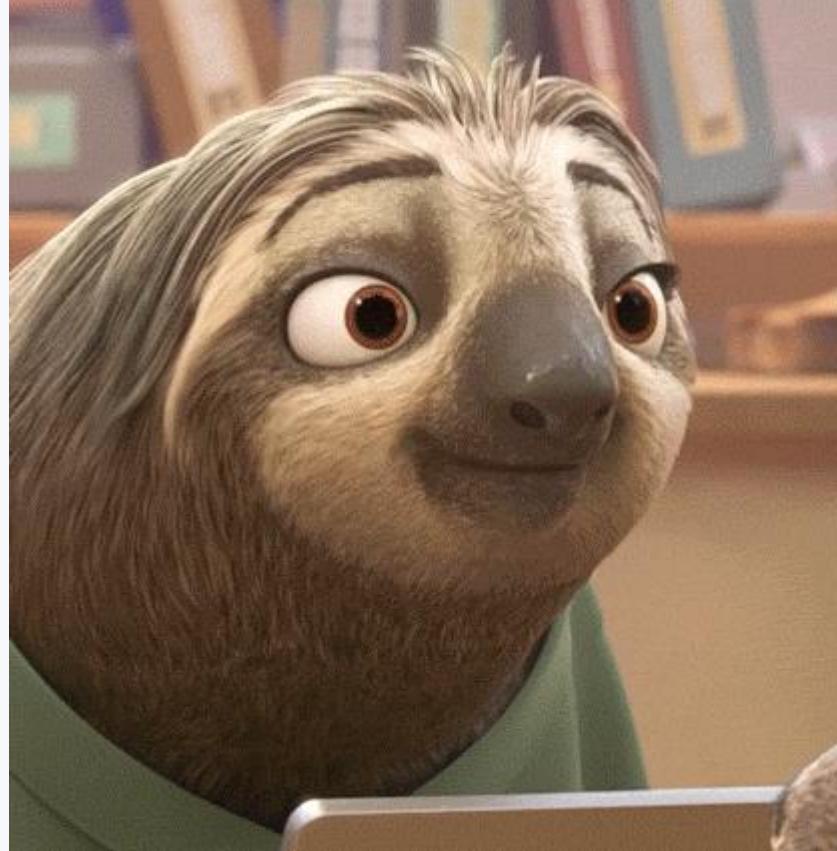
Formats

- while working with an image file, it should be saved it in a format that supports layers (*.PSD, *TIFF), so it can be changed it in the future or resaved in a new format for another purpose.
- when you prepare a raster image to incorporate into a multimedia project, you'll need a **flattened, compressed** image. For lossy formats there is always a tradeoff between image quality and the file size.

Formats

- GIF (Graphics Interchange Format) - *.gif
 - maximum 256 colors and transparency (transparent pixels);
 - lossless compression format.
- commonly used for logos and other images with lines and solid blocks of color.
- supports interlacing, so every odd line of pixels loads, then every even line loads, making graphics seem to appear faster (users see the full-sized, half-loaded graphic before the rest of the pixels appear).
- supports animation.

2-D Computer Graphics Formats



<https://dl.dropboxusercontent.com/u/70618257/HTML5Multimedia/giphy.gif>

Formats

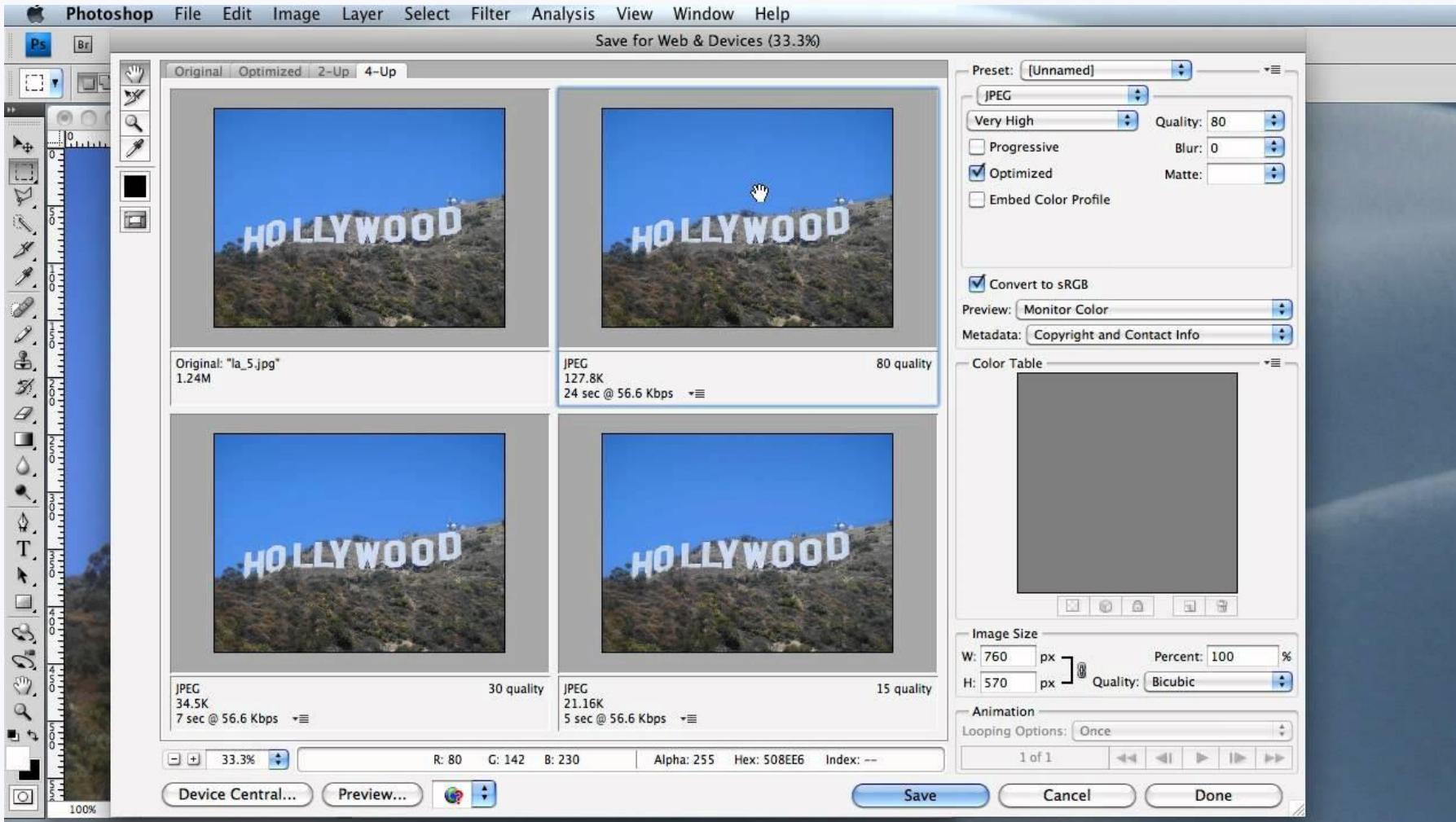
- **JPEG** (Joint Photographic Experts Group) - ***.jpeg**
 - offers 16.8 million colors
 - does not support transparency (has no transparent pixels).
 - lossy compression format and is used most often for photographs.
 - does not support interlacing.

2-D Computer Graphics Formats



JPEG - a photo of a cat with the compression rate decreasing, and hence quality increasing, from left to right [1].

2-D Computer Graphics Formats

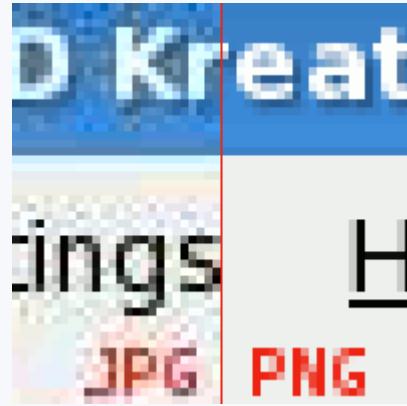


Photoshop – Save for Web menu

Formats

- **PNG** (Portable Network Graphics) - *.png
 - the most widely used lossless image compression format on the Internet [1]
 - created as an improved, non-patented replacement for Graphics Interchange Format (GIF) [1]
 - offers 16.8 million colors and transparency, but you can choose to use fewer colors to save file space (PNG 8, or PNG with 8-bit color) [2]
 - Lossless compression format [2]
 - common for a wide range of images, including *favicons* (the small web page icons in browser tabs) [2]
 - PNG files can be very small, but for photographs with many colors, they may be larger than comparable JPEGs [2]
 - This format supports interlacing.[2]

2-D Computer Graphics Formats



Composite image comparing **lossy compression** in JPEG with **lossless compression** in PNG: the JPEG artifacts are easily visible in the background, where the PNG image has solid color [1].

Formats

- Other formats:
 - ICO - Icon Resource File;
 - DIB - Device Independent Bitmap;
 - PCX - PC PaintBrush File Format;
 - TIFF - Tag Image File Format.

Raster Graphics

Huge images

- Dubai: <http://gigapan.com/gigapans/48492>
- Size: 44.88 Gigapixels



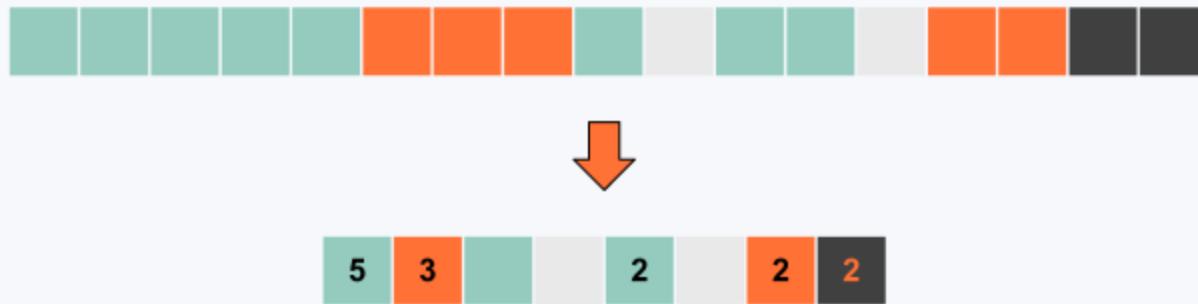
Compression

- Compression algorithms:
 - Run-length encoding (RLE)
 - Lempel–Ziv–Welch (LZW)
 - Huffman
 - JPEG

Compression - Run Length Encoding - RLE

- one of the simpler strategies to achieve **lossless** compression
- can be used to compress bitmapped image files (ex: *pcx format). Bitmapped images can easily become very large because each pixel is represented with a series of bits that provide information about its color.
- RLE generates a code to “flag” the beginning of a line of pixels of the same color. That color information is then recorded just once for each pixel. In effect, RLE tells the computer to repeat a color for a given number of adjacent pixels rather than repeating the same information for each pixel over and over. The RLE compressed file will be smaller, but it will retain all the original image data—it is “lossless.”

Compression - Run Length Encoding - RLE



Compression - Lempel–Ziv–Welch (LZW)

- lossless data compression algorithm
- used in the GIF image format
- **Encoding**
 - Initialize the dictionary to contain all strings of length one.
 - Find the longest string W in the dictionary that matches the current input.
 - Emit the dictionary index for W to output and remove W from the input.
 - Add W followed by the next symbol in the input to the dictionary.
 - Go to Step 2.

JPEG Compression

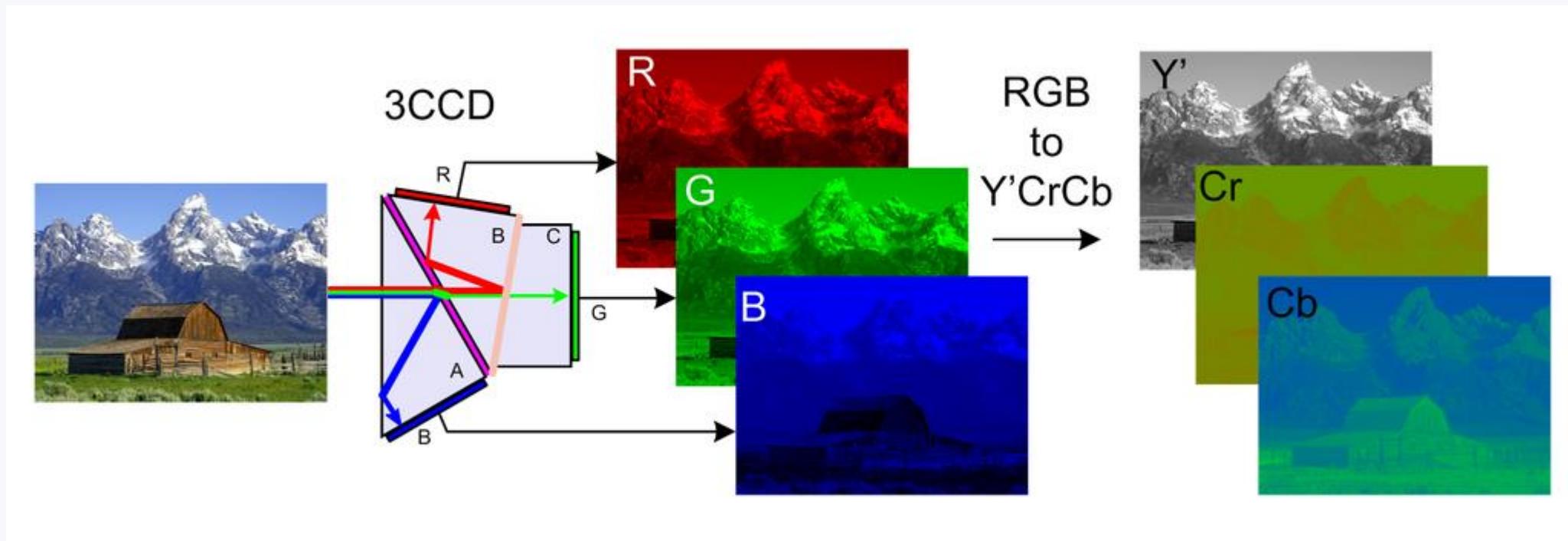
- lossy data compression algorithm

- Steps

1. color space transformation
2. downsampling
3. block splitting
4. transformation
5. quantization
6. encoding

JPEG Compression - Step 1 - Color space transformation

- The representation of the colors in the image is converted from RGB to Y'CrCb, consisting of one luma component (Y'), representing brightness, and two chroma components, (CB and CR), representing color. This step is sometimes skipped.



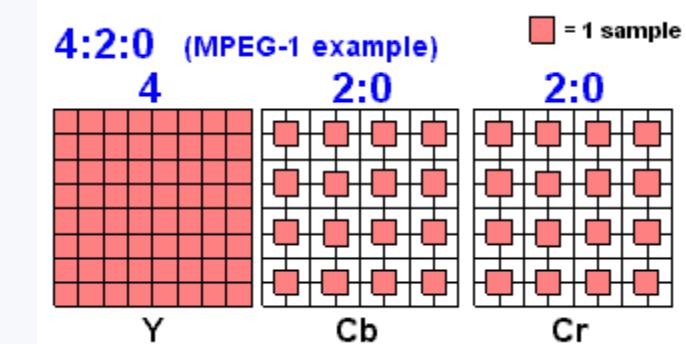
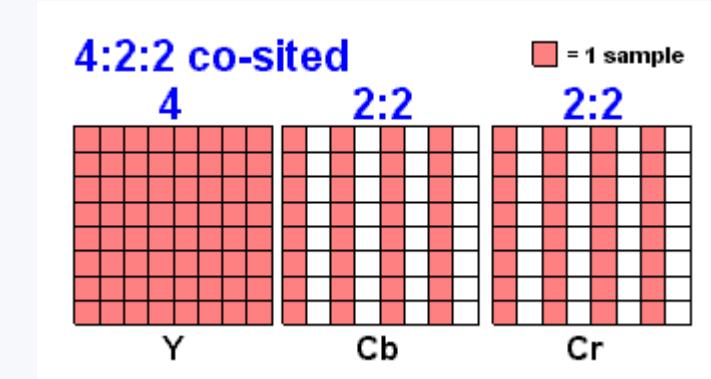
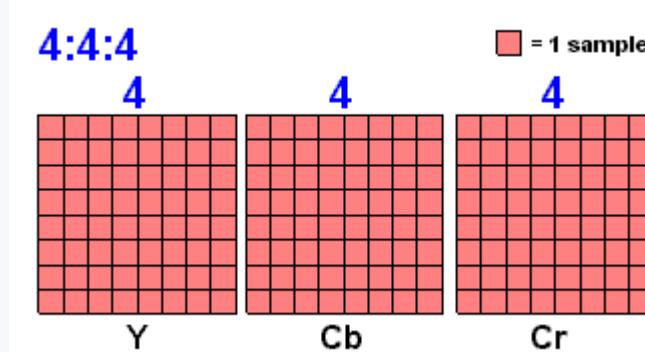
JPEG Compression - Step 1 - Color space transformation

- The $Y'C_BC_R$ color space conversion allows greater compression without a significant effect on perceptual image quality (or greater perceptual image quality for the same compression).
- The compression is more efficient because the brightness information, which is more important to the eventual perceptual quality of the image, is confined to a single channel. This more closely corresponds to the perception of color in the human visual system.

JPEG Compression – Step 2 - Downsampling

- Due to the densities of color- and brightness-sensitive receptors in the human eye, humans can see considerably more fine detail in the brightness of an image (the Y' component) than in the hue and color saturation of an image (the C_b and C_r components). Using this knowledge, encoders can be designed to compress images more efficiently.
- The transformation into the Y'C_BC_R color model enables the next usual step, which is to reduce the spatial resolution of the C_b and C_r components.

JPEG Compression – Step 2 - Downsampling



JPEG Compression – Step 2 - Downsampling

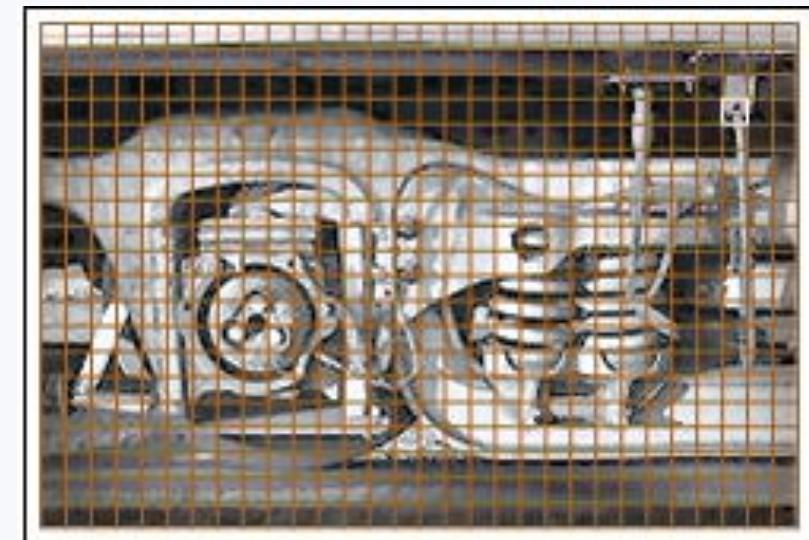
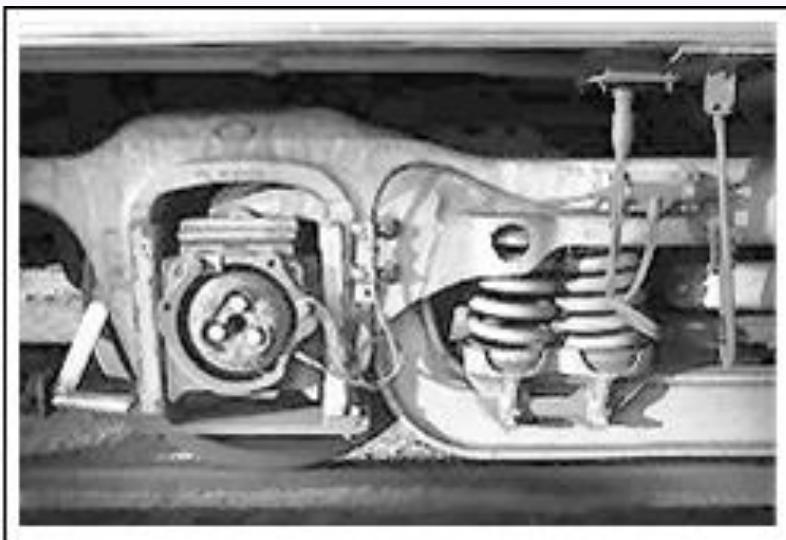
- The ratios at which the downsampling is ordinarily done for JPEG images are:
 - 4:4:4 - no downsampling,
 - 4:2:2 - reduction by a factor of 2 in the horizontal direction
 - 4:2:0 - reduction by a factor of 2 in both the horizontal and vertical directions (most common).
- For the rest of the compression process, Y', Cb and Cr are processed separately and in a very similar manner.

JPEG Compression – Step 3 - Block splitting

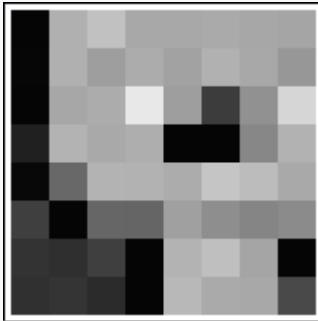
- Each channel must be split into 8×8 blocks
- Depending on chroma subsampling, this yields Minimum Coded Unit (MCU) blocks of size 8×8 (4:4:4 – no subsampling), 16×8 (4:2:2), or most commonly 16×16 (4:2:0).

JPEG Compression – Step 4 - Discrete cosine transform

- Each channel must be split into blocks of size 8 x 8 pixels
- If we have chosen an image whose dimensions are $160 \times 240 = 8*20 \times 8*30$. So this step creates $20 \times 30 = 600$ blocks.



JPEG Compression – Step 4 - Discrete cosine transform



5	176	193	168	168	170	167	165
6	176	158	172	162	177	168	151
5	167	172	232	158	61	145	214
33	179	169	174	5	5	135	178
8	104	180	178	172	197	188	169
63	5	102	101	160	142	133	139
51	47	63	5	180	191	165	5
49	53	43	5	184	170	168	74

JPEG Compression – Step 4 - Discrete cosine transform

- Before computing the DCT of the 8×8 block, its values are shifted from a positive range to one centered on zero.
- We subtract 127 from each pixel intensity in each block. This step centers the intensities about the value 0 and it is done to simplify the mathematics of the transformation and quantization steps.

JPEG Compression – Step 4 - Discrete cosine transform

5	176	193	168	168	170	167	165
6	176	158	172	162	177	168	151
5	167	172	232	158	61	145	214
33	179	169	174	5	5	135	178
8	104	180	178	172	197	188	169
63	5	102	101	160	142	133	139
51	47	63	5	180	191	165	5
49	53	43	5	184	170	168	74

-122	49	66	41	41	43	40	38
-121	49	31	45	35	50	41	24
-122	40	45	105	31	-66	18	87
-94	52	42	47	-122	-122	8	51
-119	-23	53	51	45	70	61	42
-64	-122	-25	-26	33	15	6	12
-76	-80	-64	-122	53	64	38	-122
-78	-74	-84	-122	57	43	41	-53

JPEG Compression – Step 4 - Discrete cosine transform

- The JPEG Image Compression Standard relies on the *Discrete Cosine Transformation (DCT)* to transform the image. The DCT is applied to each 8×8 block.
- The DCT is a product $C = U B U^T$ where B is an 8×8 block from the preprocessed image and U is a special 8×8 matrix.
- Loosely speaking, the DCT tends to push most of the high intensity information (larger values) in the 8×8 block to the upper left-hand of C with the remaining values in C taking on relatively small values.

JPEG Compression – Step 4 - Discrete cosine transform

-27.500	-213.468	-149.608	-95.281	-103.750	-46.946	-58.717	27.226
168.229	51.611	-21.544	-239.520	-8.238	-24.495	-52.657	-96.621
-27.198	-31.236	-32.278	173.389	-51.141	-56.942	4.002	49.143
30.184	-43.070	-50.473	67.134	-14.115	11.139	71.010	18.039
19.500	8.460	33.589	-53.113	-36.750	2.918	-5.795	-18.387
-70.593	66.878	47.441	-32.614	-8.195	18.132	-22.994	6.631
12.078	-19.127	6.252	-55.157	85.586	-0.603	8.028	11.212
71.152	-38.373	-75.924	29.294	-16.451	-23.436	-4.213	15.624

JPEG Compression – Step 5 - Quantization

- elements near zero will converted to zero and other elements will be shrunk so that their values are closer to zero. All quantized values will then be rounded to integers.
- quantization is performed in order to obtain integer values and to convert a large number of the values to 0. The Huffman coding algorithm will be much more effective with quantized data and the hope is that when we view the compressed image, we haven't given up too much resolution.

JPEG Compression – Step 5 - Quantization

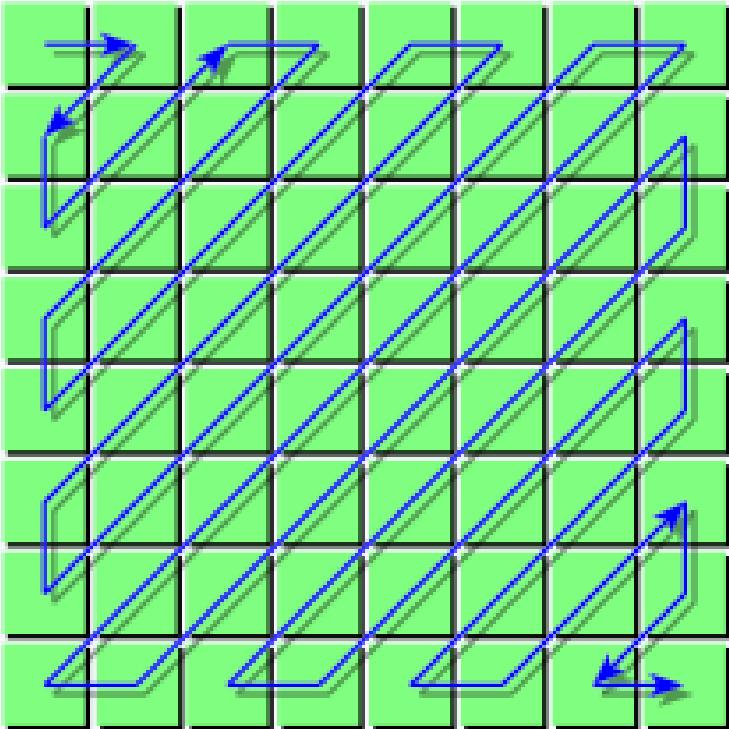
16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

Note that the values are largest in the lower right corner of Z. These divides should produce values close to zero so that the rounding function will convert the quotient to zero

JPEG Compression – Step 5 - Quantization

-2	-19	-15	-6	-4	-1	-1	0
14	4	-2	-13	0	0	-1	-2
-2	-2	-2	7	-1	-1	0	1
2	-3	-2	2	0	0	1	0
1	0	1	-1	-1	0	0	0
-3	2	1	-1	0	0	0	0
0	0	0	-1	1	0	0	0
1	0	-1	0	0	0	0	0

JPEG Compression – Step 6 - Encoding



It involves arranging the image components in a "zigzag" order employing run-length encoding (RLE) algorithm that groups similar frequencies together, inserting length coding zeros, and then using **Huffman** coding on what is left.

JPEG Compression – Step 5 - Quantization

- quantization makes the JPEG algorithm an example of *lossy compression*:
 - the DCT step is completely invertible - that is, we applied the DCT to each block B by computing $C = U B U^T$. It turns out we can recover B by the computation $B = U^T C U$.
 - converting small values to 0 and rounding all quantized values are not reversible steps. The ability to recover the original image is lost.

HTML5 Images

- represents an image in the document.
- declaring an image element:

```

```

- API: <https://developer.mozilla.org/en-US/docs/Web/API/HTMLImageElement>
- DOM interface – `HTMLImageElement`:

HTML5 Images

- Properties:
 - width, height: the rendered width / height of the image in CSS pixels;
 - naturalWidth, naturalHeight: unsigned long representing the intrinsic width / height of the image in CSS pixels;
 - src: DOMString that reflects the src HTML attribute, containing the full URL of the image including base URI.
- Events:
 - load: fired when a resource and its dependent resources have finished loading.

HTML5 Images

```
var image = $("<img>")
    .load(function () { $("body").append($(this)); })
    .attr("src", "media/Penguins.jpg");
```

HTML5 Canvas Element

- Can be used to draw graphs, make photo compositions or even perform animations.
- Declaring a canvas element:

```
<canvas id= "test" style="width:250px; height:150px">  
An alternative text describing what your canvas displays.  
</canvas>
```

- API: <https://developer.mozilla.org/en-US/docs/Web/HTML/Element/canvas>
- DOM interface: HTMLCanvasElement

HTML5 Canvas Element - Methods

- `getContext(contextType, contextAttributes);` - returns a drawing context on the canvas, or null if the context identifier is not supported;

```
var canvas = document.getElementById('test'); // sau var canvas = $('#test')[0];
var w = canvas.width, h = canvas.height;
var ctx = canvas.getContext('2d');
```

- `contextType`: DOMString containing the context identifier defining the drawing context associated to the canvas.

HTML5 Canvas Element - Methods

- possible values for contextType:
 - "2d", leading to the creation of a `CanvasRenderingContext2D` object representing a two-dimensional rendering context.
 - "webgl" which will create a `WebGLRenderingContext` object representing a three-dimensional rendering context. This context is only available on browsers that implement WebGL version 1 (OpenGL ES 2.0).
 - "bitmaprenderer" which will create a `ImageBitmapRenderingContext` which only provides functionality to replace the content of the canvas with a given `ImageBitmap`.

HTML5 Canvas Element - CanvasRenderingContext2D Interface

- used for drawing rectangles, text, images and other objects onto the canvas element. It provides the 2D rendering context for the drawing surface of a <canvas> element.
- API: developer.mozilla.org/en-US/docs/Web/API/CanvasRenderingContext2D
- Drawing rectangles:
 - clearRect() - sets all pixels in the rectangle defined by starting point (x, y) and size (width, height) to transparent black, erasing any previously drawn content.
 - fillRect() - draws a filled rectangle at (x, y) position whose size is determined by width and height.
 - strokeRect() - paints a rectangle which has a starting point at (x, y) and has a width and an h height onto the canvas, using the current stroke style.

HTML5 Canvas Element - CanvasRenderingContext2D Interface

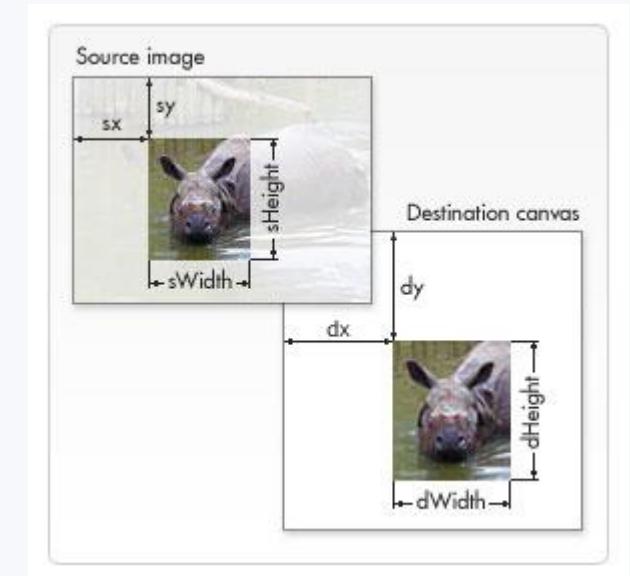
- Drawing text:
 - `fillText()` - draws (fills) a given text at the given (x,y) position;
 - `strokeText()` - draws (strokes) a given text at the given (x, y) position;
 - `measureText()` - returns a `TextMetrics` object.
- Drawing paths:
 - check [documentation](#)
- Line styles:
 - check [documentation](#)

HTML5 Canvas Element - CanvasRenderingContext2D Interface

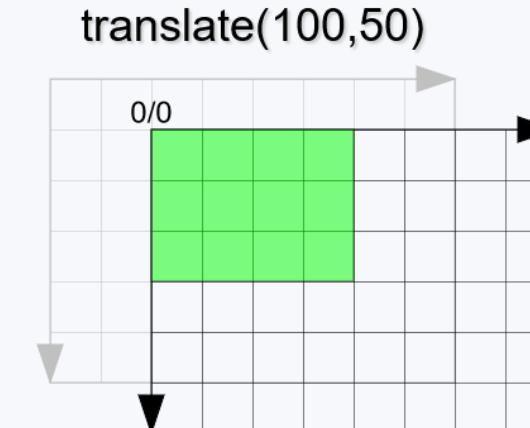
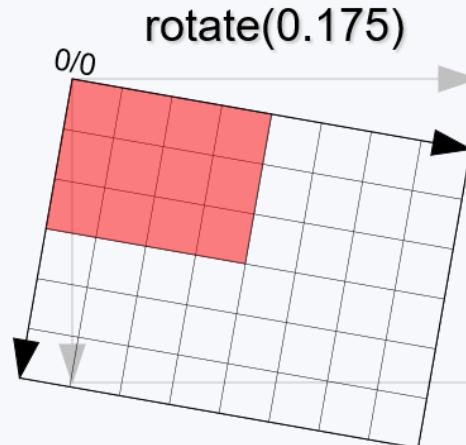
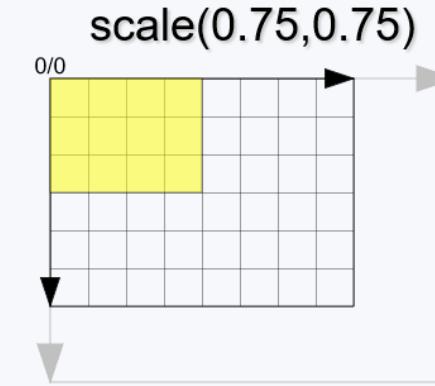
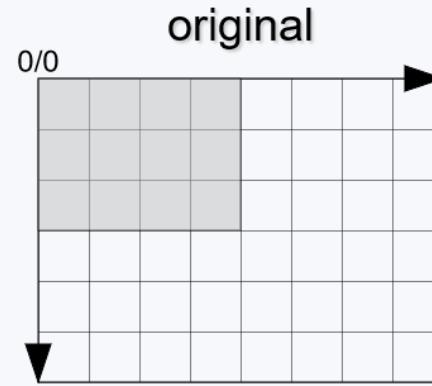
- Text styles:
 - check [documentation](#)
- Fill and stroke styles
 - check [documentation](#)
- Gradients and patterns
 - check [documentation](#)
- Shadows
 - check [documentation](#)

HTML5 Canvas Element - CanvasRenderingContext2D Interface

- Drawing images:
 - Without scaling
 - `void ctx.drawImage(image, dx, dy);`
 - With scaling
 - `void ctx.drawImage(image, dx, dy, dWidth, dHeight);`
 - `void ctx.drawImage(image, sx, sy, sWidth, sHeight, dx, dy, dWidth, dHeight);`
 - API: [Mozilla Developer Network](#)

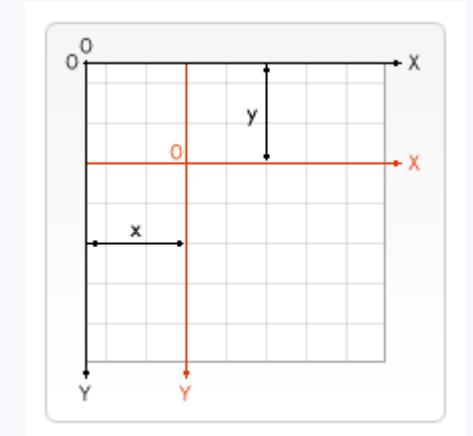


HTML5 Canvas Element - Transformations



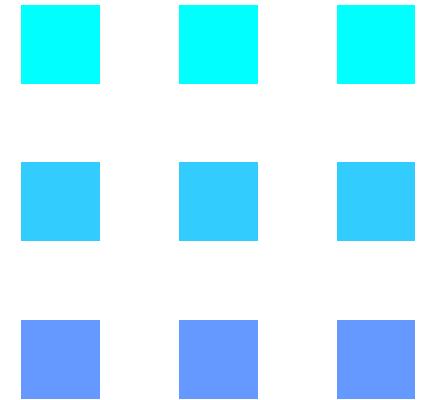
HTML5 Canvas Element - CanvasRenderingContext2D Interface

- Translating
 - `translate(x, y)`
 - changes the origin.
 - x indicates the horizontal distance to move, and y indicates how far to move the grid vertically.
 - API: [Mozilla Developer Network](#)



HTML5 Canvas Element - CanvasRenderingContext2D Interface

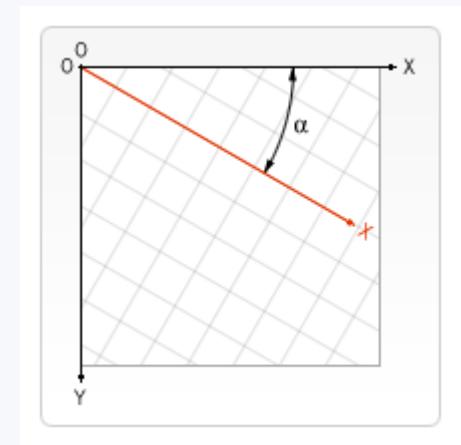
```
function draw() {  
    var ctx = document.getElementById('canvas').getContext('2d');  
    for (var i=0;i<3;i++) {  
        for (var j=0;j<3;j++) {  
            ctx.save();  
            ctx.fillStyle = 'rgb('+(51*i)+','+(255-51*i)+',255)';  
            ctx.translate(10+j*50,10+i*50);  
            ctx.fillRect(0,0,25,25);  
            ctx.restore();  
        }  
    }  
}
```



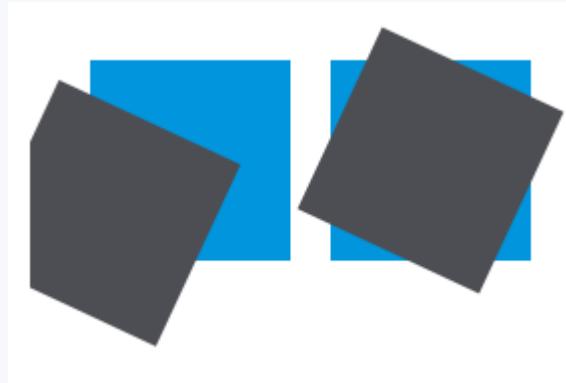
- Without the translate() method, all of the rectangles would be drawn at the same position (0,0). Using the translate() method we don't have to manually adjust the coordinates in the fillRect() function.
- JSFiddle: <https://jsfiddle.net/liviucotfas/9tfdegn7/>

HTML5 Canvas Element - CanvasRenderingContext2D Interface

- Rotating
 - `rotate(angle)`
 - Rotates the canvas clockwise around the current origin by the angle number of radians.
 - The rotation center point is always the canvas origin, unless it has been changed using the `translate()` method
 - Note: Angles are in radians, not degrees. Convert using: $\text{radians} = (\text{Math.PI}/180) * \text{degrees}$.
 - API: [Mozilla Developer Network](#)



HTML5 Canvas Element - CanvasRenderingContext2D Interface

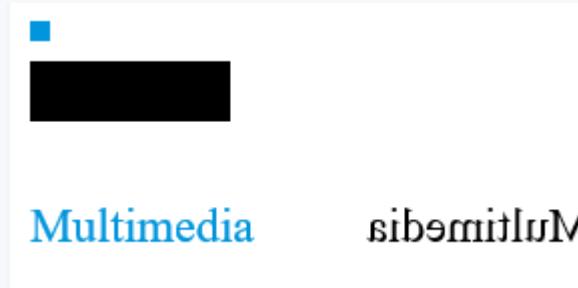


- rectangle 1: rotated based on the canvas origin
- rectangle 2: rotated from the center of the rectangle itself with the help of `translate()` method.
- JSFiddle: <https://jsfiddle.net/liviucotfas/2yf241q1/>

HTML5 Canvas Element - CanvasRenderingContext2D Interface

- Scaling
 - `scale(x, y)`
 - Scales the canvas units by x horizontally and by y vertically.
 - Both parameters are real numbers. Values that are smaller than 1.0 reduce the unit size and values above 1.0 increase the unit size. Values of 1.0 leave the units the same size.
 - Using negative numbers you can do axis mirroring
 - API: [Mozilla Developer Network](#)

HTML5 Canvas Element - CanvasRenderingContext2D Interface



- rectangle: scaled
- text: mirrored.
- JSFiddle: <https://jsfiddle.net/liviucotfas/Lyycaq7gv/>

HTML5 Canvas Element - CanvasRenderingContext2D Interface

- Combining Transforms
 - the browser is using a transformation matrix

```
context.scale(-.5, 1);
context.rotate(45 * Math.PI / 180);
context.translate(40, 10);
```

- the translate, rotate, and scale methods end up affecting the values stored by this matrix

$$\begin{pmatrix} m_{11} & m_{21} & d_x \\ m_{12} & m_{22} & d_y \\ 0 & 0 & 1 \end{pmatrix}$$

HTML5 Canvas Element - CanvasRenderingContext2D Interface

- Transforms
 - allow modifications directly to the transformation matrix
 - `transform(m11, m12, m21, m22, dx, dy)`
 - multiplies the current transformation matrix with the matrix described by its arguments.
 - API: [Mozilla Developer Network](#)

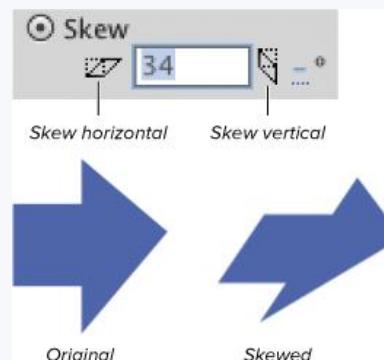
$$\begin{pmatrix} m_{11} & m_{21} & d_x \\ m_{12} & m_{22} & d_y \\ 0 & 0 & 1 \end{pmatrix}$$

HTML5 Canvas Element - CanvasRenderingContext2D Interface

- m11 - Horizontal scaling.
- m12 - Horizontal skewing.
- m21 - Vertical skewing.
- m22 - Vertical scaling.
- dx - Horizontal moving.
- dy - Vertical moving.

`transform(m11, m12, m21, m22, dx, dy)`

$$\begin{pmatrix} m_{11} & m_{21} & d_x \\ m_{12} & m_{22} & d_y \\ 0 & 0 & 1 \end{pmatrix}$$



HTML5 Canvas Element - CanvasRenderingContext2D Interface

- ex: coordinates transformation

$$\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{pmatrix} m_{11} & m_{21} & d_x \\ m_{12} & m_{22} & d_y \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$$

- resetTransform()
 - resets the current transform to the identity matrix. This is the same as calling:
`ctx.setTransform(1, 0, 0, 1, 0, 0);`

HTML5 Canvas Element - CanvasRenderingContext2D Interface

- `transform(m11, m12, m21, m22, dx, dy)`
 - resets the current transform to the identity matrix, and then invokes the `transform()` method with the same arguments.
 - basically undoes the current transformation, then sets the specified transform, all in one step.

HTML5 Canvas Element - ImageData Interface

- The ImageData interface represents the underlying pixel data of an area of a <canvas> element.
- API: [Mozilla Developer Network](#)

HTML5 Canvas Element - ImageData Interface

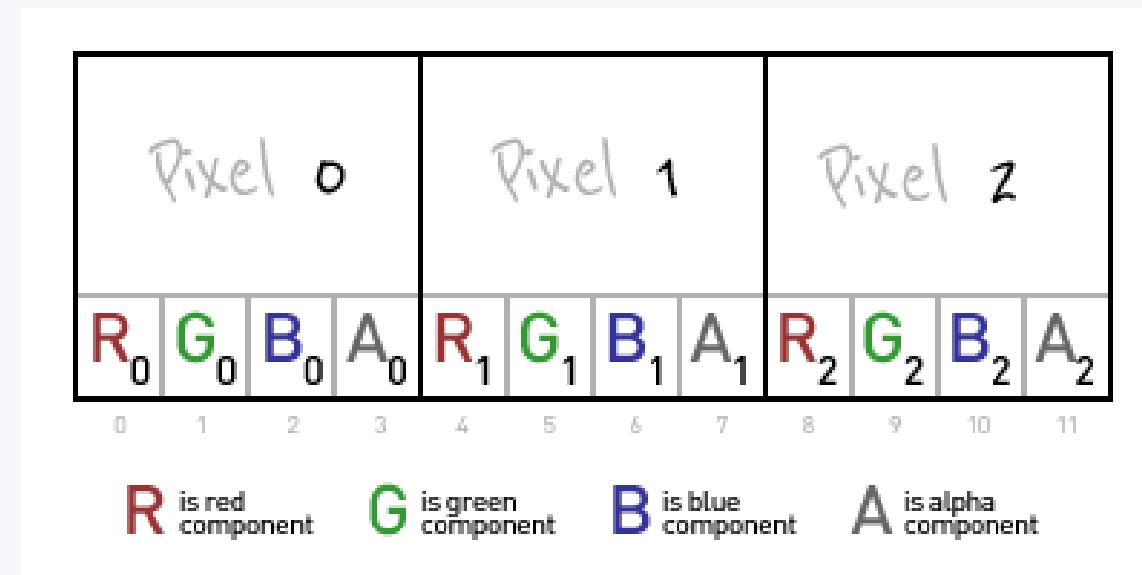
- It is created using the creator methods on the CanvasRenderingContext2D object associated with a canvas:
 - `CanvasRenderingContext2D.createImageData()`: creates a new, blank ImageData object with the specified dimensions. All of the pixels in the new object are transparent black.
 - `CanvasRenderingContext2D.getImageData(sx, sy, sw, sh)`: returns an ImageData object representing the underlying pixel data for the area of the canvas denoted by the rectangle which starts at (sx, sy) and has an sw width and sh height

HTML5 Canvas Element - ImageData Interface

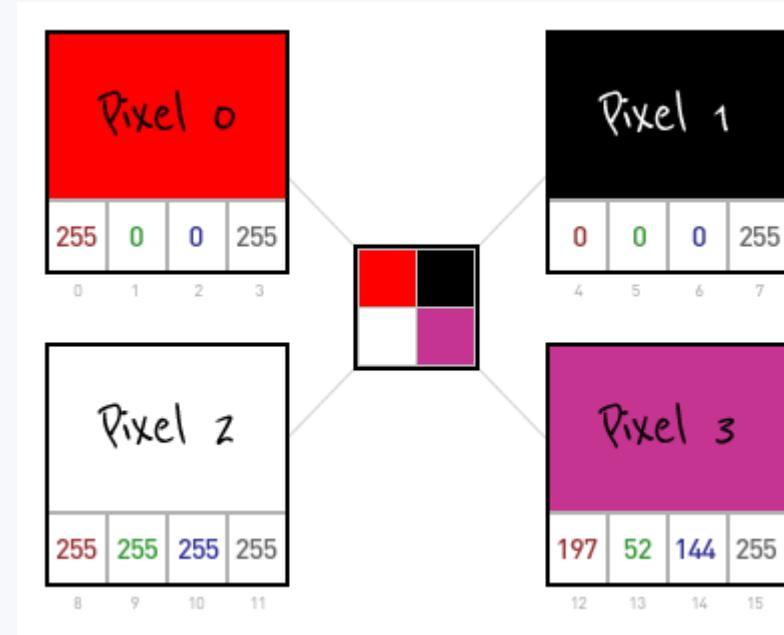
- It can also be used to set a part of the canvas by using:
 - `void ctx.putImageData(imagedata, dx, dy)`: paints data from the given `ImageData` object onto the bitmap at the given coordinates.
- JSFiddle: <https://jsfiddle.net/liviucotfas/64fzcae/>

HTML5 Canvas Element - ImageData Interface

- Properties
 - `ImageData.data` - a `Uint8ClampedArray` representing a one-dimensional array containing the data in the RGBA order, with integer values between 0 and 255 (included).



HTML5 Canvas Element - ImageData Interface



```
[255,0,0,255, 0,0,0,255, 255,255,255,255, 203,53,148,255]
```

HTML5 Canvas Element - ImageData Interface

- `ImageData.height` - an unsigned long representing the actual height, in pixels, of the `ImageData`.
- `ImageData.width` - an unsigned long representing the actual width, in pixels, of the `ImageData`.

HTML5 Canvas Element - ImageData Interface

- iterating over all the pixels in a canvas

```
var imageData = context.getImageData(0, 0, canvas.width, canvas.height);

for (var y = 0; y < canvas.height; y++) {
    for (var x = 0; x < canvas.width; x++) {
        var i = (y * canvas.width * 4) + x * 4;

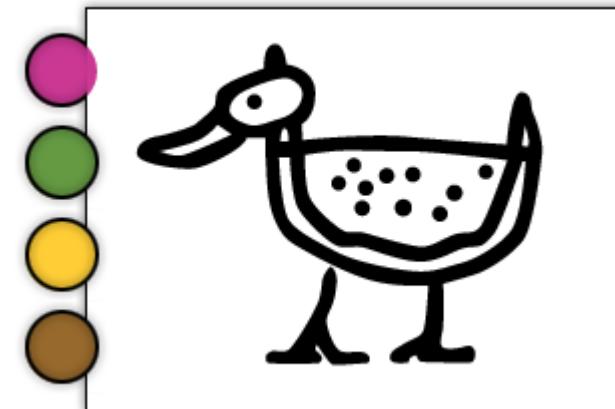
        var red = imageData.data[i]; // [0..255]
        var green = imageData.data[i+1]; // [0..255]
        var blue = imageData.data[i+2]; // [0..255]
        var transparency = imageData.data[i+3]; // [0..255]
    }
}
```

HTML5 Canvas Element

- Examples:
 - Color picker: https://developer.mozilla.org/en-US/docs/Web/API/Canvas_API/Tutorial/Pixel manipulation with canvas#A color picker
 - Zoom: https://developer.mozilla.org/en-US/docs/Web/API/Canvas_API/Tutorial/Pixel manipulation with canvas#A color picker

HTML5 Canvas Element

- Examples:
 - <http://www.williammalone.com/articles/html5-canvas-javascript-paint-bucket-tool/>
 - www.williammalone.com/articles/create-html5-canvas-javascript-drawing-app/#demo-complete



Effects

- Color Filter

- Red filter: $r' = r; g' = 0; b' = 0$

- Negative

- $r' = 255 - r; g' = 255 - g; b' = 255 - b;$

- Greyscale

- $r' = g' = b' = (r + g + b) / 3$

- $r' = g' = b' = 0.299 * r + 0.587 * g + 0.114 * b$

Effects

- Brightness
 - $r' = r + \text{value};$ if ($r' > 255$) $r' = 255$ else if ($r' < 0$) $r' = 0;$
 - $g' = g + \text{value};$ if ($g' > 255$) $g' = 255$ else if ($g' < 0$) $g' = 0;$
 - $b' = b + \text{value};$ if ($b' > 255$) $b' = 255$ else if ($b' < 0$) $b' = 0;$
- Threshold
 - $v = (0.2126*r + 0.7152*g + 0.0722*b) \geq \text{threshold} ? 255 : 0; r' = g' = b' = v$

Effects

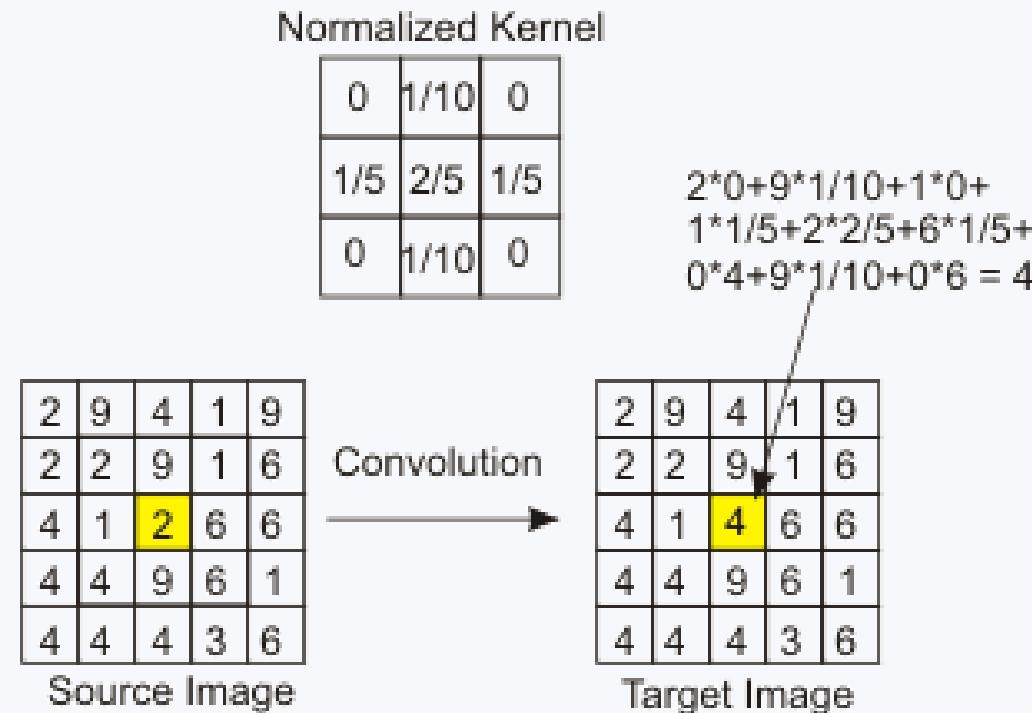
- Examples:
 - <https://www.html5rocks.com/en/tutorials/canvas/imagefilters/#toc-simplefilters>
- Further reading / examples:
 - https://developer.mozilla.org/en-US/docs/Web/API/Canvas_API/Tutorial/Pixel manipulation with canvas

Effects - Convolution filters

- Allow us to implement generic filters for image processing: blurring, sharpening, embossing, edge detection.
- Calculates the new value for a pixel based on the values of nearby pixels in the original image.
- Example: blur filter
$$\begin{bmatrix} 1/9, 1/9, 1/9, \\ 1/9, 1/9, 1/9, \\ 1/9, 1/9, 1/9 \end{bmatrix}$$
- Note: to maintain the brightness of the image, the sum of the matrix values should be one.

Effects - Convolution filters

- Examples: <https://www.html5rocks.com/en/tutorials/canvas/imagefilters/#toc-convolution>



WebGL

- Documentation: https://developer.mozilla.org/en-US/docs/Web/API/WebGL_API
- Three.js
 - cross-browser JavaScript library and Application Programming Interface (API) used to create and display animated 3D computer graphics in a web browser
 - Documentation: <https://threejs.org/>
 - Example: <https://heraclosgame.com/>

Raster Graphics

WebGL

- Babylonjs
 - JavaScript framework for building 3D games and experiences with HTML5, WebGL, WebVR and Web Audio
 - Documentation: <http://babylonjs.com/>

Vector Graphics

Vector Graphics

- In **bitmapped graphics**, the computer is given a detailed description of an image that it then matches, pixel by pixel.
- In **vector-drawn graphics**, the computer is given a **set of commands** that it executes to draw the image. Pictures contain *paths* made up of points, lines, curves and shapes.
- A **vector** is a line with a particular length, curvature, and direction. **Vector graphics** are composed of lines that are mathematically defined to form shapes such as rectangles, circles, triangles, and other polygons.

Vector Graphics

- Each vector path forms the outline of a geometric region containing color information.

Vector Graphics



Vector Graphics

- Because paths can be mathematically resized, vector graphics can be scaled up or down without losing any picture clarity.

Scaling / Zoom

GIMP



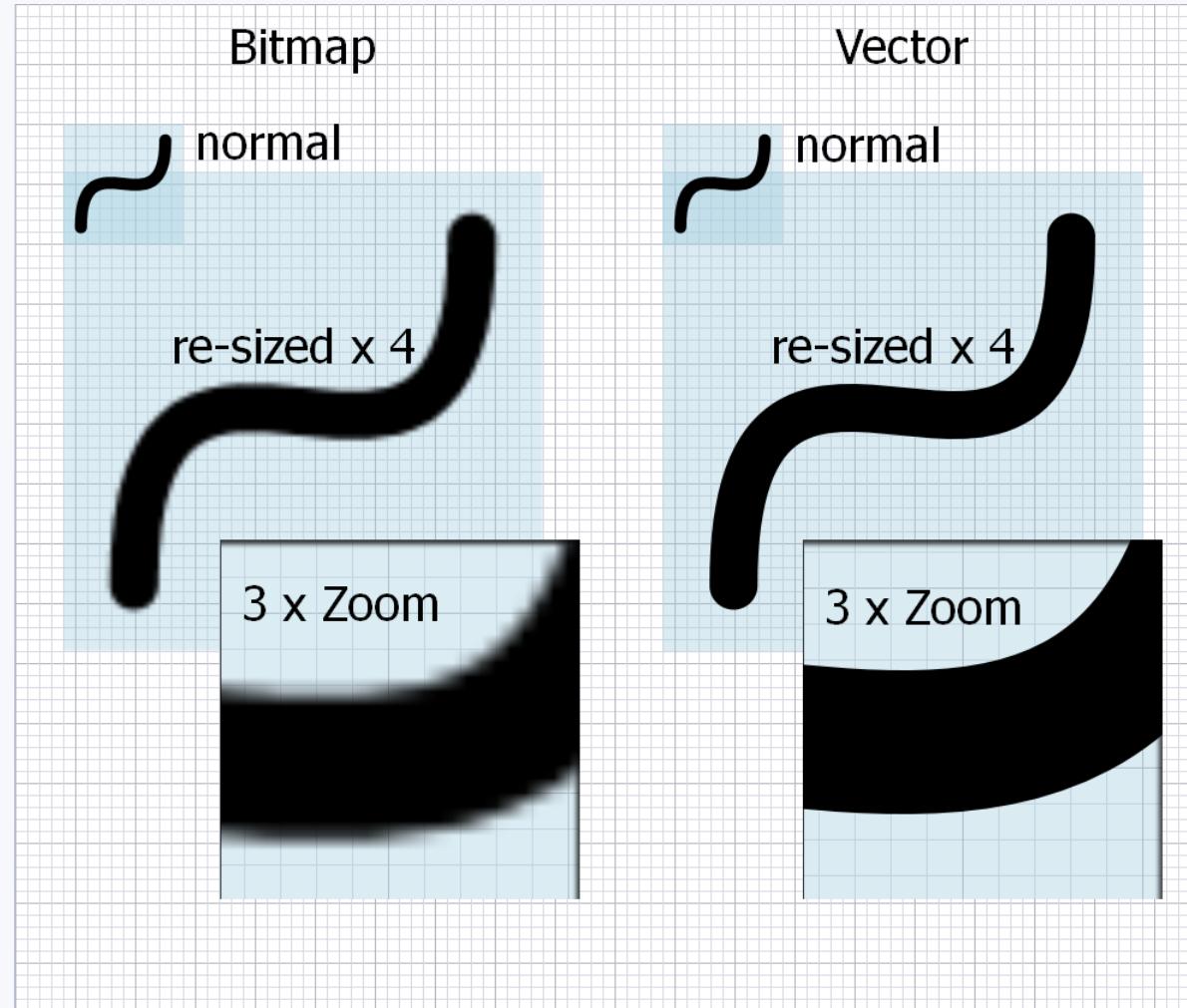
BITMAP
.jpeg .gif .png

INKSCAPE



OUTLINE
.svg

Scaling / Zoom



Animation

- You could also use vector graphics to create an animation, such as with Flash. Instead of drawing every separate frame of your project—with 24 frames appearing each second—you could create two different graphics for a segment and let your animation software mathematically interpolate the positions of the components in the in-between frames (a technique known as tweening).

Advantages and Disadvantages

- Advantages:
 - For relatively simple images, the list of drawing commands takes up much less file space than a bitmapped version of the same graphic.
 - A draw program might use a command similar to "RECT 300, 300, RED" to create a red square with sides of 300 pixels. The file for this image contains 15 bytes that encode the alphanumeric information in the command.
 - The same image could also be created with a paint program as a bitmapped graphic. Using 8-bit color resolution (one byte per pixel), this file would require 90,000 bytes (300×300). The much smaller files sizes of drawn images can be a significant advantage for multimedia developers.

Advantages and Disadvantages

- Another advantage of vector-drawn graphics is smooth **scaling**. Vector images are enlarged by changing the parameters of their component shapes. The new image can then be accurately redrawn at the larger size without the distortions typical of enlarged bitmapped graphics.
- Images that are needed in several sizes, such as a company logo, are often best handled as vector-drawn graphics.

Advantages and Disadvantages

- Disadvantages:
 - The principal disadvantage of vector-drawn graphics is lack of control over the individual pixels of the image. As a result, draw programs cannot match the capabilities of bitmapped applications for display and editing of photo-realistic images.

Formats

- SVG (Scalable Vector Graphics)
 - XML-based vector image format for two-dimensional graphics
 - provides supports for interactivity and animation
- DXF (Drawing Exchange Format)
 - is a CAD data file format developed by Autodesk for enabling data interoperability between AutoCAD and other programs.

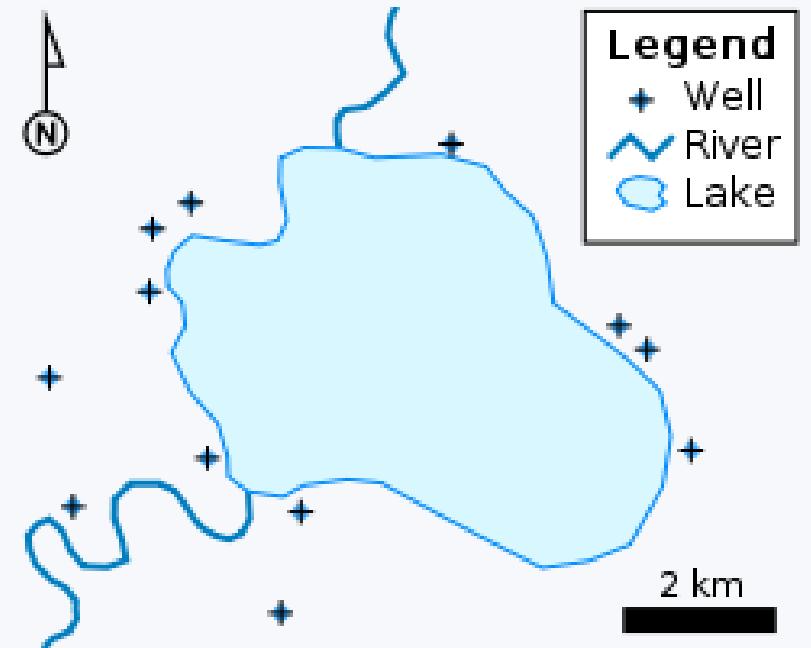
Formats

- EPS (Encapsulated Post Script)
 - Created by Adobe Systems for representing vector graphics
 - Uses a computer language called Post Script
- SHP (Shapefile)
 - developed and regulated by Esri as a (mostly) open specification for data interoperability among Esri and other GIS software products
 - popular geospatial vector data format for geographic information system (GIS) software

Vector Graphics Formats

Simple vector map that can be stored as Shape file:

- points (wells),
- polylines (rivers), and
- polygons (lake).

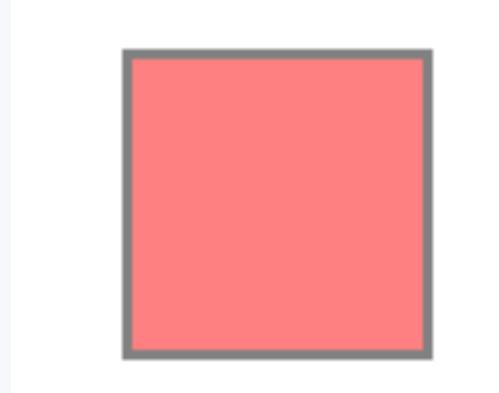


SVG – Scalable Vector Graphics

- XML-based vector image format for two-dimensional graphics
- provides supports for interactivity and animation

```
<!DOCTYPE html>
<html>
<body>
    <svg width="400" height="180">
        <rect x="50" y="20" width="150" height="150"
style="fill:red;stroke:black;stroke-width:5;opacity:0.5">
    </svg>
</body>
```

SVG – Scalable Vector Graphics



SVG – Scalable Vector Graphics

- Creating SVG Images
- SVG images can be created with any text editor, but it is often more convenient to create SVG images with a drawing program, like [Inkscape](#).

SVG – Scalable Vector Graphics

- Line

```
<line x1="start-x" y1="start-y" x2="end-x" y2="end-y">
```

- Example:

- http://www.w3schools.com/graphics/svg_line.asp

```
<svg height="210" width="500">
    <line x1="0" y1="0" x2="200" y2="200" style="stroke:rgb(255,0,0);stroke-width:2" />
</svg>
```

SVG – Scalable Vector Graphics

- Rectangle

```
<rect x="start-x" y="start-y" width="width" height="height" rx="radius-x"  
ry="radius-y"/>
```

- Example

- http://www.w3schools.com/graphics/svg_rect.asp

```
<svg width="400" height="110">  
  <rect width="300" height="100" style="fill:rgb(0,0,255);stroke-width:3;stroke:rgb(0,0,0)" />  
</svg>
```

SVG – Scalable Vector Graphics

- Circle

```
<circle cx="center-x" cy="center-y" r="radius"/>
```

- Example
 - http://www.w3schools.com/graphics/svg_circle.asp

```
<svg height="100" width="100">
  <circle cx="50" cy="50" r="40" stroke="black" stroke-width="3" fill="red" />
</svg>
```

SVG – Scalable Vector Graphics

- Elipse

```
<ellipse cx="center-x" cy="center-y" rx="radius-x" ry="radius-y"/>
```

- Polygon

```
<polygon points="x1,y1 x2,y2 ..."/>
```

- Polyline

```
<polyline points="x1,y1 x2,y2 ..."/>
```

- Text

```
<text x="start-x" y="start-y">continut</text>
```

SVG – Scalable Vector Graphics

- Grouping elements

```
<g id="id_grup">... <!-- elemente --> </g>
```

- Defining groups

```
<defs>... <!-- definire grupuri --> </defs>
```

- Reusing groups

```
<use xlink:href="#id_grup" x="30" y="14"/>
```

Vector Graphics

SVG – Scalable Vector Graphics

- Interacting with SVG using CSS
- Link: [https://developer.mozilla.org/en-US/docs/Web/Guide/CSS/Getting started/SVG and CSS](https://developer.mozilla.org/en-US/docs/Web/Guide/CSS/Getting_started/SVG_and_CSS)

SVG – Scalable Vector Graphics

- Interacting with SVG using JavaScript / jQuery
 - similar to the approach used for HTML elements;
- Particularities
 - when creating an element we need to use the SVG namespace

```
document.createElementNS("http://www.w3.org/2000/svg", „TAG_SVG")
```

Vector Graphics

SVG – Scalable Vector Graphics

- Example

```
$(document.createElementNS("http://www.w3.org/2000/svg", "rect"))  
    .attr({x:160, y:160, width:12, height:12})  
    .appendTo($("#drawing"));
```

<https://developer.mozilla.org/en-US/docs/Web/SVG>

Digital Video

Definition

- Digital video is a representation of **moving visual images** in the form of encoded digital data. This is in contrast to analog video, which represents moving visual images with analog signals.
- Digital video comprises a series digital images displayed in rapid succession. In contrast, one of the key analog video methods, motion picture film, uses a series of photographs which are projected in rapid succession.
- Digital video was first introduced commercially in 1986 with the Sony D1 format, which recorded an uncompressed standard definition component video signal in digital form instead of the high-band analog forms that had been commonplace until then.

Advantages

- Digital video can be processed using specialized computer software.
- Digital video can be **copied** with no degradation in quality. In contrast, when analog sources are copied, they experience generation loss.
- Digital video can also be **stored** on hard disks or **streamed** over **the Internet** to end users who watch content on a desktop computer screen or a digital Smart TV.
- The soundtrack is also stored as digital audio .

Characteristics

- Screen Resolution
- Color Depth
- Frame Rate
- Interlaced / Progressive
- Compression Method (codec)

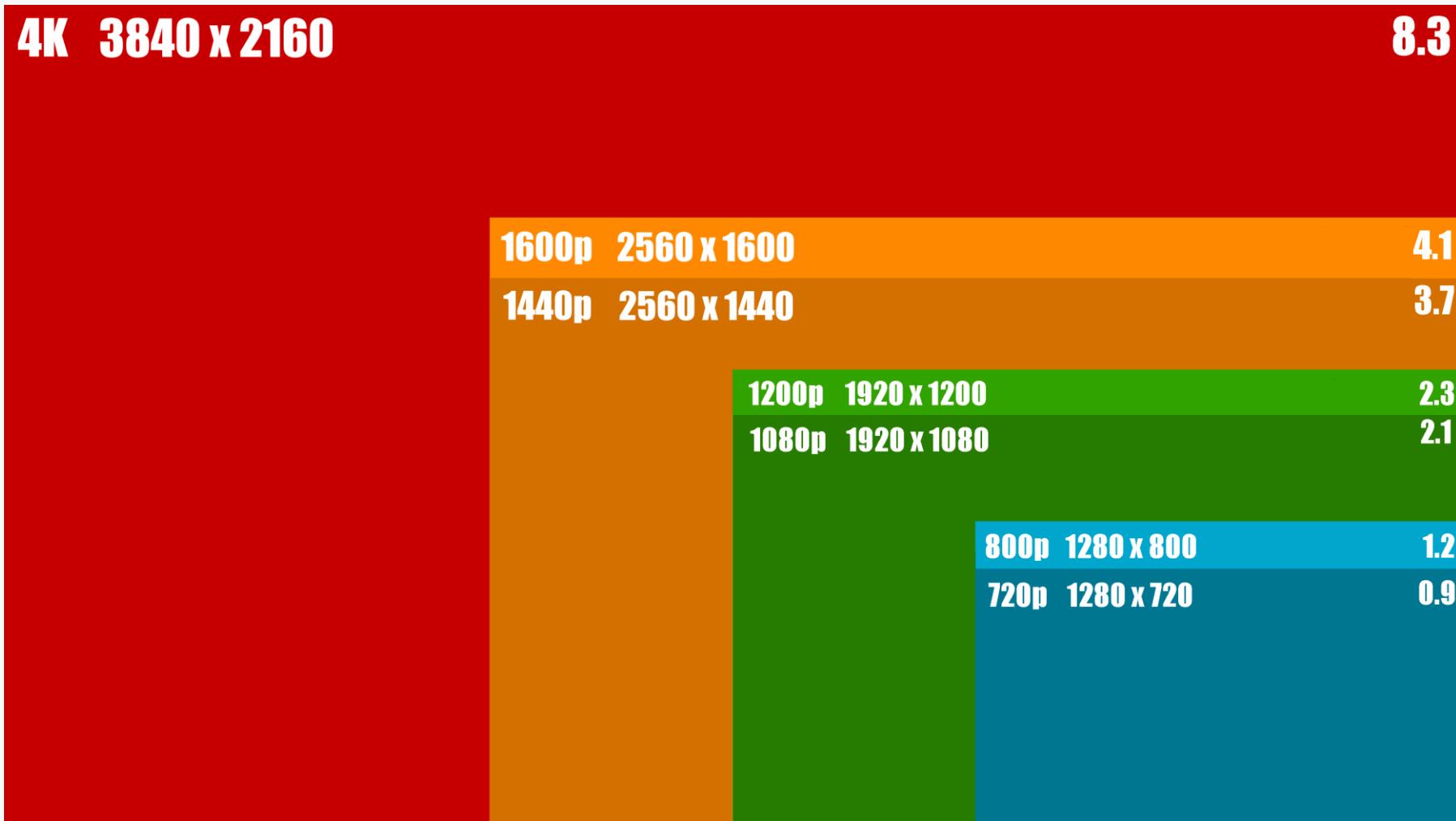
Characteristics - Screen Resolution

- means the **width** and **height** of the displayed image, measured in pixels. In other words, the total number of pixels contained in each individual frame (**also called Spatial resolution**) [1]
- the smaller the screen resolution of a digital video, the less processing, storage, and transmission it requires [2].
- The output resolution of the relatively high-quality DV (digital video) format is **720 × 480 pixels**. This requires the computer to process and transmit information for nearly **350,000 pixels** at rates of up to 30 times per second [2].
- Reducing display size to **176 × 144** for mobile phones yields a pixel count of approximately **25,000** [2].

Characteristics – Common Screen Resolution

Name	Pixels (width x height)	Aspect Ratio	Notes
<i>Standard Definition (SD)</i>			
480p / 480i	720x480 (or 704x480)	4:3 (approx)	NTSC
576p / 576i	720x576 (or 704x576)	4:3 (approx)	PAL
<i>High Definition (HDTV)</i>			
720p	1280x720	16:9	
1080p / 1080i	1920x1080	16:9	
<i>Ultra High Definition (UHDTV)</i>			
4K (2160p)	3840x2160	16:9	Exactly 4 × 1080p
8K (4320p)	7680x4320	16:9	Exactly 16 × 1080p
8640p	15360x8640	16:9	Exactly 32 × 1080p
<i>Digital Cinema (DCI)</i>			
2K	2048 × 1080	1.90:1	The first generation of digital cinema projectors.
4K	4096 × 2160	1.90:1	2nd generation digital cinema.

Characteristics - Screen Resolution



Characteristics - Screen Resolution



Characteristics - Color Depth

- Color **depth** is the number of bits used to indicate the color of a single **pixel** in a video frame buffer, or the number of bits used for each color component of a single **pixel**
- Similar to raster images, the more bits are used for storing the color, the more subtle variations of colors can be reproduced.

Characteristics – Frame Rate

- Frame rate, also known as frame frequency, is the frequency (rate) at which an imaging device displays consecutive images called frames.
- The perception of continuous motion in video is dependent on two factors. First, images must be displayed rapidly enough to allow persistence of vision to fill the interval between frames. Second, the changes in the location of objects from frame to frame must be relatively gradual.
- Lowering the frame rate both slows the delivery of individual images and drops out frames of video. If the rate is low enough, viewers will experience a string of still images with abrupt changes of content—in other words, a jerky video.

Characteristics – Frame Rate

- A common frame rate for broadcast video is 30 frames per second (fps). Video intended for streaming over the Internet is often delivered at a rate of just 15 fps, effectively cutting the required data rate in half [1]
- NTSC used about 30 frames per second and PAL used 25 frames per second [2].

Characteristics – Interlaced / Progressive

- **Progressive video**
 - each frame is displayed similar to the text on a page - line by line, top to bottom.
- **Interlaced video**
 - each frame is composed of two halves of an image. In the first pass all odd numbered lines are displayed, from the top left corner to the bottom right corner. The second pass displays the second and all even numbered lines, filling in the gaps in the first scan.
 - the two halves are referred to individually as fields. Two consecutive fields compose a full frame. If an interlaced video has a frame rate of 15 frames per second the field rate is 30 fields per second.

Characteristics – Interlaced / Progressive

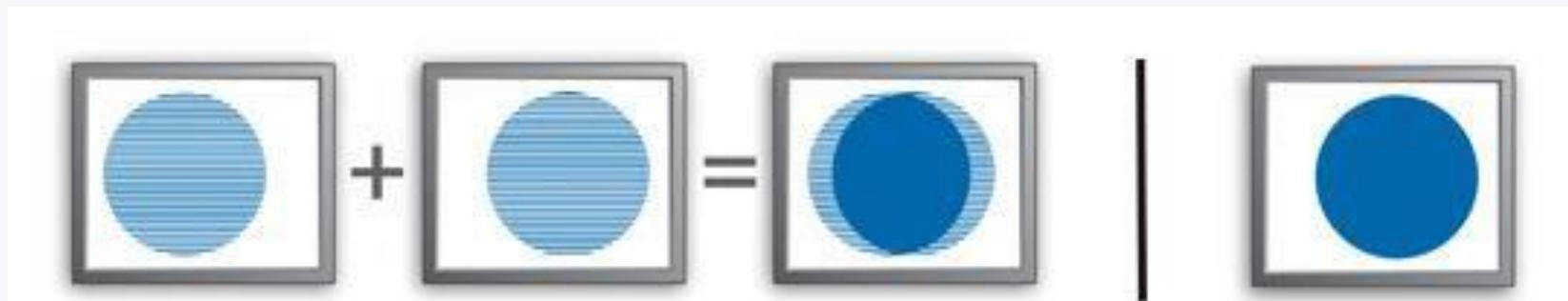


Characteristics – Interlaced / Progressive

- Examples of formats:
 - PAL -576p (progressive) / 576i (interlaced)
 - FullHD – 1080p (progressive) / 1080i (interlaced)
- Benefits of interlacing
 - for a fixed bandwidth, interlace provides a video signal with twice the display refresh rate for a given line count (versus progressive scan video at a similar frame rate—for instance 1080i at 60 half-frames per second, vs. 1080p at 30 full frames per second).
 - bandwidth benefits **only apply** to an **analog or uncompressed digital video** signal. With digital video compression, as used in all current digital TV standards, interlacing introduces additional inefficiencies.

Characteristics – Interlaced / Progressive

- Interlacing issues
 - Because each interlaced video frame is composed of two fields captured at different moments in time, interlaced video frames can exhibit motion artifacts known as interlacing effects, if recorded objects move fast enough to be in different positions when each individual field is captured.
 - These artifacts may be more visible when interlaced video is displayed at a slower speed than it was captured, or in still frames.



Characteristics – Compression

- **Redundancy** - the amount of wasted space consumed by storage media to record picture information in a digital image / digital video.

- The goal of **video compression** is two-fold:
 1. to reduce the file size of an image by eliminating or rewriting as much of the redundant information as possible;
 2. to retain the visible quality of an image.

Characteristics – Compression

- Redundancies can occur:
 - within the two-dimensional space of a single frame of video (as with a photograph) - *spatial redundancy*.
 - across time in a video sequence containing many frames – *temporal redundancy*.
- Example: a five-second (150 frames) shot of a blue sky on a cloudless day.
 - thousands of blue pixels retain the same color value across the entire sequence of 150 frames. This phenomenon is called *temporal redundancy* and occurs whenever the value of a pixel remains unchanged from one frame to the next in a time-based sequence. The pixels also stretch outward within the space of each individual frame. This phenomenon is called *spatial redundancy*.

Characteristics – Compression



Spatial redundancy

Characteristics – Compression



Temporal redundancy (1 second / 30 Frames)

Characteristics – Compression

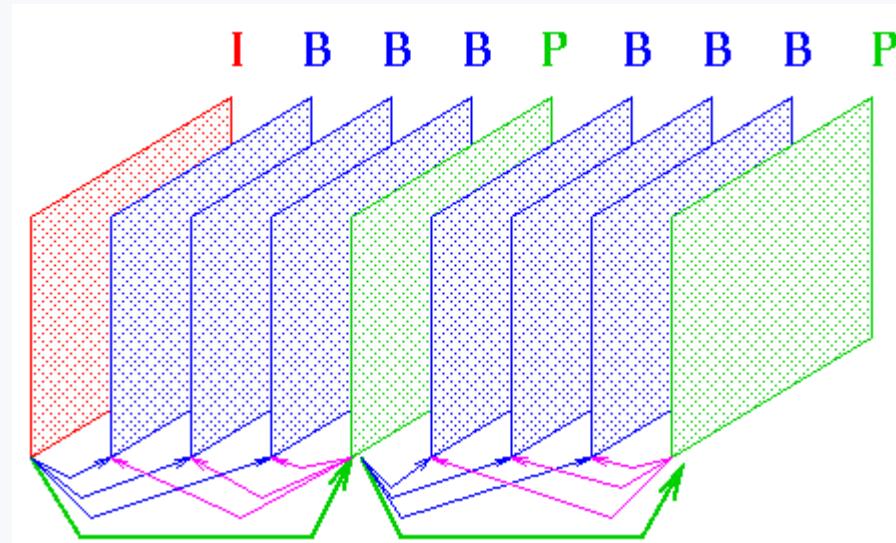
- *Intraframe (or I-frame) compression*
 - Eliminates spatial redundancies “within” a video frame in much the same way that JPEG compression is used to reduce them in a digital photograph.
 - I-frames are typically compressed at a ratio of 10:1. This means that a compressed I-frame consumes as little as 10% of the file space of a raw uncompressed frame.
 - Since I-frames are fully defined by information from within the frame, they can be easily decoded and rendered onscreen during playback and editing.
 - However, the overall amount of compression that’s achieved with this approach is limited since temporal redundancies are not addressed.

Characteristics – Compression

- *Interframe compression* (more common method)
 - exploits both spatial and temporal redundancies.
 - using the previous method of **intraframe compression**, all of the frames in a video stream are turned into I-frames. Each one is *intracoded* to eliminate spatial redundancy. Thus, compression is applied evenly to all of the frames within a video stream.
 - with **interframe compression**, I-frames are created at fixed intervals (typically every 15 frames). An I-frame marks the beginning of a packaged sequence of adjacent frames called a GOP (Group of Pictures). The fully defined I-frame serves as a *keyframe* or reference for other frames in the group. Its job is to hold repeating color values in place that will not change across the sequence. Basically, it creates a digital marker on the frame that says “do not change the color of this pixel until you are told to do so.”

Characteristics – Compression

- MPEG Compression
 - exploits both spatial and temporal redundancies (interframe compression)
 - each I-frame is followed by a sequence of 14 frames designated as either a *P-frame* or a *B-frame*.



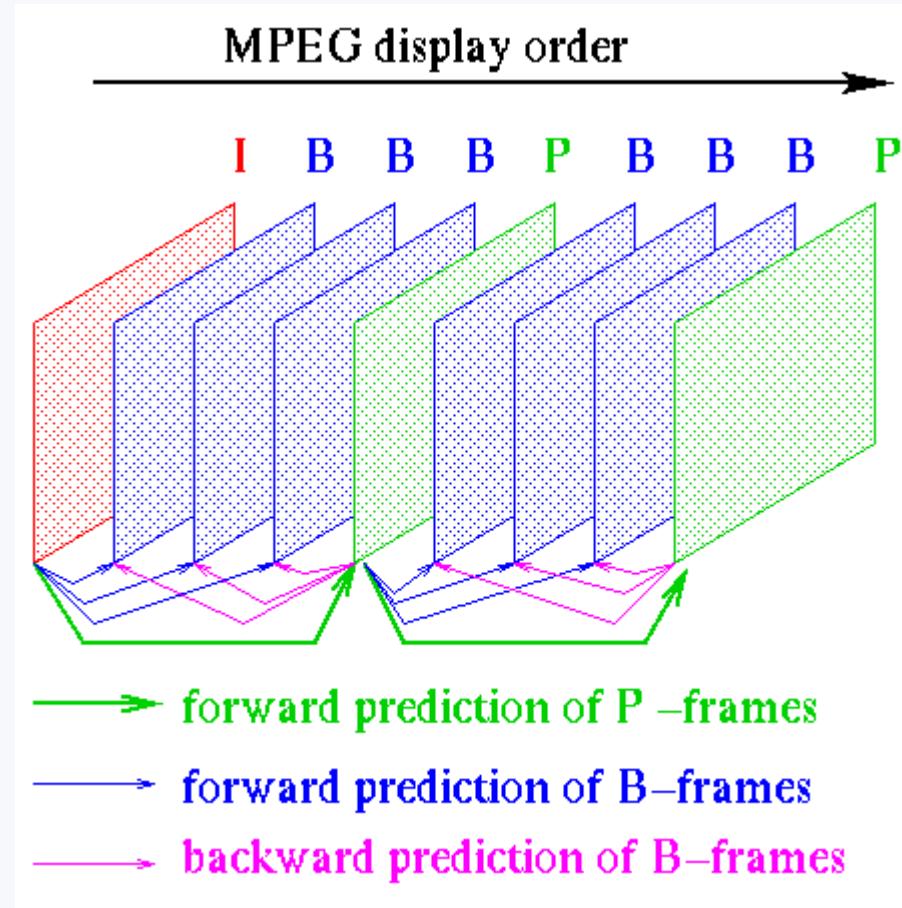
Characteristics – Compression

- A *P-frame*
 - a predictive coded image that only stores data for pixels that are different from the preceding frame.
 - Example: in a shot of a bird flying across a blue sky, only pixels related to the moving bird would be encoded to a P-frame. The unchanged background pixels simply carry forward from information stored in the previous frame.
 - on average, a P-frame can be compressed twice as much as an I-frame.

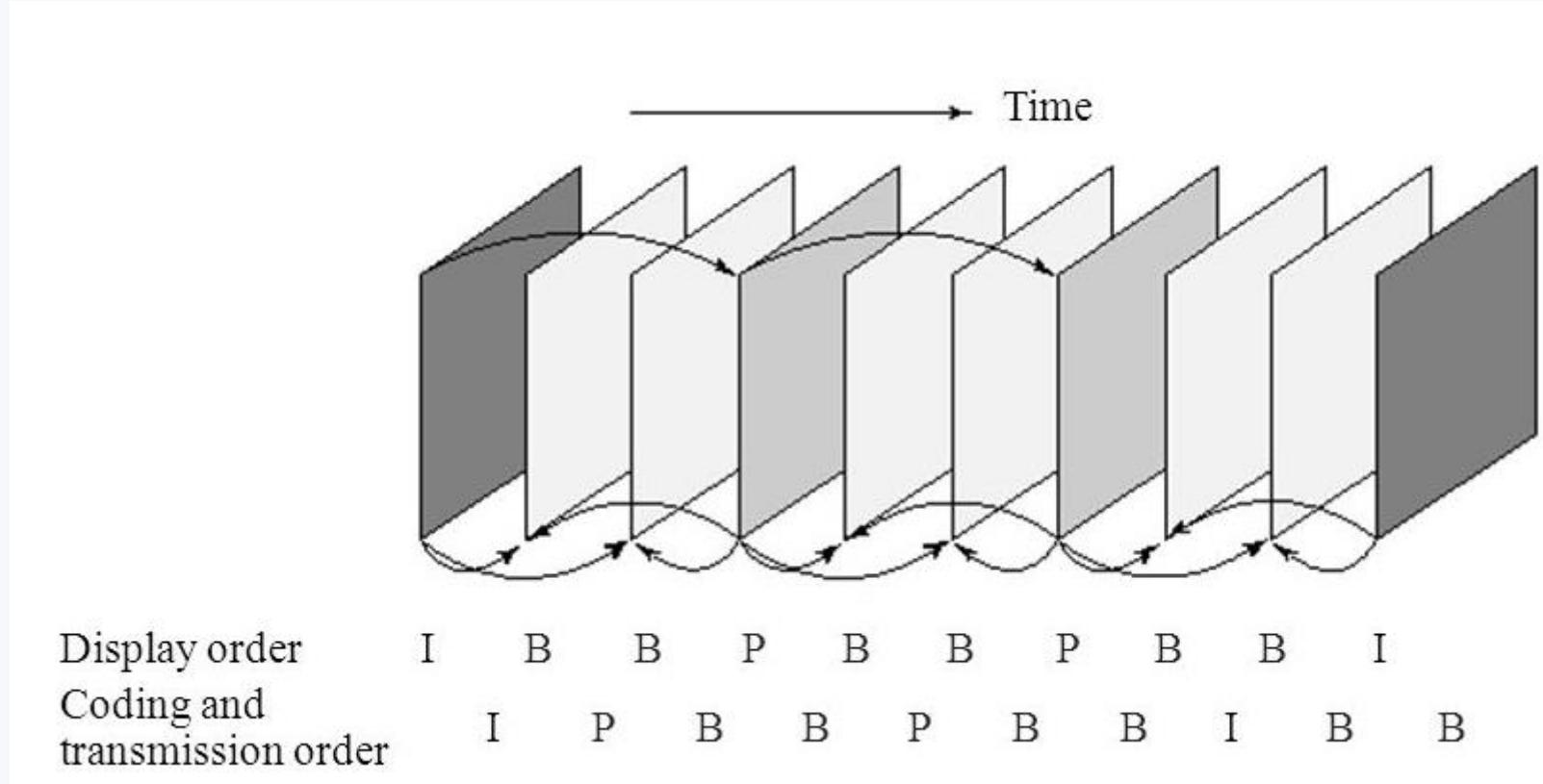
Characteristics – Compression

- A *B-frame*
 - a bidirectional predictive coded image. It records changes from both the preceding frame and the one immediately following.
 - On average, a B-frame can be compressed twice as much as a P-frame.
- With **interframe encoding**, all frames are not equally compressed. The more heavily compressed P-frames and B-frames require more processing power to encode and decode.

Characteristics – Compression



Characteristics – Compression



Characteristics – Video Formats - Containers

- Container:
 - exists solely for the purpose of bundling all of the audio, video, and codec files into one organized package.
 - in addition, the container often contains chapter information for DVD or Blu-ray movies, metadata, subtitles, and/or additional audio files such as different spoken languages.

Characteristics – Video Formats - Containers

- **Matroska Multimedia Container MKV:**
 - file extension: .mkv .mk3d .mka .mks
 - Google *.webm is based on the specifications of this format
 - open standard, free container format
 - supports almost any audio or video format which makes it adaptable, efficient, and highly regarded as one of the best ways to store audio and video files.
 - supports multiple audio, video and subtitle files even if they are encoded in different formats.
 - due to the options the container offers, as well as its handling of error recovery (which allows you to play back corrupted files), it has quickly become one of the best containers currently available.

Characteristics – Video Formats - Containers

- **MPEG-4 (MP4):**
 - file extension: .mp4
 - digital multimedia container format most commonly used to store video and audio
 - recommended format for uploading video to the web
 - utilizes MPEG-4 encoding, or H.264, as well as AAC or AC3 for audio. It's widely supported on most consumer devices, and the most common container used for online video

Characteristics – Video Formats - Containers

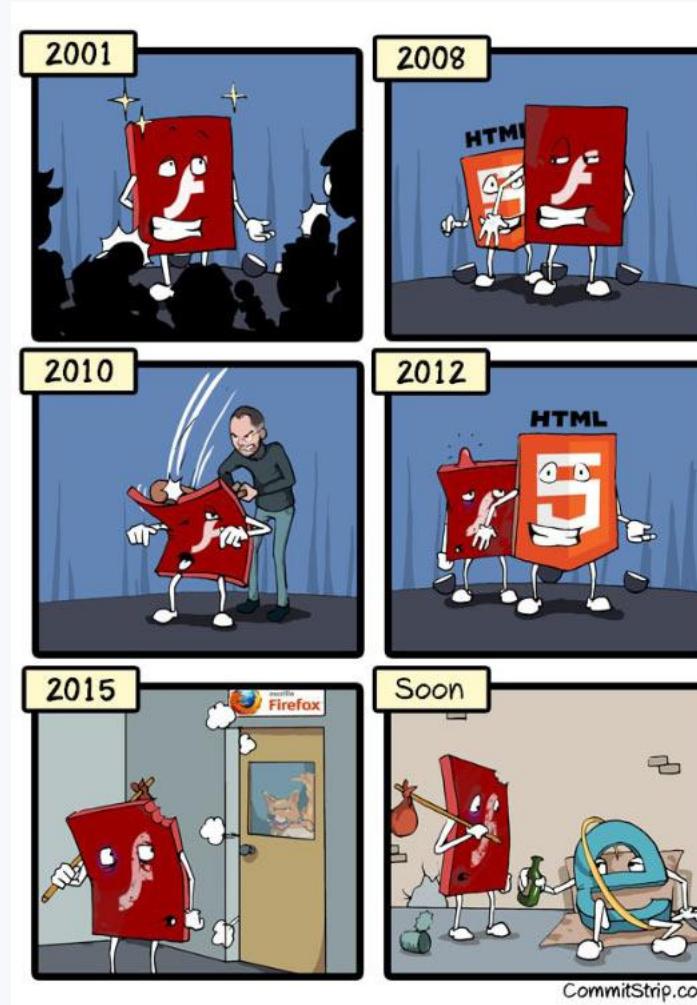
- Other popular Video Containers:
 - Ogg - free, open container format
 - AVI – Windows Professional
 - MOV – Mac everything
 - MPEG or MPG – by the MPEG group
 - FLV – Flash video
 - MP4 – by the MPEG group
 - VOB – DVDs
- Comparison:
 - https://en.wikipedia.org/wiki/Comparison_of_video_container_formats

Web Video

"Flash was created during the PC era – for PCs and mice. Flash is a successful business for Adobe, and we can understand why they want to push it beyond PCs. But the mobile era is about low power devices, touch interfaces and open web standards – all areas where Flash falls short. The avalanche of media outlets offering their content for Apple's mobile devices demonstrates that Flash is no longer necessary to watch video or consume any kind of web content."

Steve Jobs

Web Video - The Evolution Of Flash



Web Video

- <video> - HTML element used to embed video content in a document. The video element contains one or more video sources. To specify a video source, use either the src attribute or the <source> element; the browser will choose the most suitable one.

```
<video controls>
  <source src="foo.webm" type="video/webm">
  <source src="foo.ogg" type="video/ogg">
  <source src="foo.mov" type="video/quicktime">
  I'm sorry; your browser doesn't support HTML5 video.
</video>
```

Web Video

- <video>
 - attribute: *autoplay, controls, src, volume, ...*
 - API: <https://developer.mozilla.org/en-US/docs/Web/HTML/Element/video>
- HTMLVideoElement (JavaScript)
 - properties: currentSrc, currentTime, duration, ended, error, paused, readyState, volume
 - methods canPlayType, load, pause, play
 - events: canplay, ended, pause, play, volumechange, waiting
- API: <https://developer.mozilla.org/en-US/docs/Web/API/HTMLVideoElement>

Web Video

- <track>
 - HTML element used as a child of the media elements - <audio> and <video>. It lets you specify timed text tracks (or time-based data), for example to automatically handle subtitles.
 - The tracks are formatted in WebVTT format (.vtt files) - Web Video Text Tracks.
 - Link: <https://developer.mozilla.org/en-US/docs/Web/HTML/Element/track>

Web Video

- <source>
 - HTML element is used to specify multiple media resources for either the <picture>, the <audio> or the <video> element.
 - It is an empty element.
 - It is commonly used to serve the same media content in multiple formats supported by different browsers..
 - Link: <https://developer.mozilla.org/en-US/docs/Web/HTML/Element/source>

```
<video controls>
  <source src="foo.webm" type="video/webm">
  <source src="foo.ogg" type="video/ogg">
  I'm sorry; your browser doesn't support HTML5 video.
</video>
```

Web Video

- recommended video formats:
 - webm – type = video/webm
 - mp4 – type = video/mp4
 - .ogg – type = video/ogg

```
<video controls>
  <source src="foo.webm" type="video/webm">
  <source src="foo.ogg" type="video/ogg">
I'm sorry; your browser doesn't support HTML5 video.
</video>
```

Web Video

- Live Demo: <https://www.w3.org/2010/05/video/mediaevents.html>
- API: <https://www.w3.org/TR/html5/embedded-content-0.html#mediaevents>
- Media Player:
 - [https://developer.mozilla.org/en-US/Apps/Fundamentals/Audio and video delivery/Adding captions and subtitles to HTML5 video](https://developer.mozilla.org/en-US/Apps/Fundamentals/Audio_and_video_delivery/Adding_captions_and_subtitles_to_HTML5_video)

Web Video

```
var W = canvas.width = video.clientWidth;
var H = canvas.height = video.clientHeight;

context.drawImage(video, 0, 0, W, H);
var imageData = context.getImageData(0, 0, W, H);

for (var y = 0; y < H; y++) {
    for (var x = 0; x < W; x++) {
        var i = (y * W * 4) + x * 4;
            // change values in imageData.data[i+...]
    }
}
context.putImageData(imageData, 0, 0);
// other canvas drawing operations
```

Web Video

```
//create the video element using jQuery
var v = $("<video></video>")
    .attr({
        "controls": "",
        "autoplay": "",
        "src": "media/movie.mp4"
    })
    .load()
    .appendTo($("#body"));

// change the video file
v[0].src = "media/test.mp4";
v[0].load();
v[0].play();
```

Web Video – Simple playlist

```
$ (function () {
    var lista = ["movie.mp4", "v2.mp4"];
    var index = 0;

    var video = $( "#myVideo" );

    video.on("ended", function () {
        index = index + 1;
        if (index >= lista.length) index = 0;

        video[0].src = lista[index];
        video[0].load();
        video[0].play();
    });
});
```

Lab Examples

- <https://ase-multimedia.azurewebsites.net/video-player/>
- <https://ase-multimedia.azurewebsites.net/video-processing/>
- <https://ase-multimedia.azurewebsites.net/video-effects/>



Audio

Sound

- Sound is a form of mechanical energy transmitted as vibrations in a medium.
- The medium is usually air, though sound can also be transmitted through solids and liquids.
- Example: a clap of the hands produces sound by suddenly compressing and displacing air molecules. The disturbance is transmitted to adjacent molecules and propagated through space in the form of a wave. We hear the hand clap when these vibrations cause motions in the various parts of our ears.

Sound

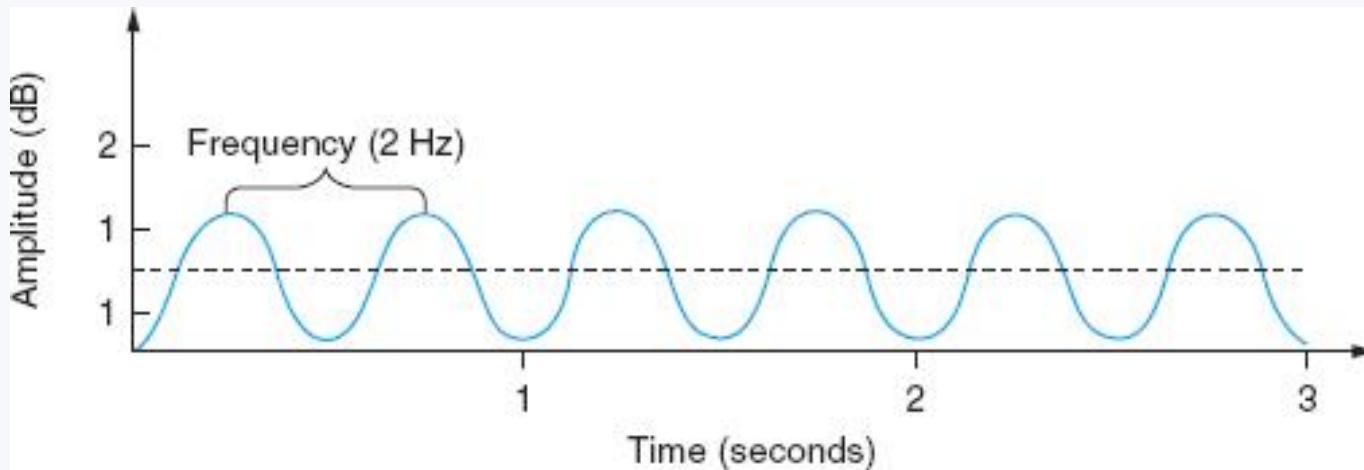
- Sound waves are often compared to the ripples produced when a stone is thrown into a pond. The stone displaces the water to produce high points, or wave peaks, and low points, or troughs. We see these alternating peaks and troughs as patterns of waves moving outward from the stone's point of impact. The clap of the hand also produces peaks and troughs as high air pressure is followed by a return to lower pressure. These changes in air pressure produce patterns of waves spreading in all directions from the sound's source.



Sound

- Humans can hear sound waves with frequencies between about 20 Hz and 20 kHz
- **Noise** is unwanted sound judged to be unpleasant, loud or disruptive to hearing. From a physics standpoint, noise is indistinguishable from sound, as both are vibrations through a medium, such as air or water. The difference arises when the brain receives and perceives a sound.

Representation

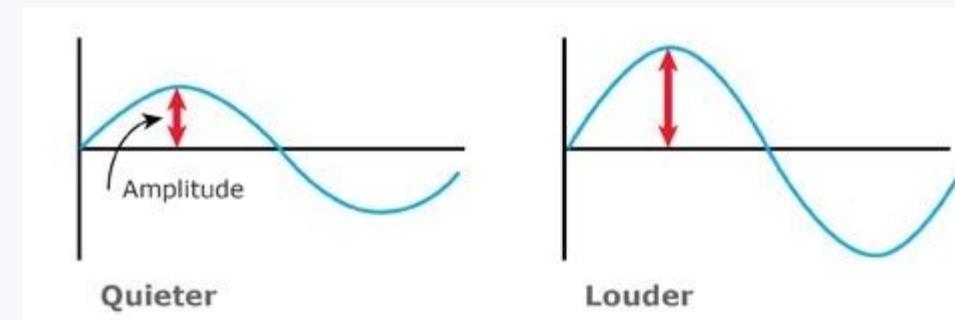


Characteristics

- amplitude
- frequency
- duration

Characteristics

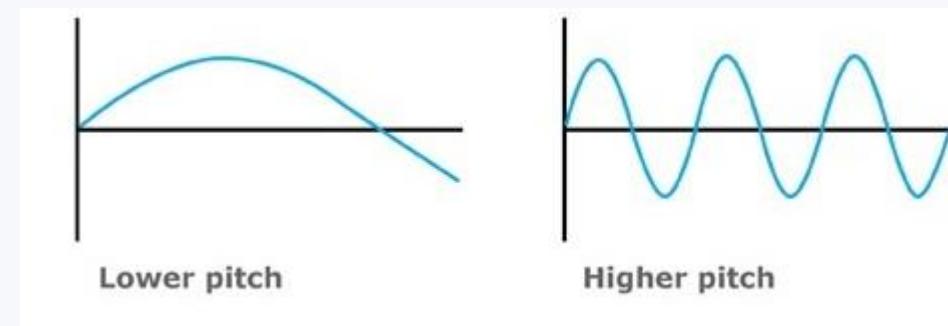
- **Amplitude** is a measure of sound pressure or the amount of energy associated with the sound. This is represented by the vertical, or *y*-axis, of the sine wave. Amplitude is perceived as the sound's **volume**, which is usually measured in **decibels (dB)**.



- In general, sounds with higher amplitudes are experienced as *louder*. The range of human hearing is approximately 3 to 140 dB. Each 10 dB increase roughly doubles the perceived volume of a sound.

Characteristics

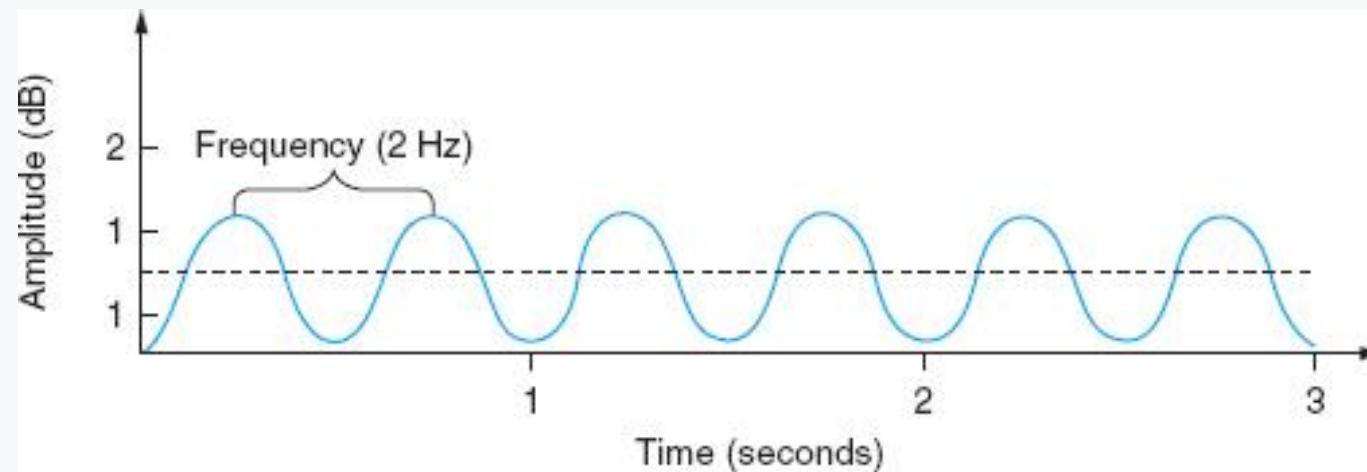
- **Frequency** is the number of times a waveform repeats in a given interval of time. It is represented on the horizontal axis as the distance between two wave peaks or troughs. Frequency is measured in *hertz* (Hz).
- One **hertz** is one repetition of a waveform in one second of time.



- Frequency is perceived as **pitch**. High frequencies produce sounds of higher pitch, and low frequencies produce low pitch. Pitch is the psychological perception of sound frequency. Humans can perceive a frequency range of 20 Hz to 20,000 Hz (or 20 *kilohertz* (kHz), *thousands* of hertz), though most adults cannot hear frequencies above 16 kHz.

Characteristics

- The **duration** of the sound is the length of time it lasts. The total length of the horizontal axis represents duration

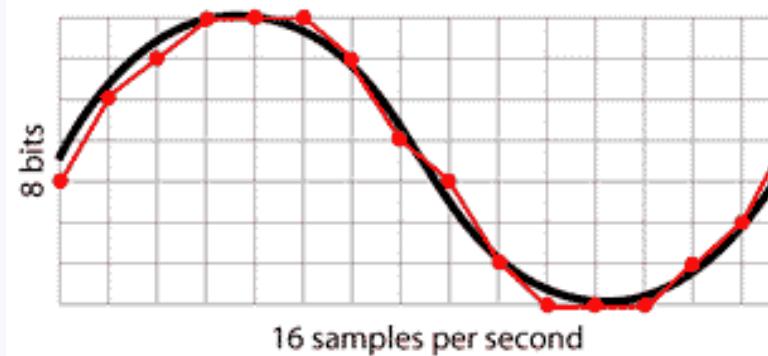
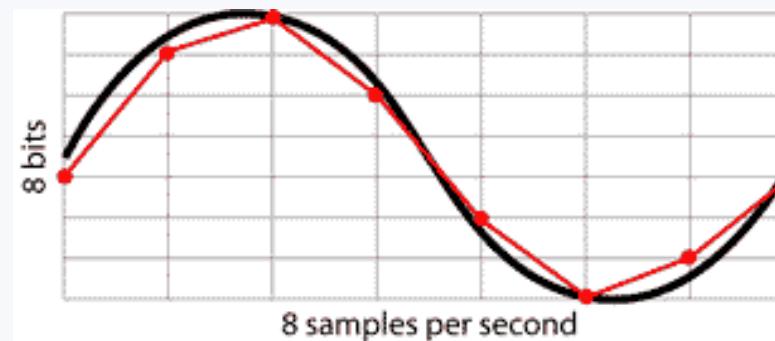


Digital Audio

- Digital techniques represent sound as discrete (or discontinuous) elements of information.
- There are two major types of digital sound:
 - *sampled*
 - *synthesized*.

Digital Audio

- Sampled sound is a digital recording of previously existing analog sound waves. A file for sampled sound contains many thousands of numerical values, each of which is a record of the amplitude of the sound wave at a particular instant, a *sampling* of the sound.



Digital Audio

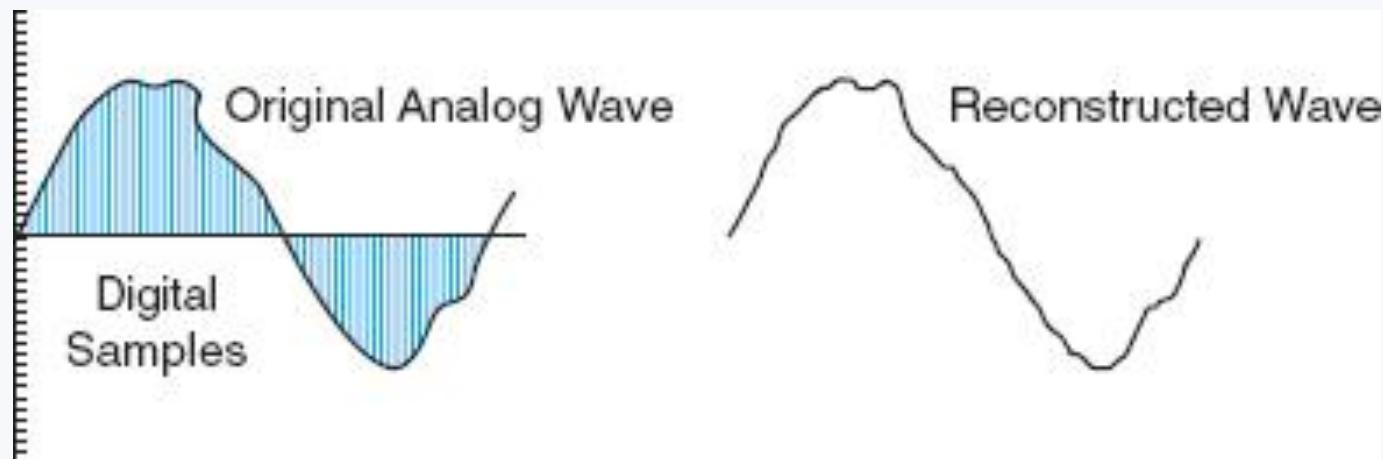
- **Synthesized** sound is new sound generated (or synthesized, “put together”) by the computer. A file for synthesized sound contains instructions that the computer uses to produce its own sound.
- **Sampling** is usually used to capture and edit naturally occurring sounds such as human speech, musical and dramatic performances, bird calls, rocket launches, and so on. **Synthesized** sound is generally used to create original musical compositions or to produce novel sound effects.

Digital sampling

- capturing and storing sound in a digital format.
- the sound is captured by recording many separate measurements of the amplitude of a wave using an **ADC**, or *analog-to-digital converter*. An analog device, such as a microphone or the amplifier in a speaker system, generates a continuously varying voltage pattern to match the original sound wave. The ADC samples these voltages thousands of times each second. The samples are recorded as digital numbers. These digital values are then used to re-create the original sound by converting the digital information back to an analog form using a **DAC**, or *digital-to-analog converter*. The DAC uses the amplitude values to generate matching voltages that power speakers to reproduce the sound.

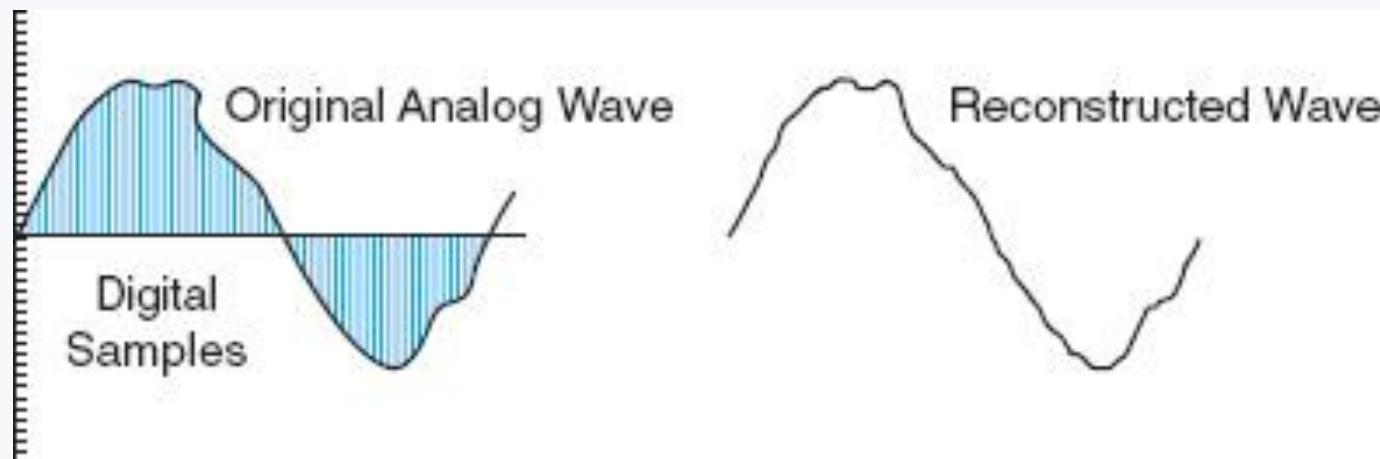
Digital sampling

- Digital sampling replaces the continuous waveform of the original sound with a new wave created from a fixed number of discrete samples.
- Some information is always lost in sampling, because a continuous wave is infinitely divisible and sampling always yields a finite number of values.
- The quality of sampled sound is dependent on two factors directly connected to this sampling process: **sample resolution** and **sample rate**.



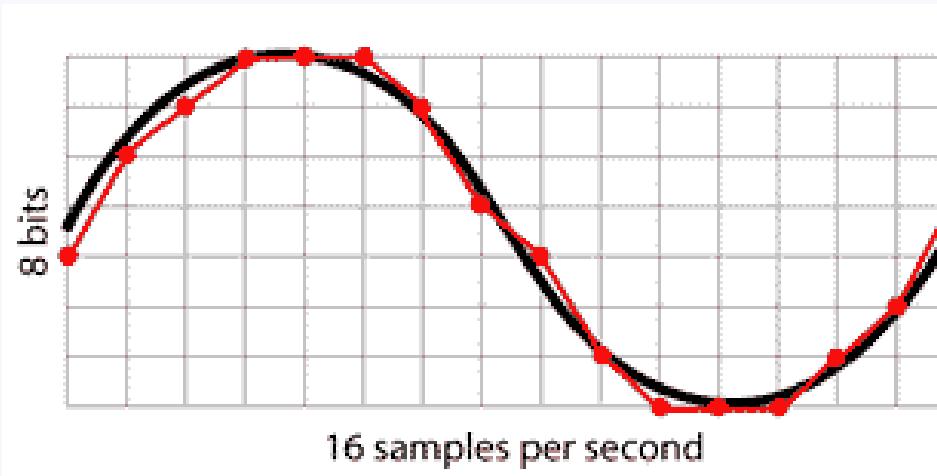
Digital sampling

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Digital sampling

- **Sample Resolution** Each measurement of amplitude made by an ADC is recorded using a fixed number of bits. The number of bits used to encode amplitude is known as **sample resolution**.
- Sample resolutions for digital audio range from 8 to 32 bits, with the most common being the 16-bit CD-Audio standards and 24-bit DVD-Audio standards.



Digital sampling

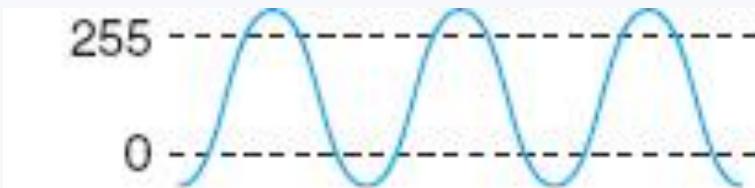
- Eight bits can record 256 different amplitude levels. This is adequate to capture the variations in limited decibel ranges, such as those between a human whisper and a shout, but higher sample resolutions are needed to accurately reproduce sounds with a wider range of amplitudes, such as musical performances. Thus, 8-bit audio is generally used only for simple sounds or in multimedia applications requiring very small file sizes.
- The CD-Audio standard, with its 16 bits per sample, supports over 65 thousand different amplitude levels, whereas the 24-bit DVD-Audio standard can represent over 16 million levels.

Digital sampling

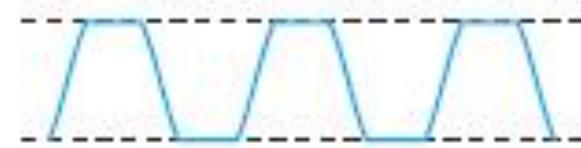
- Inadequate sample resolution can distort sound in two different ways: **quantization** and **clipping**.
- **Quantization** - each amplitude sample must be assigned one of the numbers available in the code being used. If the number of distinct values is too small, perceptually different amplitudes will be assigned the same number. Rounding a sample to the closest available value is known as **quantization**. In the case of sound, excessive quantization may produce a background hissing or a grainy sound. The solution is to record with a higher sample resolution (for instance, by using 16 rather than 8 bits).

Digital sampling

- **Clipping** - sound-sampling equipment is designed for a selected decibel range. If the source sound exceeds this range (as, for instance, when someone yells into a microphone held close to their lips), higher amplitudes cannot be encoded, because no values are available to represent them. The waveform of a clipped sound shows square tops and bottoms marking the point at which the highest amplitudes could not be captured. Clipping can produce a harsh, distorted sound.



Clipping occurs when wave amplitude exceeds available sample values.



Clipped waves have square tops and bottoms and a harsh sound.

Digital sampling

- The solution to **clipping** is to lower the amplitude of the source sound to record within the limits of the ADC circuitry.
- Recording equipment usually includes some form of meter such as a swinging needle, colored bars, or lights to show input levels and alert users when the amplitude range has been exceeded.
- The familiar, “Testing—one, two, three,” is often used to establish the proper distance and speech level when recording with a microphone.

Digital sampling

- Clipping can also occur during the mixing of different audio tracks.
- **Mixing** is the process of combining two or more sound selections, or *tracks*, into a single track. For example, a background music track might be mixed with a voice track of a poetry reading. This combination of two or more tracks may produce an amplitude that exceeds the available range. Adjustments to the volume of each track can eliminate the problem.
- Another solution is to use higher sample resolutions (for instance, 24-bit) to provide a wider range of amplitude values.

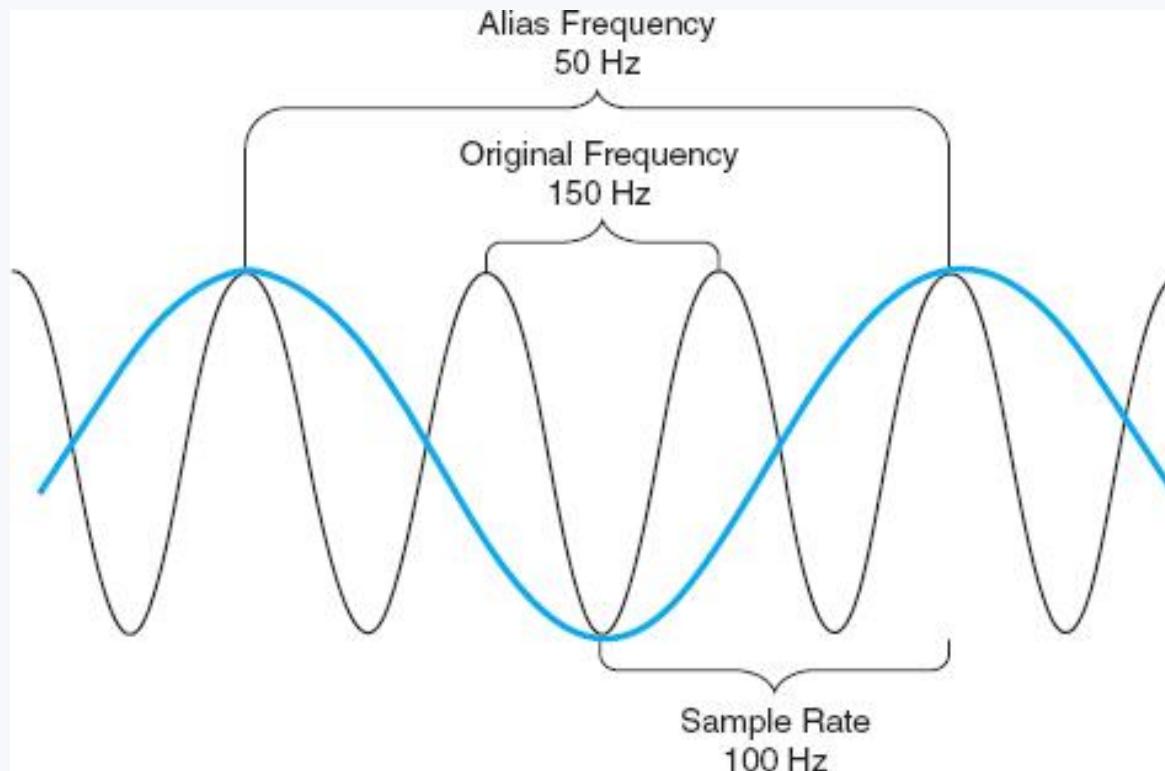
Digital sampling

- **Sample rate** is the number of samples taken in a fixed interval of time. A rate of one sample per second is designated as a Hertz.
- Because sound samples are always taken thousands of times each second, sample rates are usually stated in kilohertz.
- Sample rate affects sound quality by determining the range of frequencies that can be represented in a digital recording. At least two measurements are required to capture each cycle of a sound wave—one for each high value, or peak, and one for each low value, or trough. The highest frequency that can be captured is thus one-half of the sample rate.
- CD-quality sound captures 44,100 samples per second (44.1 kHz sample rate) and can represent frequencies as high as 22,050 Hz or 22.05 kHz. DVD-Audio uses a sampling frequency of 96 kHz to capture frequencies as high as 48 kHz.

Digital sampling

- Sounds that do not contain high frequencies can be more efficiently represented using lower sample rates because this will produce a smaller overall file size. One potential problem with lower sample rates, however, is **aliasing**.

Digital sampling



Balancing File Size and Sound Quality

- It is not always necessary to use DVD-quality sound. For example normal speech, contain relatively low frequencies and a limited range of amplitudes. In this case, higher sample rates and sample resolutions do not improve sound quality, but they create needlessly large files. Using a rate of 11.025 kHz for voice recording results in a file only one-quarter the size of a CD-quality sound file. In addition, 8-bit sample resolution and monaural sound are usually adequate for speech. This further reduces file size by a factor of four, one-sixteenth the size of a stereo CD recording.

Resolution	Rate	Stereo/Mono	Size (1 Minute)	Quality
16	44.1 kHz	Stereo	10 MB	CD
16	22.05 kHz	Stereo	5 MB	FM radio
8	11.025 kHz	Mono	650 KB	AM radio
8	5.5 kHz	Mono	325 KB	Bad telephone

Sound Compression

- Lowering the sample rate and reducing sample resolution are two ways to reduce the size of a sampled sound file. These methods work well for sounds at relatively low frequencies and narrow amplitude ranges. They are not effective for sounds that contain wider ranges of both frequency and amplitude, such as musical performances. In these cases another strategy can be used: compression.
- Compression can be either **lossless** or **lossy**. Lossless compression uses more efficient coding to reduce the size of a file while preserving all the information of the original. Lossy compression discards some of the original information.

Sound Compression

- Because **lossy strategies** produce much smaller files, they are the preferred technique for sound compression.
- Lossy sound compression **codecs** (coder/decoders) use various techniques to reduce file sizes. Some of these take advantage of **psychoacoustics**, the interplay between the psychological conditions of human perception and the properties of sound. For instance, while humans with optimal hearing can perceive frequencies as high as about 20 kHz, most people cannot distinguish frequencies above approximately 16 kHz. This means that higher-frequency information can be eliminated and most listeners will not miss it. Higher amplitude sounds in one stereo channel will also typically “drown out” softer sounds in the other channel. Again, this is information that usually will not be missed.

Sound Compression

- Lossy compression also uses other techniques such as **variable bit rate encoding (VBR)**. In VBR, sounds are encoded using a different number of bits per second depending on the complexity of the sound. For simple passages of sound with limited frequencies, a smaller number of bits per second is used than for more complex passages, such as those with many different instruments and higher frequencies.
- Lossy codecs such as the widely supported **MP3** can reduce file sizes by as much as 80% while remaining virtually indistinguishable from the original CD-quality sound.

Sampled Sound File Formats

- MP3 (MPEG1, audio layer 3)
 - extensions: .mp3 or .mpga
 - popular audio format that supports significant compression while preserving excellent quality.
 - widely supported across different computer platforms and is frequently used on the Internet.

Sampled Sound File Formats

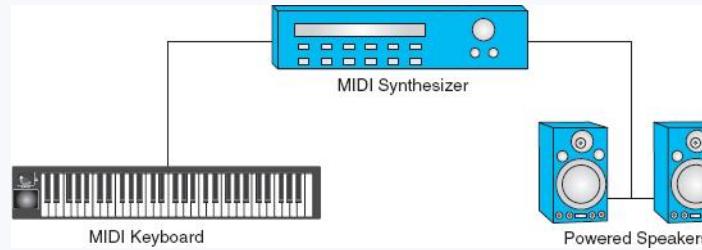
- AAC (advanced audio coding)
 - extension: .mp4 and .aac
 - the successor to MP3 specified in the MPEG4 standard, that produces better sound quality than MP3 at comparable bit rates.
 - it can also significantly reduce file sizes for comparable-quality audio.
 - many commercial users (including Apple iPod, Apple iPad, Apple iPhone, Blackberry, YouTube, and Sony PlayStation) have adopted the AAC standard for their digital audio.

Sampled Sound File Formats

- Other sound file formats:
 - WMA (Windows Media Audio);
 - WAV;
 - ReadAudio;
 - AIFF;
 - AU.

Audio

Synthesized Sound



Further reading: <https://en.wikipedia.org/wiki/MIDI>

Web Audio

- <audio> - HTML element is used to embed sound content in documents. It may contain one or more audio sources, represented using the src attribute or the <source> element; the browser will choose the most suitable one.

```
<audio controls>
  <source src="foo.wav" type="audio/wav">
  Your browser does not support the <code>audio</code>
  element.
</audio>
```

Web Audio

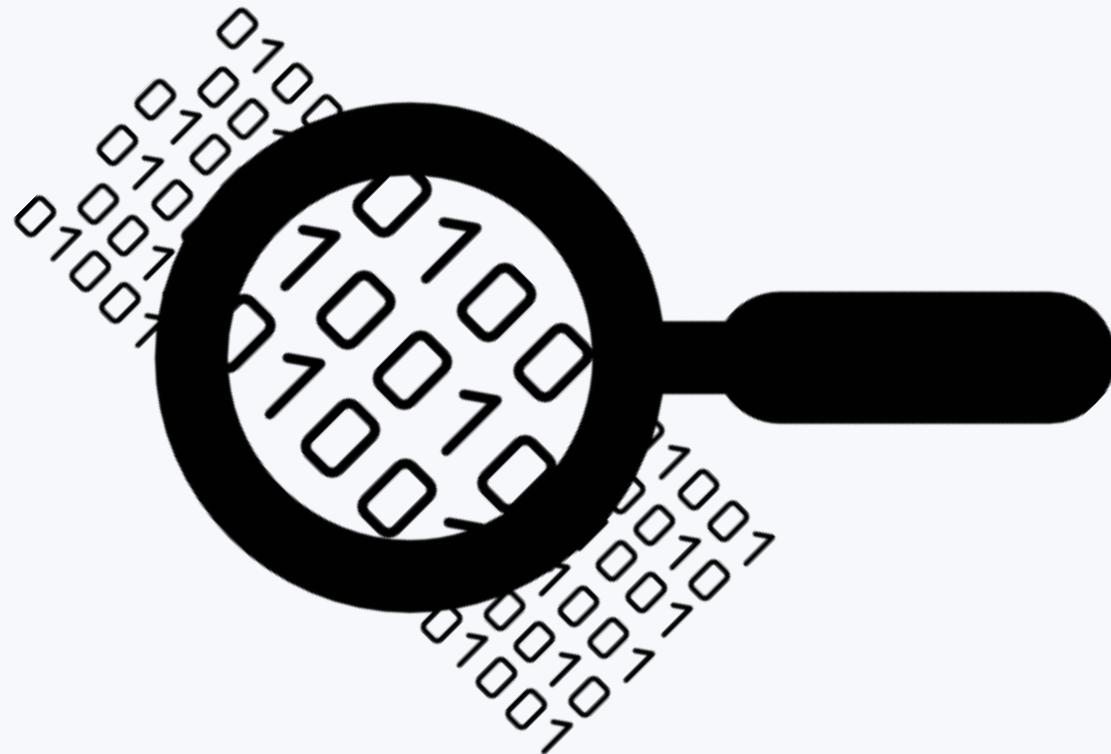
- <audio>
 - attributes:
 - *autoplay*
 - *controls*
 - *loop*
 - *src*
 - *volume* (numeric) – value between 0 and 1
 - API: <https://developer.mozilla.org/en-US/docs/Web/HTML/Element/audio>

Web Audio

- **HTMLAudioElement (JavaScript)**
 - provides access to the properties of <audio> elements, as well as methods to manipulate them. It derives from the HTMLMediaElement interface.
 - properties:
 - currentSrc, currentTime, duration, ended, error, paused, readyState, volume
 - methods:
 - canPlayType, load, pause, play
 - events:
 - canplay, ended, pause, play, volumechange, waiting
 - API: <https://developer.mozilla.org/en-US/docs/Web/API/HTMLAudioElement>

Lab Example:

- <https://ase-multimedia.azurewebsites.net/audio-playlist/>



Web Audio API

- The Web Audio API provides a powerful and versatile system for controlling audio on the Web, allowing developers to choose audio sources, add effects to audio, create audio visualizations, apply spatial effects (such as panning) and much more.
- API: https://developer.mozilla.org/en-US/docs/Web/API/Web_Audio_API
- Web RTC API: <https://developer.mozilla.org/en-US/docs/Web/API/MediaDevices/getUserMedia>

Web Audio

- Sound visualization using HTML5 Canvas: <http://nipe-systems.de/webapps/html5-web-audio/>
- Creating visualizations: https://developer.mozilla.org/en-US/docs/Web/API/Web_Audio_API/Visualizations_with_Web_Audio_API
- Record and save as MP3: <http://audior.ec/blog/recording-mp3-using-only-html5-and-javascript-recordmp3-js/> ,
<https://www.html5rocks.com/en/tutorials/getusermedia/intro/>

WebRTC API

- WebRTC (Web Real-Time Communications) is a technology which enables Web applications and sites to capture and optionally stream audio and/or video media, as well as to exchange arbitrary data between browsers without requiring an intermediary.
- The set of standards that comprises WebRTC makes it possible to share data and perform teleconferencing peer-to-peer, without requiring that the user install plug-ins or any other third-party software.
- Web RTC API: https://developer.mozilla.org/en-US/docs/Web/API/WebRTC_API,
<https://developer.mozilla.org/en-US/docs/Web/API/MediaDevices/getUserMedia>

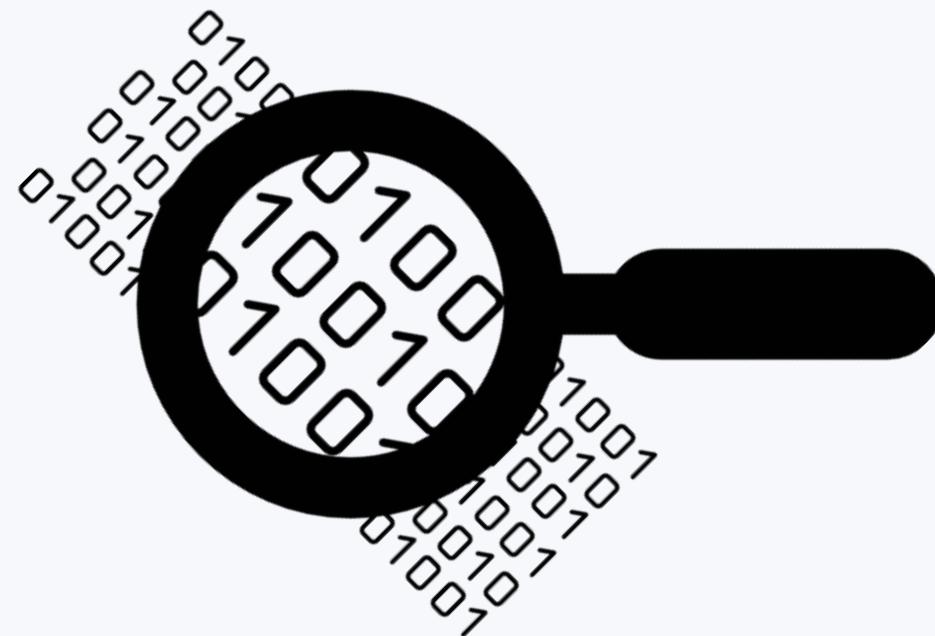
Demo

- https://developer.mozilla.org/en-US/docs/Web/API/WebRTC_API/Taking_still_photos



Lab Example: Web Audio API

- <https://ase-multimedia.azurewebsites.net/audio-web-audio-api/>



Lab Example: Speech API

- <https://ase-multimedia.azurewebsites.net/speech-api/>



Recommendations

- Consider the playback environment:
 - Public vs. private use (ex: autoplay)
 - Give users control:
 - Over volume.
 - To stop or start play.
- Avoid excessive use of sound. Sound can be more tiring for users than images or text

Animation

Animation

- Animation is the process of creating the illusion of motion and the illusion of change
- Main techniques:
 - movie technique
 - key frames
 - color changing

Digital Animation

- Digital animation takes two different forms:
- two-dimensional - has evolved from traditional techniques, particularly cel animation;
- three-dimensional - exploits the capabilities unique to the computer to produce an entirely new form of animation.

Digital Animation

- 1. frame-by-frame animation
 - animators produce each successive frame manually
 - technique that provides complete control over frame content, but is also very time consuming

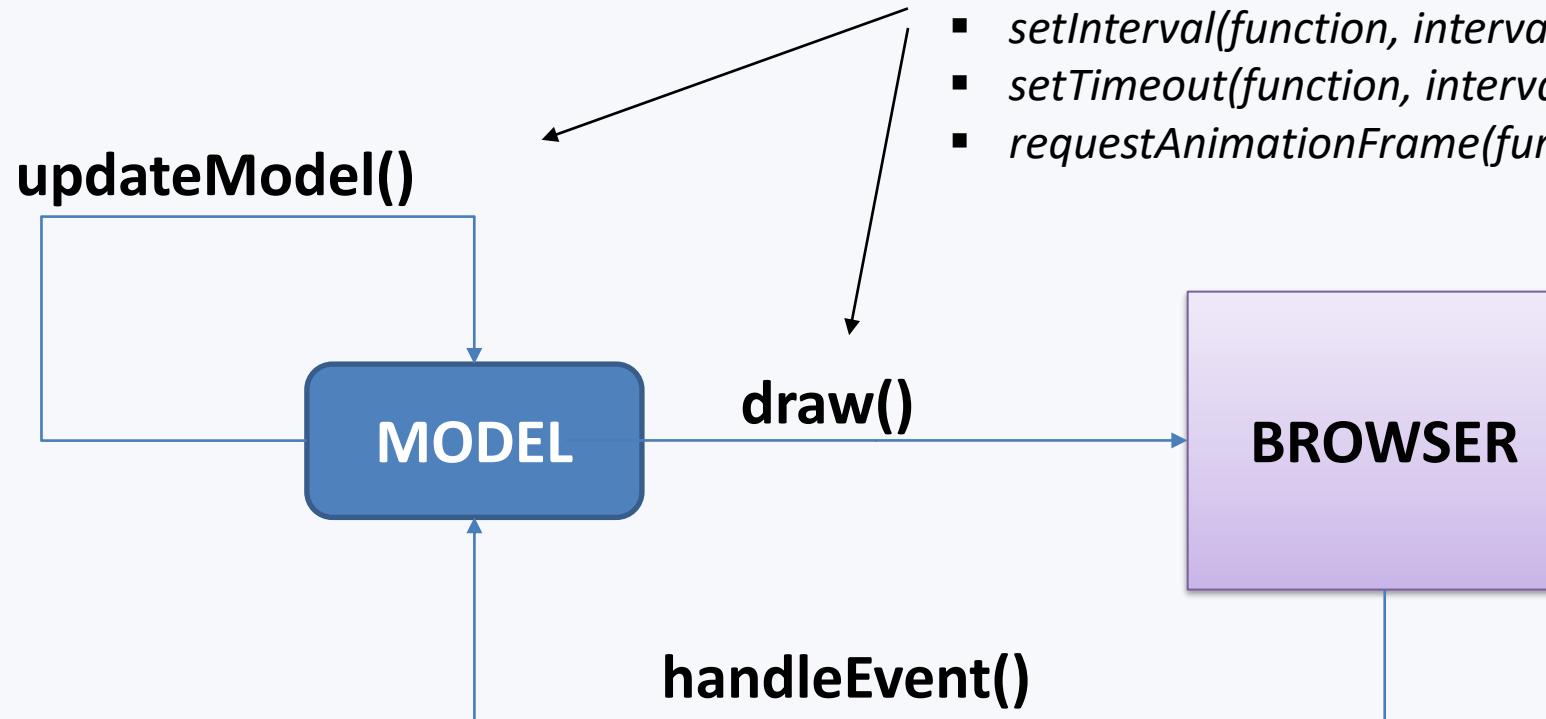
Digital Animation

- 2. tween animation
 - the animator creates the key frames and the computer automatically produces the tweens.
 - There are several different types of tweens:
 - motion tween - can be used to move an object from one position to another. The first key frame places the object in one position and the second places it in another. The program then fills in the intervening frames.
 - path-based animation: the animator draws a path from one key frame to another and the computer fills in the intervening images, spaced out along the path, to produce the desired motion
 - morphing - the shape of one image is gradually modified until it changes into another shape

Digital Animation

- size tweening - the first key frame is the object at its initial size and the second is the final size.
- alpha tweening- color and transparency can be animated using key frames representing initial and final image properties.
- 3. programmed animation

Web Animation



Demo

- lab animation examples



CSS Transitions

- Guide: https://developer.mozilla.org/en-US/docs/Web/CSS/CSS_Transitions/Using_CSS_transitions

CSS Animations

- API: https://developer.mozilla.org/en-US/docs/Web/CSS/CSS_Animations
- Guide: https://developer.mozilla.org/en-US/docs/Web/CSS/CSS_Animations/Using_CSS_animations

Web Animations API

- The **Web Animations API** allows for synchronizing and timing changes to the presentation of a Web page, i.e. animation of DOM elements.
- Limited browser support: <https://caniuse.com/#feat=web-animation> (compared to **CSS Animations** with <https://caniuse.com/#feat=css-animation>)
- API: https://developer.mozilla.org/en-US/docs/Web/API/Web_Animations_API

Demo

<https://css-tricks.com/css-animations-vs-web-animations-api/>



Progressive Web Apps

Progressive Web Apps

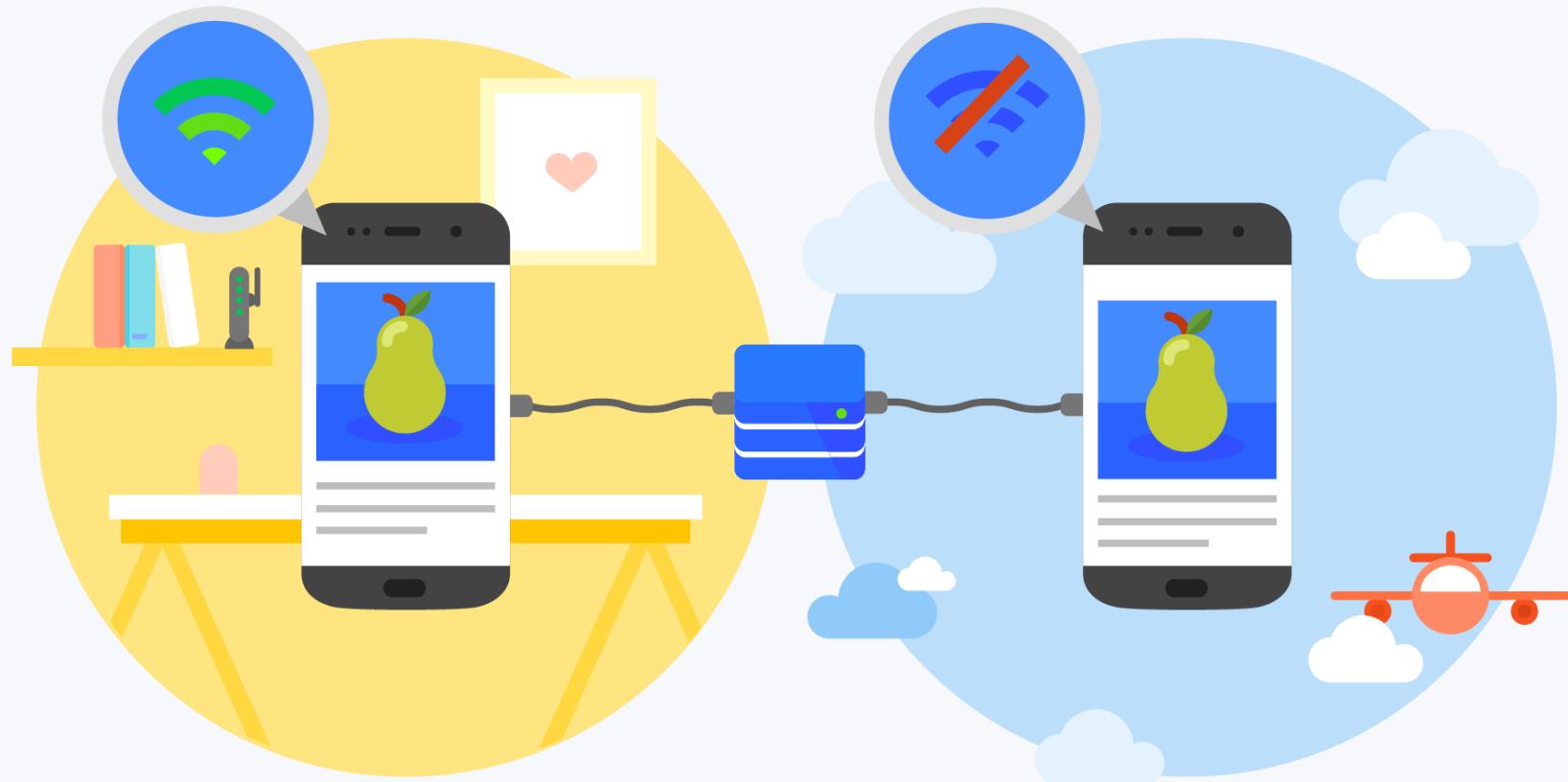
- An application developed using standard web technologies (HTML5, JavaScript, CSS3) which is:
- **Reliable** - load instantly even in uncertain network conditions.
- **Fast** - respond quickly to user interactions with silky smooth animations and no janky scrolling.
- **Engaging** - feel like a natural app on the device, with an immersive user experience.

Reliable

- Progressive web apps are not dependent on the user's connection like traditional websites are.
- When a user visits a progressive web app, it will register a **service worker** that can detect and react to changes in the user's connection. It can provide a fully featured user experience for users who are offline, online, or suffering from an unreliable connection.
- A **service worker**, written in JavaScript, is like a **client-side proxy** and puts you in control of the cache and how to respond to resource requests. By pre-caching key resources you can eliminate the dependence on the network, ensuring an instant and reliable experience for your users.

Reliable

- When launched from the user's home screen, **service workers** enable a Progressive Web App to load instantly, regardless of the network state.



Reliable

- A service worker, written in JavaScript, is like a client-side proxy and puts you in control of the cache and how to respond to resource requests. By pre-caching key resources you can eliminate the dependence on the network, ensuring an instant and reliable experience for your users.

Fast

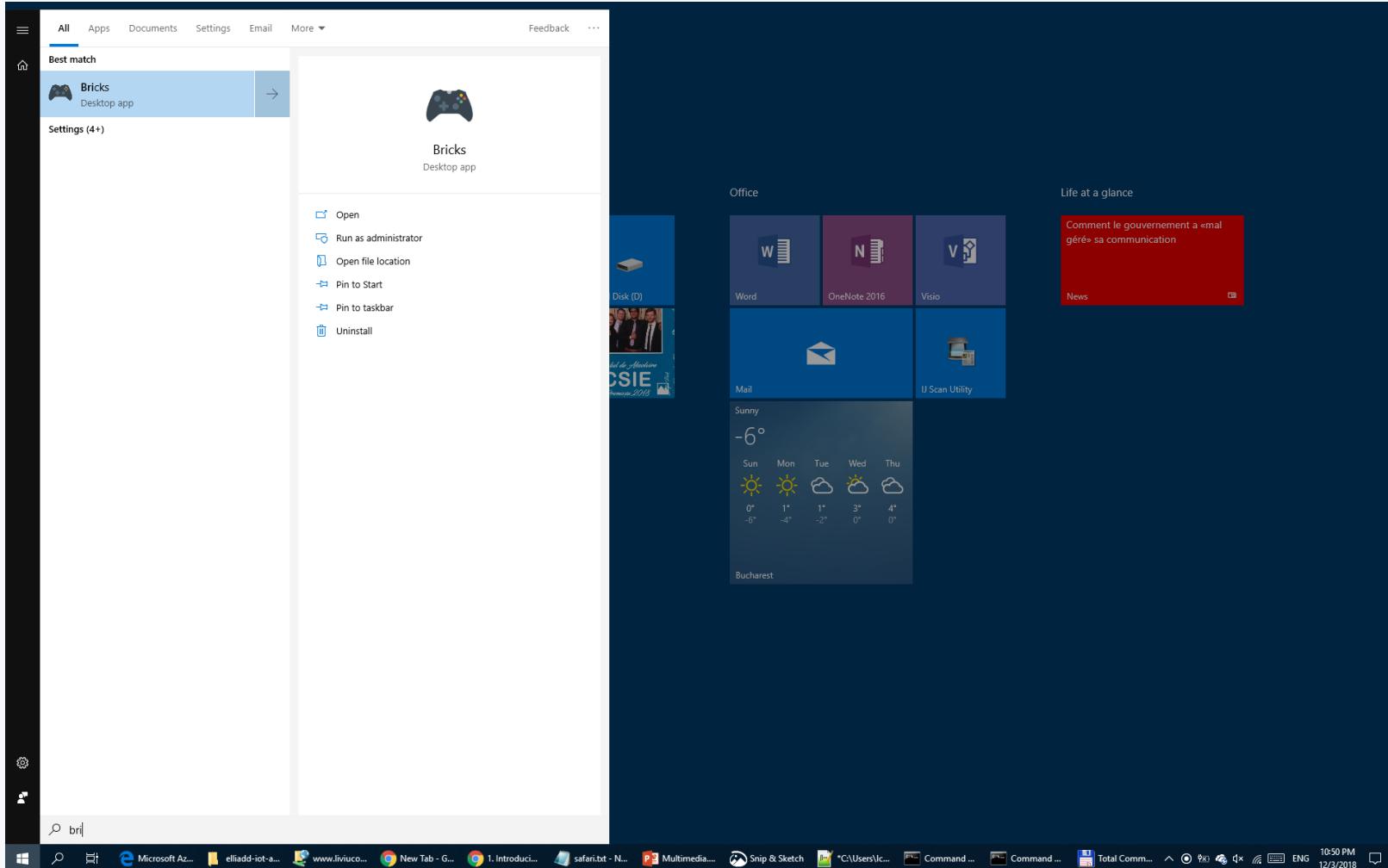
- Using service workers, progressive web apps can launch in an instant, whether the user has a blazing fast connection, an unreliable 2G connection, or even no connection at all. Sites can load in milliseconds, much faster than anything we have experienced on the web before, and sometimes faster than native apps.

Engaging

- Push notifications
 - Progressive web apps can send notifications to their users. The notifications have a completely native feel and are indistinguishable from native app notifications.
- Homescreen shortcut
 - Once a user has shown interest in a progressive web app, the browser will automatically suggest that he add a shortcut to his homescreen—completely indistinguishable from any native app.

Progressive Web Apps

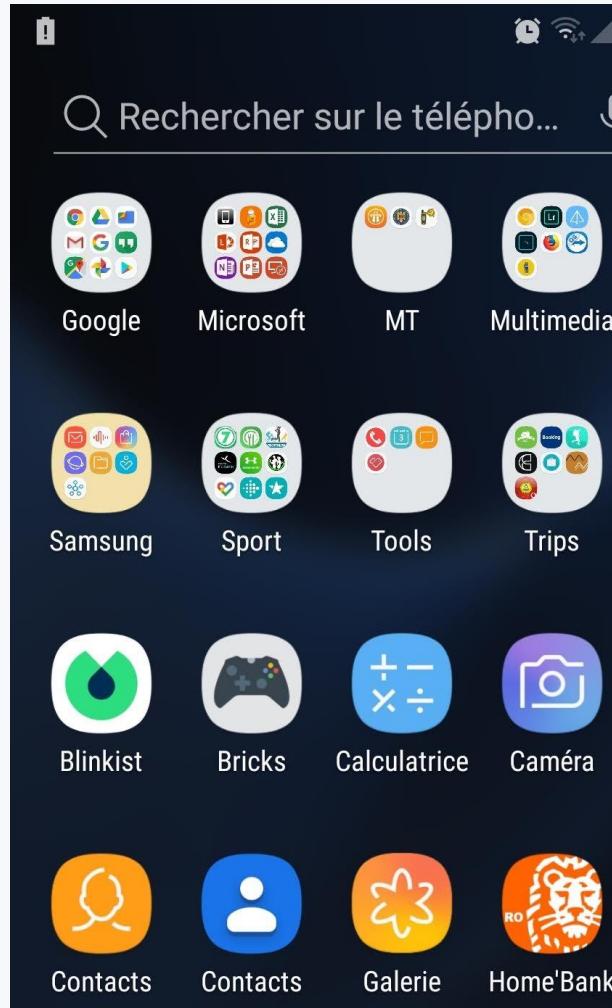
Engaging



Desktop - Homescreen shortcut

Progressive Web Apps

Engaging



Mobile - Homescreen shortcut

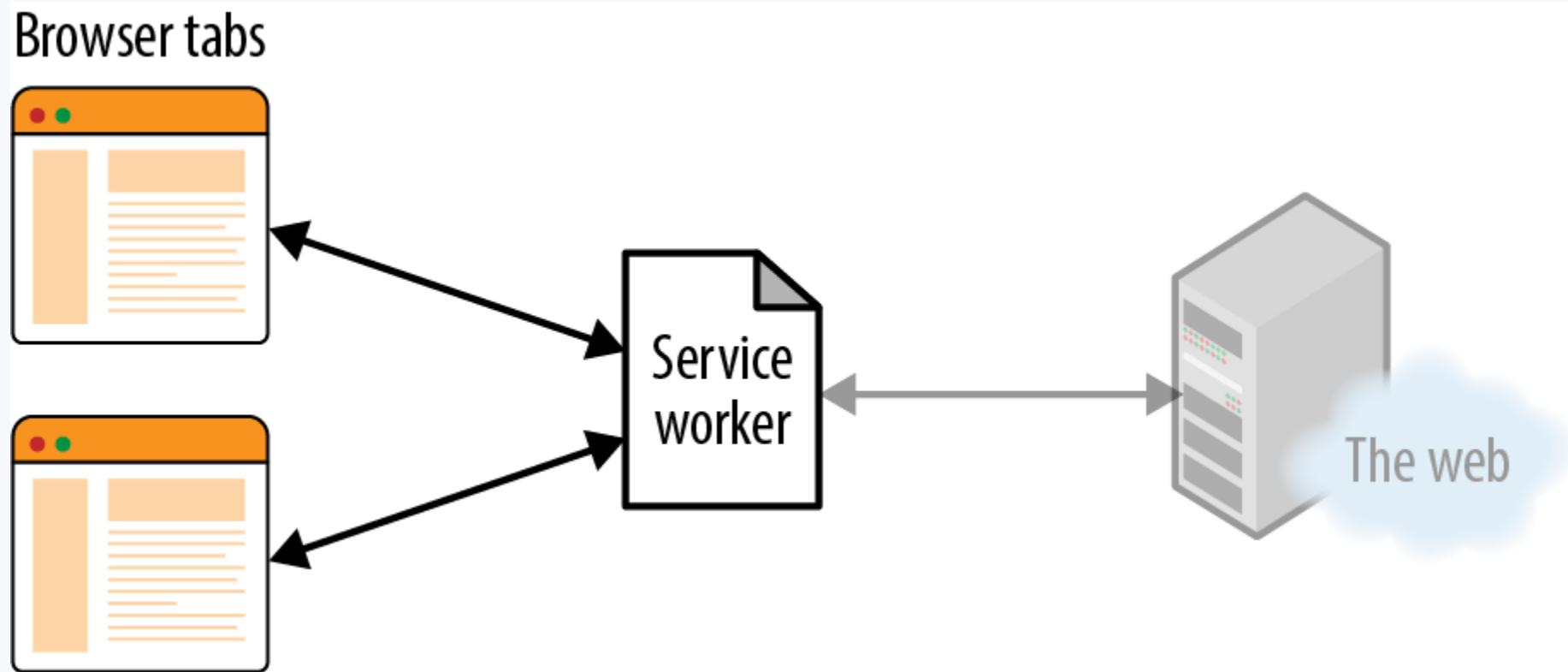
Engaging

- Native look
 - Progressive web apps launched from the homescreen can have an entirely native, app-like look. They can have a splash screen as they are loading. They can launch in full-screen mode, without the browser and phone UI around them. They can even lock themselves to a specific screen orientation (a vital requirement for games).

Service Worker

- At the heart of every progressive web app is the service worker.
- Before service workers, we had code running either on the server or in the browser window. Service workers introduce another layer.
- A service worker is a script that can be registered to control one or more pages of your site. Once installed, a service worker sits outside of any single browser window or tab.
- From this place, a service worker can listen and act on events from all pages under its control. Events such as requests for files from the web can be intercepted, modified, passed on, and returned to the page

Service Worker



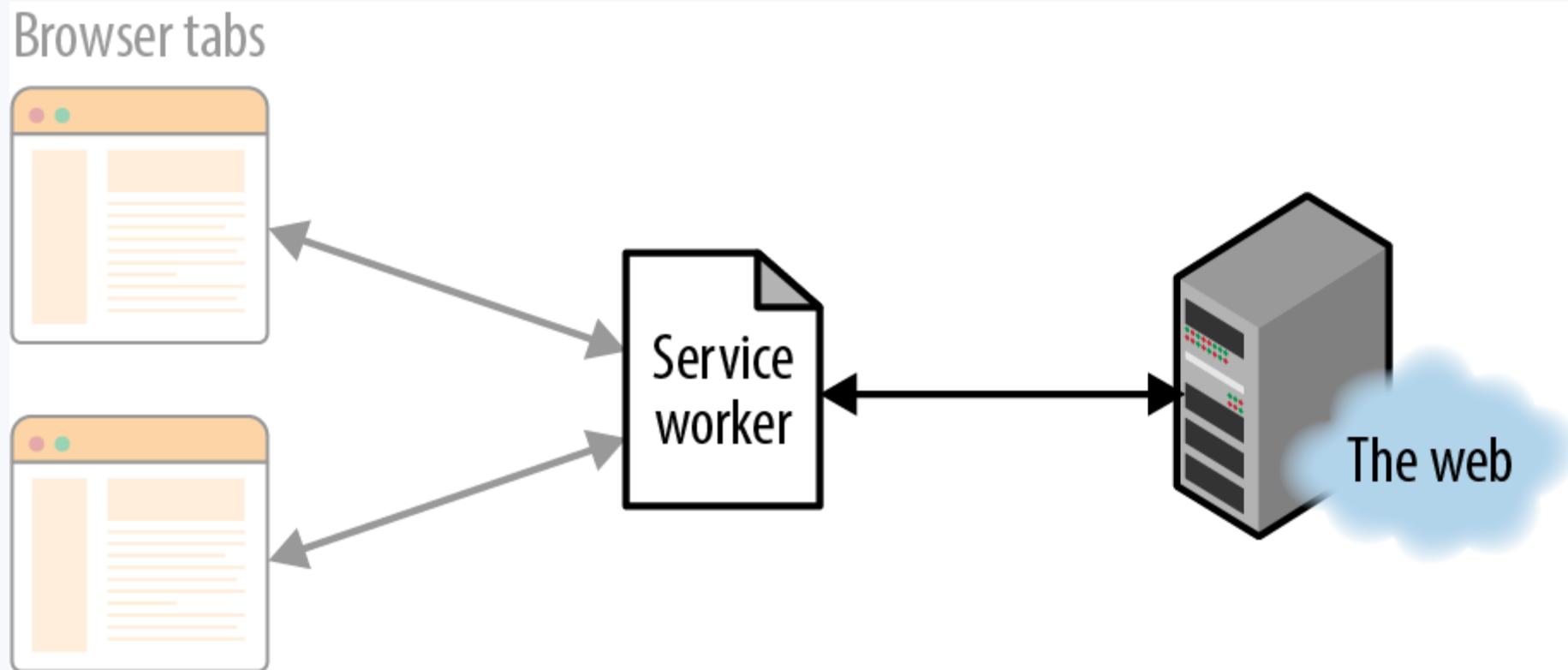
Pages communicating with a service worker while the user is **offline**

Checking the tabs associated with a service worker

- Using the Developer Tools in Google Chrome we can easily check the browser tabs corresponding to a service worker

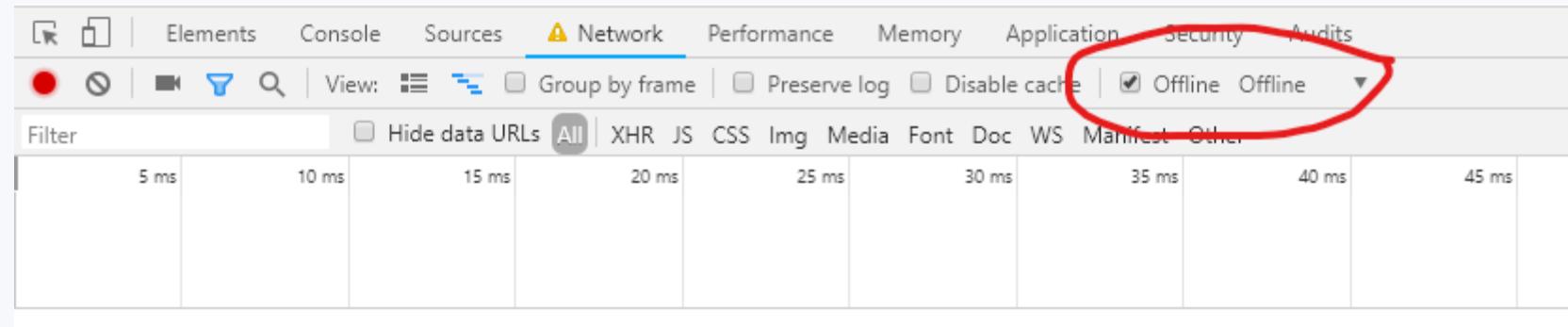
The screenshot shows the 'Service Workers' panel in the Google Chrome DevTools. At the top, there are three checkboxes: 'Offline', 'Update on reload', and 'Bypass for network'. Below this, the URL '127.0.0.1' is displayed. Under 'Source', a link to 'serviceworker.js' is shown with a red '8' indicating multiple errors. The 'Received' timestamp is '12/11/2018, 11:40:44 AM'. The 'Status' section shows two entries: '#5335 activated and is running' (green dot) and '#5501 waiting to activate' (orange dot). The 'Received' timestamp for the second entry is '12/17/2018, 10:49:51 PM'. Under 'Clients', three tabs are listed, each with the URL 'http://127.0.0.1:5500/index.html' and a 'focus' status. The URLs are highlighted with yellow scribbles.

Service Worker



The service worker communicating with a server after a user has left the page

Simulating an offline state in Google Chrome



Service Worker

- Documentation:
 - [https://developer.mozilla.org/en-US/docs/Web/API/Service Worker API](https://developer.mozilla.org/en-US/docs/Web/API/Service_Worker_API)
- A service worker is run in a worker context: it therefore has no DOM access, and runs on a different thread to the main JavaScript that powers your app, so it is not blocking.
- It is designed to be fully async; as a consequence, APIs such as synchronous [XMLHttpRequest](#) and [Web Storage API](#) can't be used inside a service worker.
- Service workers only run over HTTPS, for security reasons.

Service Worker

- Registration:
 - A service worker is first registered using the `ServiceWorkerContainer.register()` method. If successful, the service worker will be downloaded to the client and attempt installation/activation for URLs accessed by the user inside the whole origin, or inside a subset specified by you.
- Documentation:
 - <https://developer.mozilla.org/en-US/docs/Web/API/ServiceWorkerContainer/register>

Service Worker

- Note: check the [documentation](#) for an example also declaring a scope

```
if ("serviceWorker" in navigator) {  
  navigator.serviceWorker.register("/serviceworker.js")  
    .then(function(registration) {  
      console.log("Service Worker registered with scope:", registration.scope);  
    }).catch(function(err) {  
      console.log("Service worker registration failed:", err);  
    });  
}
```

Demo

- Create an empty html page and try to register a service worker
 - Note: the registration will fail because we have not yet created the "serviceworker.js" file

```
Service worker registration failed: TypeError: Failed to register a index.html:20
ServiceWorker: A bad HTTP response code (404) was received when fetching the script.
```



Service Worker

- Verify that the current browser supports service workers

```
if ("serviceWorker" in navigator) {
```

- The register call returns a *promise*. If the promise is fulfilled, meaning the service worker was registered successfully, the function defined in the then statement is called. If there was any problem, the function defined inside the catch block would be executed.

```
navigator.serviceWorker.register("/serviceworker.js")
```

- If there was any problem, the function defined inside the catch block would be executed.

Service Worker

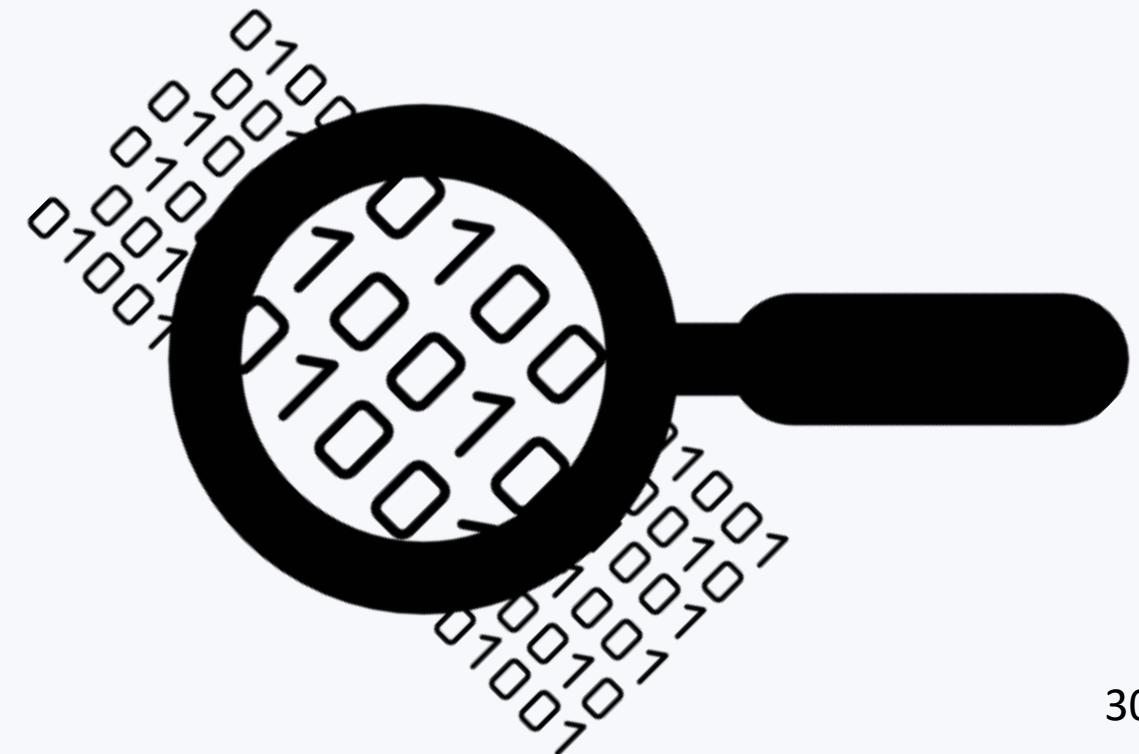
- Intercept requests from the Service Worker

```
self.addEventListener("fetch", function(event) {  
    console.log("Fetch request for:",  
    event.request.url);  
});
```

- The code adds an event listener to our service worker by calling addEventListener on self (self within a service worker refers to the service worker itself).
- The function we define to handle these events accesses the request object (available as a property of the fetch event) and logs the URL of that request.

Demo

- Create a service worker and subscribe to the “fetch” event



Service Worker

- every request made by our page (including to third-party servers) now passes through our service worker. All of those requests can now be intercepted, analyzed, and even manipulated. ☺

```
self.addEventListener("fetch", function(event) {  
  if (event.request.url.includes("bootstrap.min.css")) {  
    event.respondWith(  
      new Response(  
        "div {background: green;}",  
        { headers: { "Content-Type": "text/css" } }  
      )  
    );  
  }  
});
```

Service Worker

- Respond to requests with content from the web:

```
self.addEventListener("fetch", function(event) {  
  if (event.request.url.includes("/img/logo.png")) {  
    event.respondWith(  
      fetch("/img/logo-rotated.png")  
    );  
  }  
});
```

Fetch API

- Documentation: https://developer.mozilla.org/en-US/docs/Web/API/Fetch_API
- Provides an interface for fetching resources (including across the network).
- Similar to **XMLHttpRequest**, but the new API provides a more powerful and flexible feature set.
- Moreover, **XMLHttpRequest** is **not** available in ServiceWorkers.

Fetch API

```
// Fetch by URL  
fetch("/img/logo.png");  
// Fetch by the URL in the request object  
fetch(event.request.url);  
// Fetch by passing a request object.  
// In addition to the URL, the request object may contain additional  
headers,  
// form data, etc.  
fetch(event.request);
```

- The first argument in fetch is mandatory and can contain either a request object, or a string with a relative or absolute URL

Fetch API

- The second argument is **optional** and can contain an object with options for the request.

```
return fetch(url, { // Default options are marked with *
  method: "POST", // *GET, POST, PUT, DELETE, etc.
  mode: "cors", // no-cors, cors, *same-origin
  cache: "no-cache", // *default, no-cache, reload, force-cache, only-if-cached
  credentials: "same-origin", // include, *same-origin, omit
  headers: {
    "Content-Type": "application/json; charset=utf-8",
    // "Content-Type": "application/x-www-form-urlencoded",
  },
  redirect: "follow", // manual, *follow, error
  referrer: "no-referrer", // no-referrer, *client
  body: JSON.stringify(data), // body data type must match "Content-Type" header
})
.then(response => response.json()); // parses response to JSON
```

Service Worker - Capturing Offline Requests

- Handle the communication error using "catch"
- Simple "text" response:

```
self.addEventListener("fetch", function(event) {  
  event.respondWith(  
    fetch(event.request).catch(function() {  
      return new Response(  
        "There seems to be a problem with your connection.\n"  
      );  
    })  
  );  
});
```

Service Worker - Capturing Offline Requests

```
var responseContent =  
"<html><body>" +  
"<style>body {text-align: center; background-color: #333; color: #eee; }" +  
"</style>" +  
"<h1>Progressive Web Apps</h1>" +  
"<p>There seems to be a problem with your connection.</p>" +  
"</body></html>;  
  
self.addEventListener("fetch", function(event) {  
  event.respondWith(  
    fetch(event.request).catch(function() {  
      return new Response(  
        responseContent,  
        {headers: {"Content-Type": "text/html"} }  
      );  
    })  
  );  
});
```

Demo

- Check what happens if we remove the headers

- Note:
 - Most web servers are configured to automatically serve most common file types with the correct headers automatically.
 - When a server sends an HTML file, it constructs a response that contains both the HTML, as well as many headers, including a Content-Type header letting the browser know what to do with the response.
 - Because we are constructing a response from scratch, it is up to us to set the correct headers.



Service Worker

- If we modify the Service Worker, the changes **don't immediately** take effect after refreshing the browser. This is because the **old service worker** is still the *active* one, while your new service worker remains in a *waiting* state until the old one is no longer controlling the page.
- To ease development, we can tell the browser to let new service workers take immediate control of the page. In Chrome, this can be done by opening the Application tab of the developer tools, and under the Service Workers section enabling “Update on reload”. This makes sure that each time we change the service worker and refresh the page, the new service worker will immediately take control of the page.

Progressive Web Apps

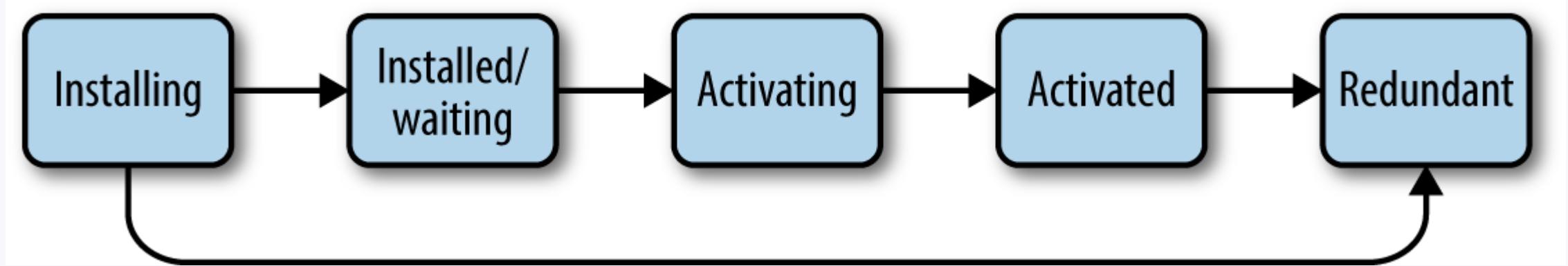
Service Worker

The screenshot shows the Chrome DevTools interface with the Application tab selected. In the left sidebar under 'Application', 'Service Workers' is selected, indicated by a grey background. The main panel displays information about a service worker registered at '127.0.0.1'. The service worker's source is listed as 'serviceworker.js', received on '12/4/2018, 9:49:11 AM'. Its status is shown as green with the message '#4996 activated and is running'. A client is listed as 'http://127.0.0.1:5500/index.html'. There are two interaction boxes: one for 'Push' containing 'Test push message from DevTools.' with a 'Push' button, and one for 'Sync' containing 'test-tag-from-devtools' with a 'Sync' button.

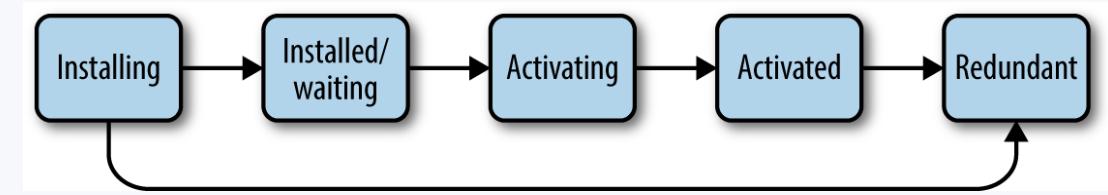
Turning on **Update on reload**

Service Worker LifeCycle

- The lifecycle of a service worker after being downloaded:

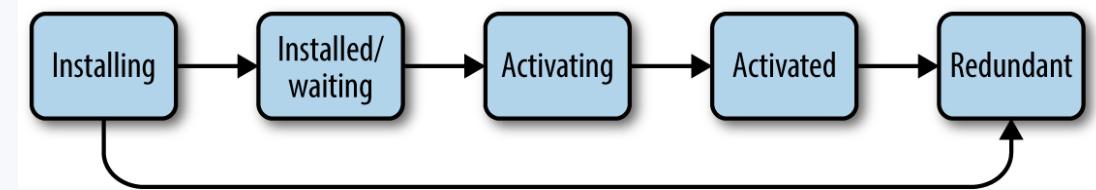


Service Worker LifeCycle



- Download
 - the service worker is immediately downloaded when a user first accesses a service worker–controlled site/page.

Service Worker LifeCycle

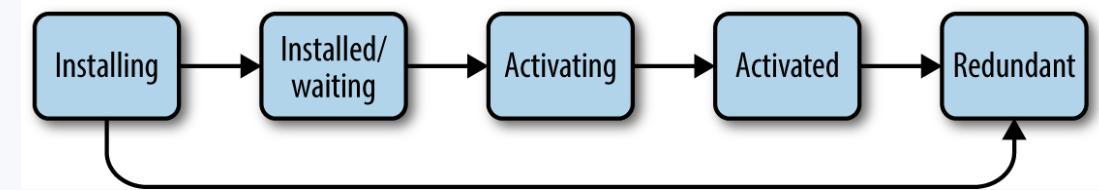


- **Installing state**

- When a new service worker is registered using `navigator.serviceWorker.register`, the JavaScript is downloaded, parsed, and enters the **installing** state.
- If the installation succeeds, the service worker will proceed to the **installed** state.
- The state can be extended by calling `event.waitUntil()` and passing it a promise.

```
self.addEventListener('install', function(e) {  
  e.waitUntil(  
    caches.open(cacheName).then(function(cache) {  
      return cache.addAll(filesToCache);  
    })  
  );  
});
```

Service Worker LifeCycle



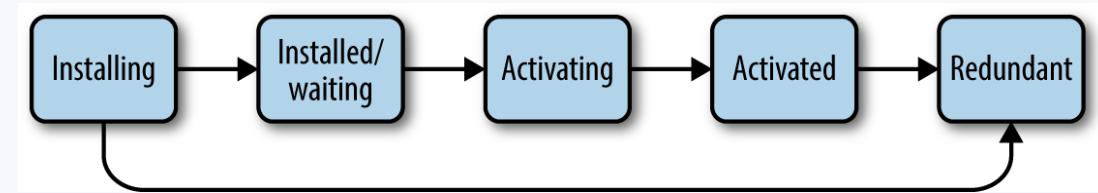
- If an error occurs during installation, the script will instead be moved to the redundant state.

```
self.addEventListener("install", function() {
  console.log("install");
  throw 'error';
});
```

The screenshot shows the 'Application' tab in the Chrome DevTools developer console. Under the 'Service Workers' section, there is a single entry for '127.0.0.1 - deleted'. The entry details are as follows:

- Source:** [serviceworker.js](#) (with a red 'x' icon and the number 10)
- Received:** 12/17/2018, 10:54:46 PM
- Status:** ● #5507 is redundant
- Push:** Push
- Sync:** Sync

Service Worker LifeCycle

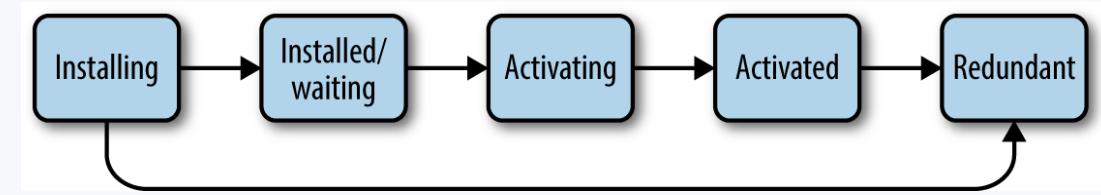


- **Installed/waiting state**

- Once a service worker has successfully installed, it enters the **installed state**.
- It will then immediately move on to the **activating state** unless another active service worker is currently controlling this app, in which case it will remain **waiting**.

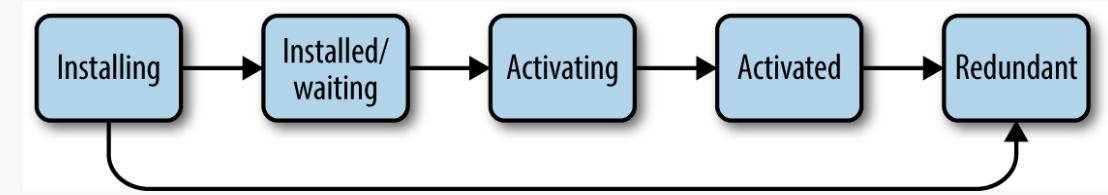
The screenshot shows the Chrome DevTools Application tab for the URL 127.0.0.1. The left sidebar lists 'Manifest', 'Service Workers' (which is selected), and 'Clear storage'. The main panel displays information for a service worker with the source file `serviceworker.js`, received on 12/17/2018, 11:07:59 PM. Its status is listed as '#5509 activated and is running' with a green dot. Another entry shows '#5511 waiting to activate' with an orange dot, highlighted with a yellow box. This entry was received on 12/17/2018, 11:08:15 PM. The clients section shows the URL `http://127.0.0.1:5500/index.html` and a `focus` link.

Service Worker LifeCycle



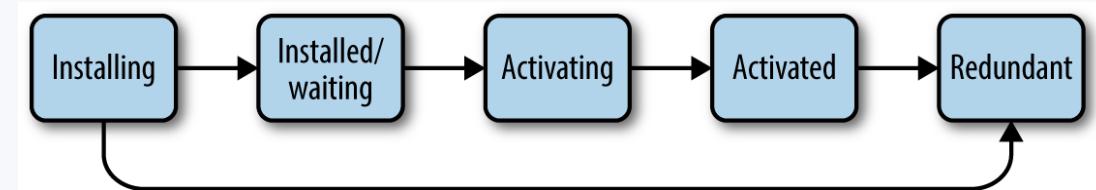
- It is only move to the **activating state** when there are no longer any pages loaded that are still using the old service worker.
- **Why?** Imagine a scenario in which you release a new version of a service worker, and this service worker's install event deletes userdata.json from the cache, adds users.json instead, and changes the fetch event to return the new file when user data is requested. If multiple service workers controlled different pages, the ones controlled by the old service worker might look for the old userdata.json file in the cache after it was removed, causing your app to break.
- Activation can happen sooner using `ServiceWorkerGlobalScope.skipWaiting()` and existing pages can be claimed by the active worker using `Clients.claim()`.

Service Worker LifeCycle



- Activating state
 - Before a service worker becomes active and takes control of the app, the `activate` event is triggered.
 - The **activating state** can be extended by calling `event.waitUntil()` and passing it a promise.

Service Worker LifeCycle

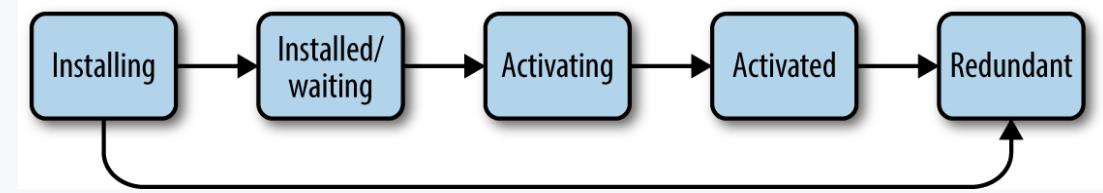


- Activating state

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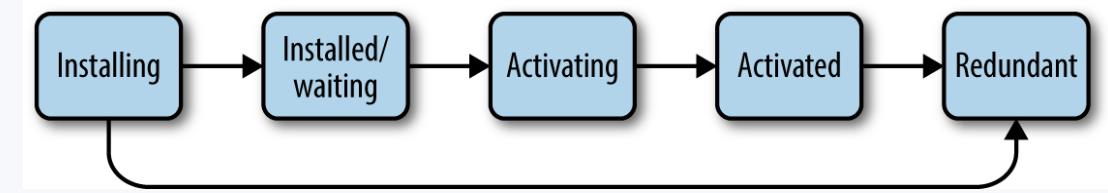
```
self.addEventListener('activate', function(e) {  
  e.waitUntil(  
    caches.keys().then(function(keyList) {  
      return Promise.all(keyList.map(function(key) {  
        if (key !== cacheName) {  
          return caches.delete(key);  
        }  
      }));  
    })  
  );  
  return self.clients.claim();  
});
```

Service Worker LifeCycle



- Activated state
 - Once a service worker is activated, it is ready to take control of the page and listen to functional events (such as `fetch`).
 - Note: a service worker can only take control of pages before they start loading. This means that pages that began loading before the service worker became active cannot be controlled by it.

Service Worker LifeCycle



- Redundant state
 - Service workers that failed during registration, or installation, or were replaced by newer versions, are placed in the **redundant state**. Service workers in this state no longer have any effect on your app.

Service Worker

- Further reading:
 - Service Worker Cookbook (Mozilla) - collection of working, practical examples of using service workers in modern web sites: <https://serviceworke.rs/>

CacheStorage API

- Documentation:
 - <https://developers.google.com/web/fundamentals/instant-and-offline/web-storage/cache-api>
- The **Cache API** was created to enable Service Workers to cache network requests so that they can provide appropriate responses even while offline. However, the API can also be used as a general storage mechanism.

CacheStorage API

- How to check whether the API is available?

```
const cacheAvailable = 'caches' in self;
```

- Creating and opening a cache

```
caches.open('my-cache').then((cache) => {
  // do something with cache...
});
```

CacheStorage API

- Retrieving from a cache using `cache.match`

```
cache.match(request).then((response) => console.log(request, response));
```

- Retrieving all matching responses using `cache.matchAll`.

```
cache.matchAll(request).then((responses) => {
  console.log(`There are ${responses.length} matching responses.`);
});
```

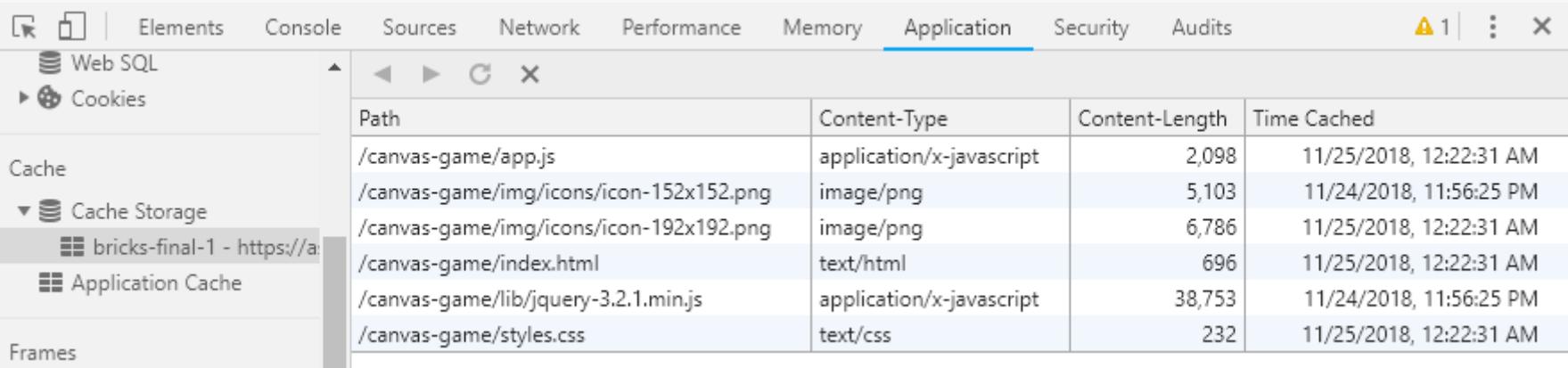
CacheStorage API

- Adding to a cache
 - There are three ways to add an item to a cache - `put`, `add` and `addAll`. All three methods return a Promise.
 - `cache.put`

```
cache.put('/test.json', new Response('{"foo": "bar"}'));
```
 - `cache.add`
 - `cache.addAll`

CacheStorage API

```
let cacheName = 'bricks-final-1';
let filesToCache = [
  'index.html',
  'app.js',
  'styles.css',
  'img/icons/icon-152x152.png',
  'img/icons/icon-192x192.png'
];
```



The screenshot shows the Google Chrome DevTools Application tab. On the left, there's a sidebar with 'Web SQL', 'Cookies', 'Cache', 'Cache Storage' (which is expanded to show 'bricks-final-1 - https://a...', 'Application Cache', and 'Frames'). The main area has tabs for 'Path', 'Content-Type', 'Content-Length', and 'Time Cached'. The table lists the cached files from the provided code:

Path	Content-Type	Content-Length	Time Cached
/canvas-game/app.js	application/x-javascript	2,098	11/25/2018, 12:22:31 AM
/canvas-game/img/icons/icon-152x152.png	image/png	5,103	11/24/2018, 11:56:25 PM
/canvas-game/img/icons/icon-192x192.png	image/png	6,786	11/25/2018, 12:22:31 AM
/canvas-game/index.html	text/html	696	11/25/2018, 12:22:31 AM
/canvas-game/lib/jquery-3.2.1.min.js	application/x-javascript	38,753	11/24/2018, 11:56:25 PM
/canvas-game/styles.css	text/css	232	11/25/2018, 12:22:31 AM

Checking the **Cache Storage** in Google Chrome

CacheStorage API

- Deleting an item

```
cache.delete(request);
```

- Where request can be a Request or a URL string.

CacheStorage API

- Deleting a cache

```
caches.delete(key)
```

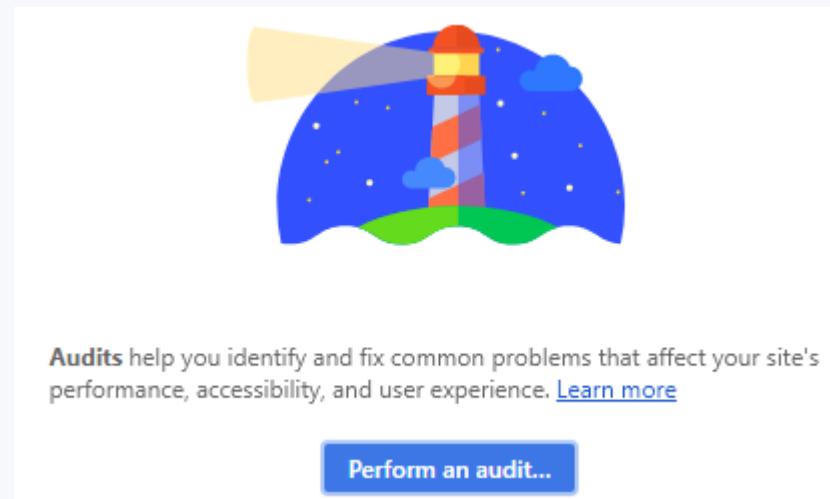
- The function returns a Promise that resolves to true if the cache existed and was deleted, or false otherwise.

CacheStorage API

```
//2. Delete the old version of the cache
self.addEventListener('activate', function(e) {
  e.waitUntil(
    caches.keys().then(function(keyList) {
      return Promise.all(keyList.map(function(key) {
        if (key !== cacheName) {
          return caches.delete(key);
        }
      }));
    })
  );
  return self.clients.claim();
});
```

Lighthouse

- an open-source, automated tool for improving the quality of Progressive Web Apps, that eliminates much of the manual testing that was previously required.
- integrated in Google Chrome.



Is your App a Progressive Web App?

- Checklist: <https://developers.google.com/web/progressive-web-apps/checklist>
- Most of the checks are already included in Lighthouse ☺

Examples



Social Media - Twitter

- Windows Store Application
 - <https://www.microsoft.com/ro-ro/p/twitter/9wzdncrfj140>
- Twitter Lite for Android
 - <https://play.google.com/store/apps/details?id=com.twitter.android.lite&hl=en>

Examples

Drawing- Google Chrome Canvas

- <https://canvas.apps.chrome/>

JavaScript

JavaScript

- Modern_JavaScript.zip on <http://online.ase.ro>
- <http://jstherightway.org/>

Web Storage API

- Documentation:
 - https://developer.mozilla.org/en-US/docs/Web/API/Web_Storage_API