Graphics Programming

Lecture 2

Light and Vision

- Light is composed of electromagnetic waves that can travel without a medium, unlike sound.

- The behaviour of light can be seen in the behaviour of waves and photons, the basic unit of light.

- A wavelength (which varies inversely with frequency) manifests itself as colour, while wave amplitude is perceived as luminous intensity or brightness; it is measured by the standard unit of a candela.

- Humans can see light that ranges between 380 nm and 740 nm, but cannot see light that is below the frequency of visible red light or above the frequency of visible violet light.

- Light at the red end of the visible spectrum has long wavelengths (and is lower frequency), while light at the violet end has short wavelengths (and is higher frequency).

- Light waves enter the eye as long (red), medium (green), and short (blue) waves; the color of an object is the color the object reflects.
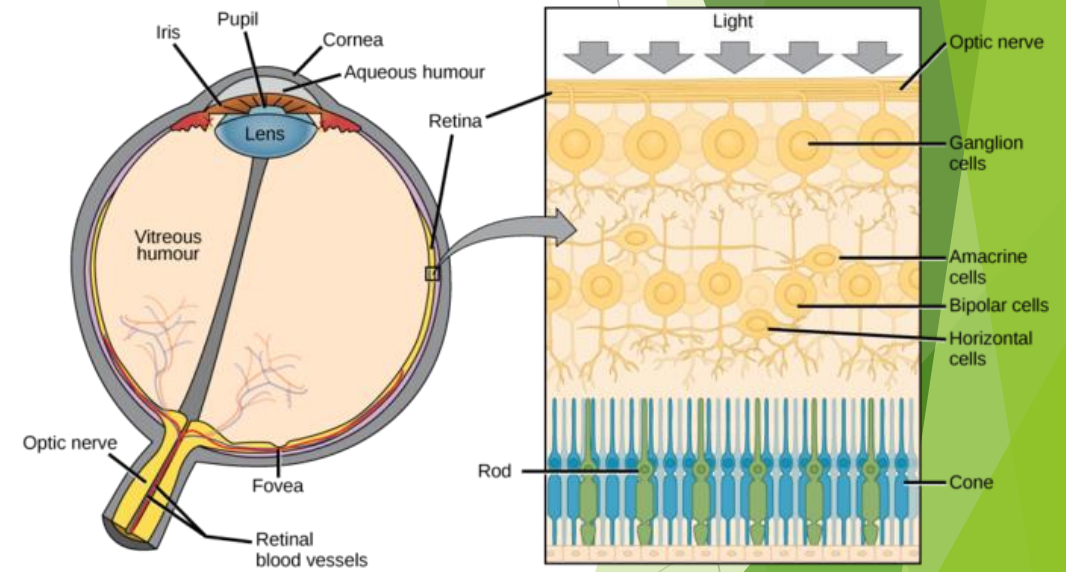
Light and Vision

Human Visual System

Rods and Cones

Thalamus

Visual Cortex

Retina Layers

Light

Optic Nerve
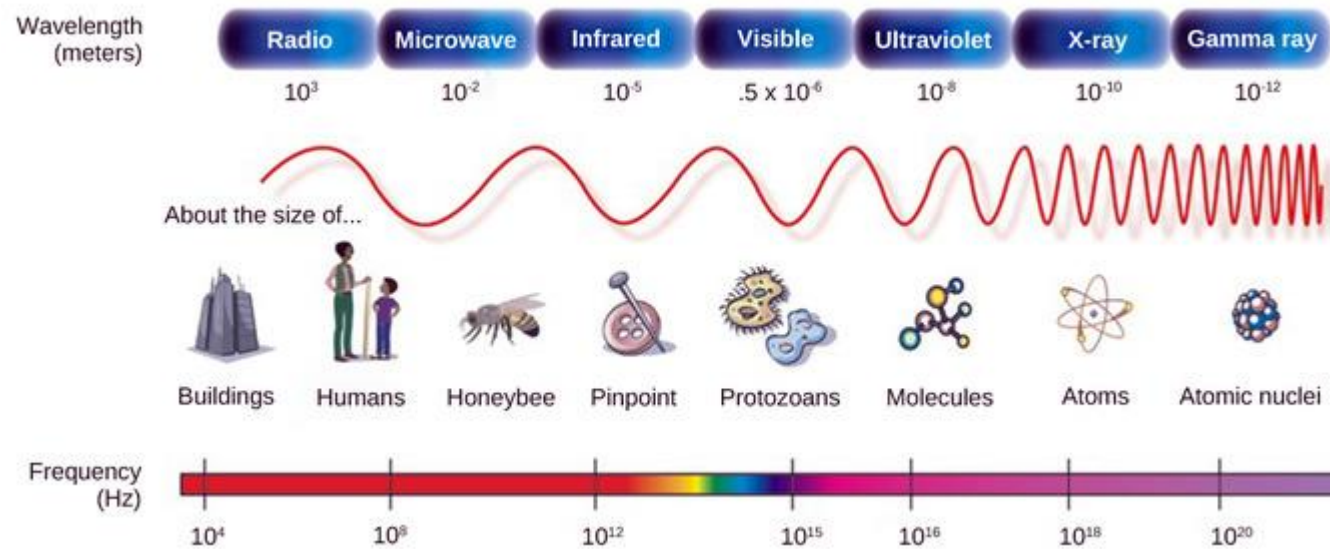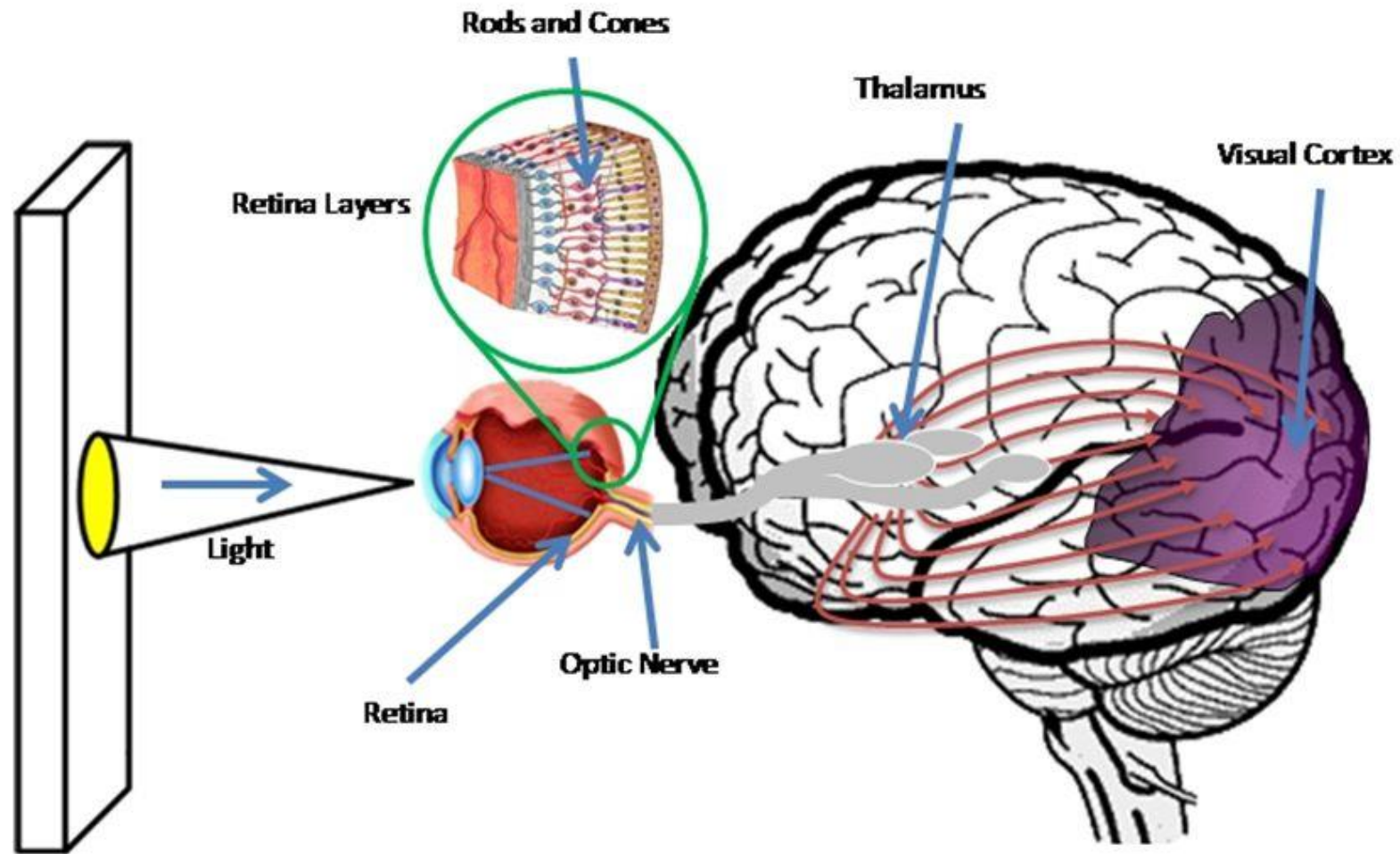
Retina

# Light and Vision

- Rods are used for peripheral and night-time vision; cones are used for daytime and colour vision.
  - **Rod**: a rod-shaped cell located in the outer retina of the eye that is extremely sensitive to light
  - **Cone**: cell located near the centre of the retina that is weakly photosensitive and is responsible for colour vision in relatively bright light
- The fovea is responsible for acute vision because it has a high density of cones.

Light and Vision
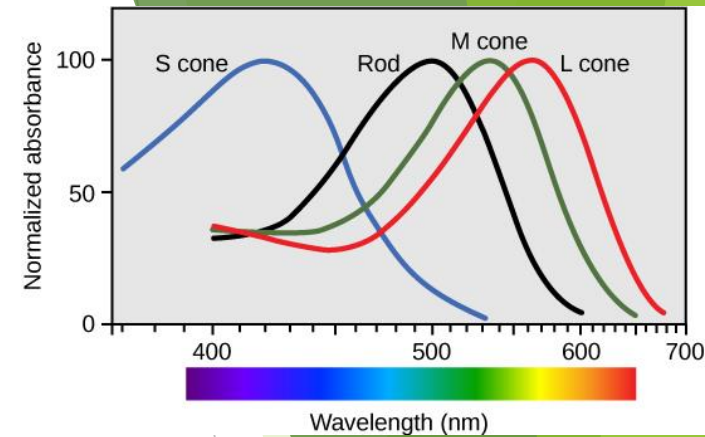
- Three types of cones that differ in the wavelength to which they are most responsive.

  - Some cones are maximally responsive to short light waves of 420 nm; they are called S cones ("S" for "short").

  - Other cones (M cones, for "medium") respond maximally to waves of 530 nm.

  - A third group (L cones, or "long" cones) responds maximally to light of longer wavelengths at 560 nm.

- With only one type of cone, color vision would not be possible; a two-cone (dichromatic) system has limitations.

- Primates use a three-cone (trichromatic) system, resulting in full color vision.

Human Visual System

- Have you ever tried to swat a fly
  - They can only move at <5mph
- Animals see the world around them like a continuous video.
  - In reality, they piece together images sent from the eyes to the brain in distinct flashes a set number of times per second.
  - Humans average 60 flashes per second, turtles 15, and flies 250.
  - Killer fly (catches and eats other flys) >400 fps
  - Time moves 4 times slower for a fly (slow motion)
- 60Hz is flicker fusion rate for humans (some people can detect flicker at 60Hz)
  - AC is distributed at 60Hz

Not so simple

- Fighter pilots have demonstrated an ability to perceive an image flashed on the screen for 1/250th of a second

- Games output moving images, and therefore invoke different visual systems to the ones that simply process light.

  - Can see motion artefacts at up to 1000Hz

  - The middle part of your vision (foveal region) which is the most detailed, is very bad at detecting motion - so if you're watching things in the middle of the screen moving, it's not that big a deal what the refresh rate is; you can't possibly see it with that part of your eye.

  - On the periphery of our eyes we detect motion incredibly well

- When doing a visual search/multiple object tracking, humans can only **act** on video at 13Hz – brain averages intermediate images (can see at higher frequencies but not act on them) – can see signal in EEG

- High frequencies may present image sooner than at lower frequency – hence faster reaction times

What is Computer Graphics?
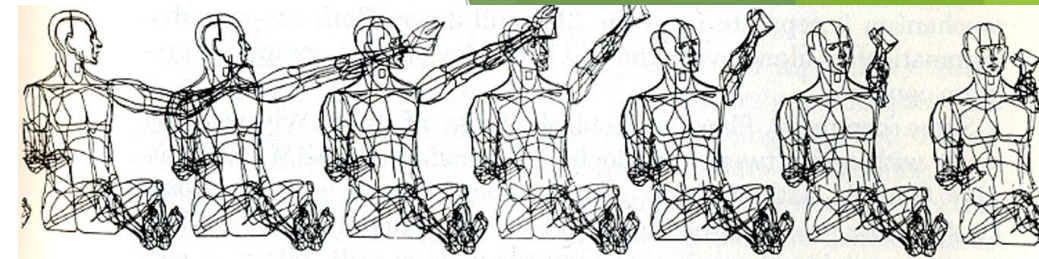
Above: Mechanical analogue plotter draws pilot for computer-animated film by William Fetter of the Boeing Company in Seattle, Washington. Below: Animated sequence from the film. Photo: Boeing Company.

▶ William Fetter coined term "computer graphics" in 1960 to describe new design methods he was pursuing at Boeing for cockpit ergonomics

▶ Created a series of widely reproduced images on "pen plotter" exploring cockpit design, using 3D model of human body.

"Perhaps the best way to define computer graphics is to find out what it is not. It is not a machine. It is not a computer, nor a group of computer programs. It is not the know-how of a graphic designer, a programmer, a writer, a motion picture specialist, or a reproduction specialist.

Computer graphics is all these – a consciously managed and documented technology directed toward communicating information accurately and descriptively."

Computer Graphics, by William A. Fetter, 1966

What is **Interactive** Computer Graphics?

▶ User controls content, structure, and appearance of objects and their displayed images via rapid visual feedback

▶ Basic components of an interactive graphics system

  ▶ input (e.g., mouse, stylus, multi-touch, in-air fingers…)

  ▶ processing (and storage of the underlying representation/model)

  ▶ display/output (e.g., screen, paper-based printer, video recorder…)

▶ First truly interactive graphics system, Sketchpad, pioneered by Ivan Sutherland 1963 Ph.D. thesis Sketchpad, *"A Man-Machine Graphical Communication System"*

  ▶ Used TX-2 transistorized "mainframe" at MIT Lincoln Lab

  ▶ Ability to zoom in and out

  ▶ Could draw directly on computer display

  ▶ Comprised light-pen and "organ-console" (to erase/move drawing/etc.)

What is **Interactive** Computer Graphics?

▶ Almost all key elements of interactive graphics system are expressed in first paragraph of Sutherland's 1963 Ph.D. thesis

The Sketchpad system uses drawing as a novel communication medium for a computer. The system contains input, output, and computation programs which enable it to interpret information drawn directly on a computer display. Sketchpad has shown the most usefulness as an aid to the understanding of processes, such as the motion of linkages, which can be described with pictures. Sketchpad also makes it easy to draw highly repetitive or highly accurate drawings and to change drawings previously drawn with it...
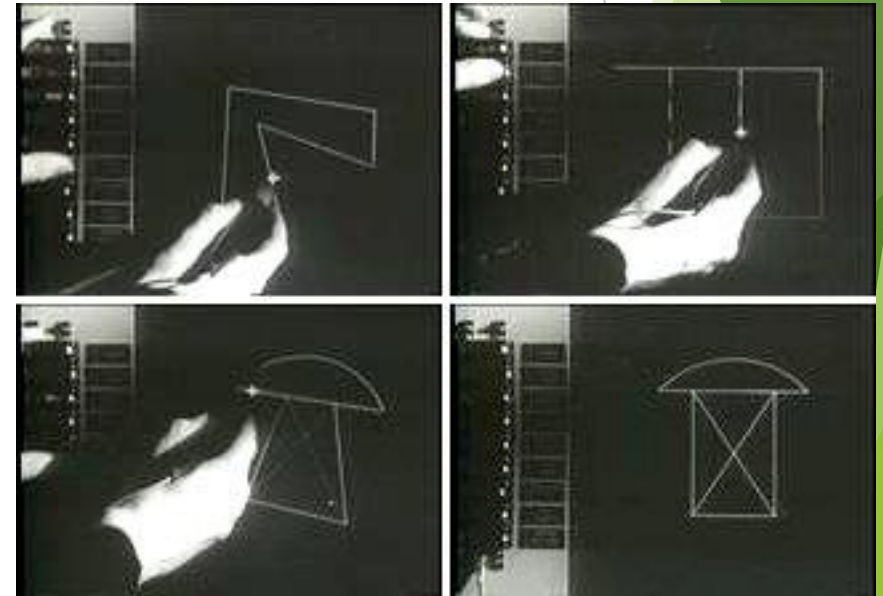
What is **Batch** Computer Graphics?

- Today, non-interactive batch mode (aka offline) rendering is still used for final production-quality content (special effects – FX).

- Applications – TV, films and game cut-sequences

- Rendering a single frame of The Good Dinosaur (2015, a 24 fps movie) averaged 48 hours on a 30,000-core render farm!

Computer Graphics: Definitions

- Computer Graphics:
  - Producing pictures or images using a computer
  - Computer graphics generally means creation, storage and manipulation of models and images
  - Such models come from diverse and expanding set of fields including physical, biological, mathematical, artistic, and conceptual/abstract structures
- Imaging
  - Visual representation or reproduction of an object's form
- Modeling
  - Simulation of an object (usually in 3D)
- Rendering
  - Constructing 2D images from 2D/3D models
- Animation
  - Simulating changes over time

Computer Graphics: Applications
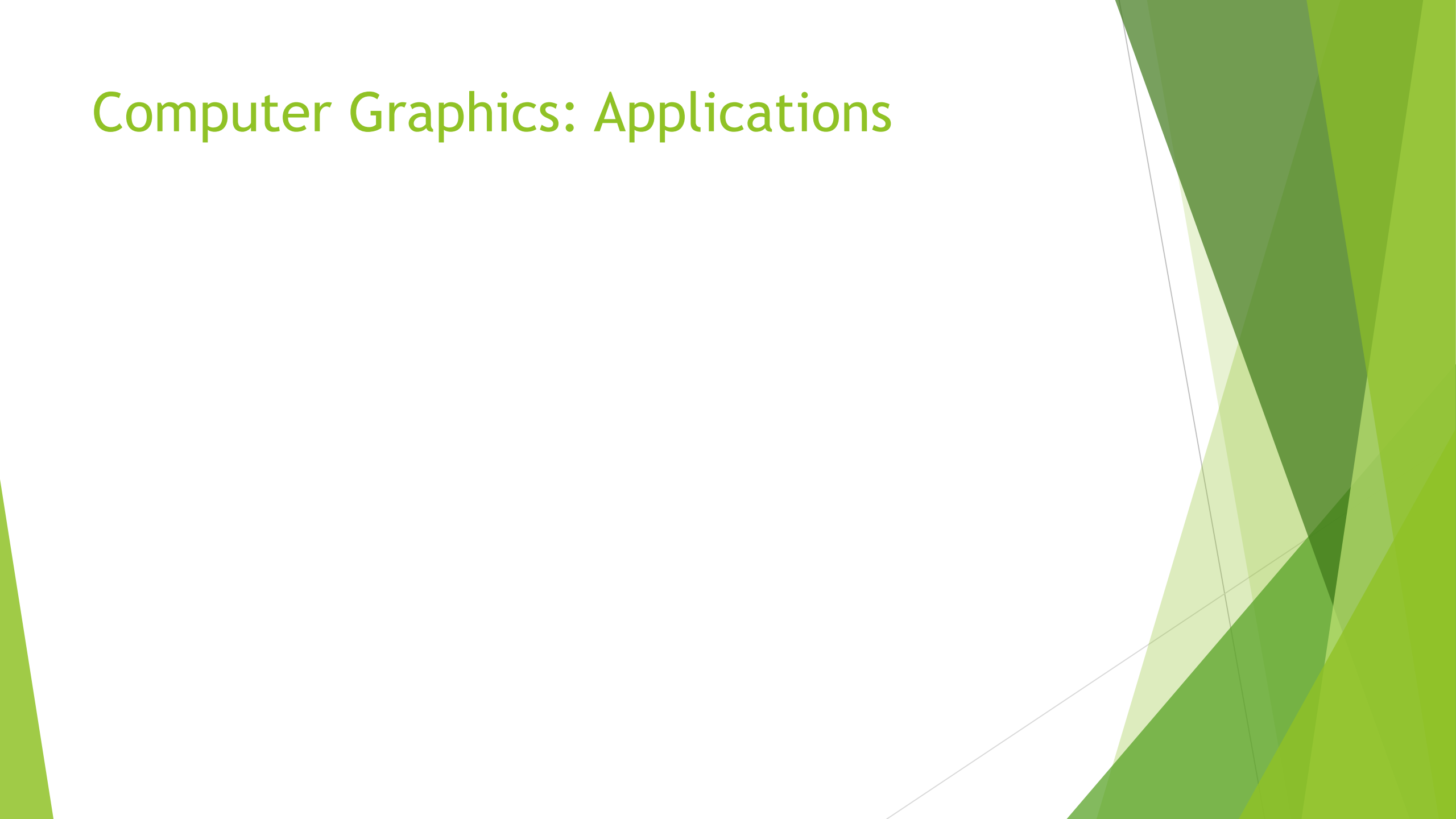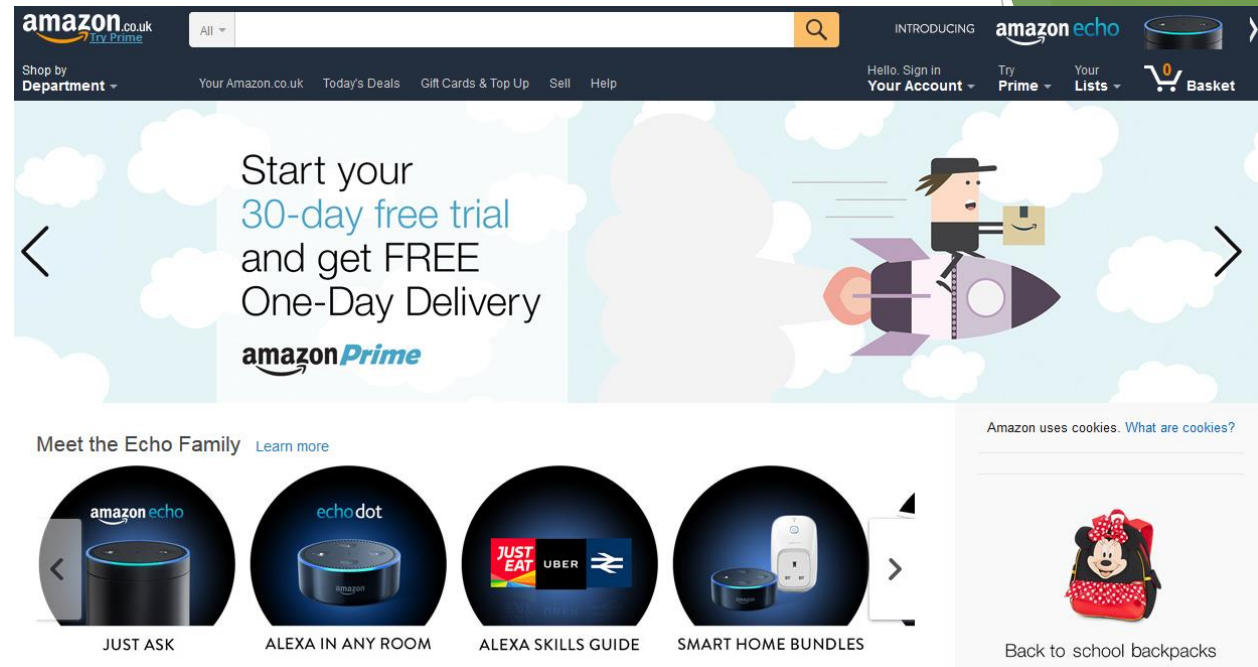
Scientific Visualisation
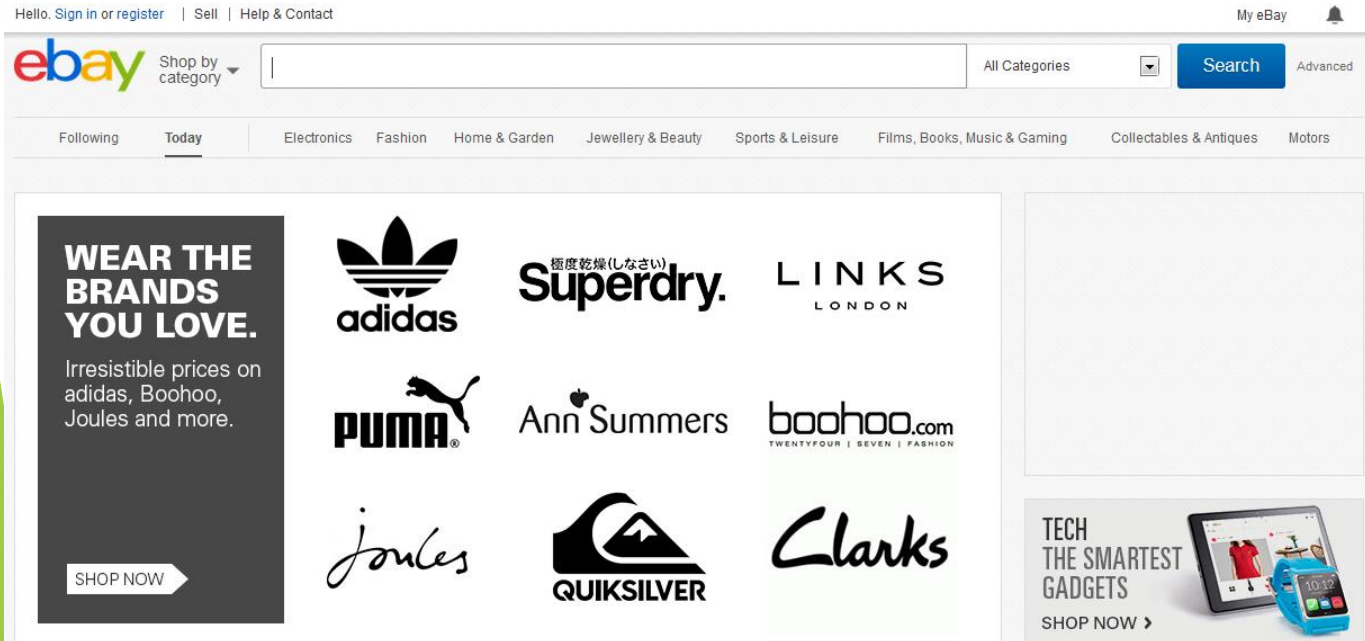
- Data analysis

E-Commerce

3D personalized avatars
e.g. teleconferencing

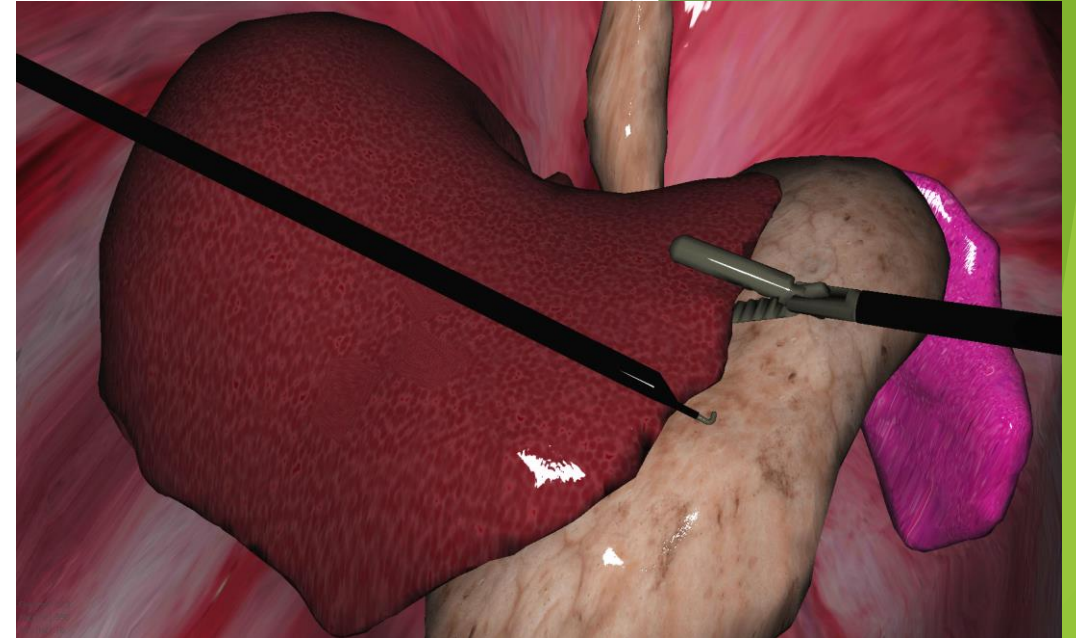# Medical applications

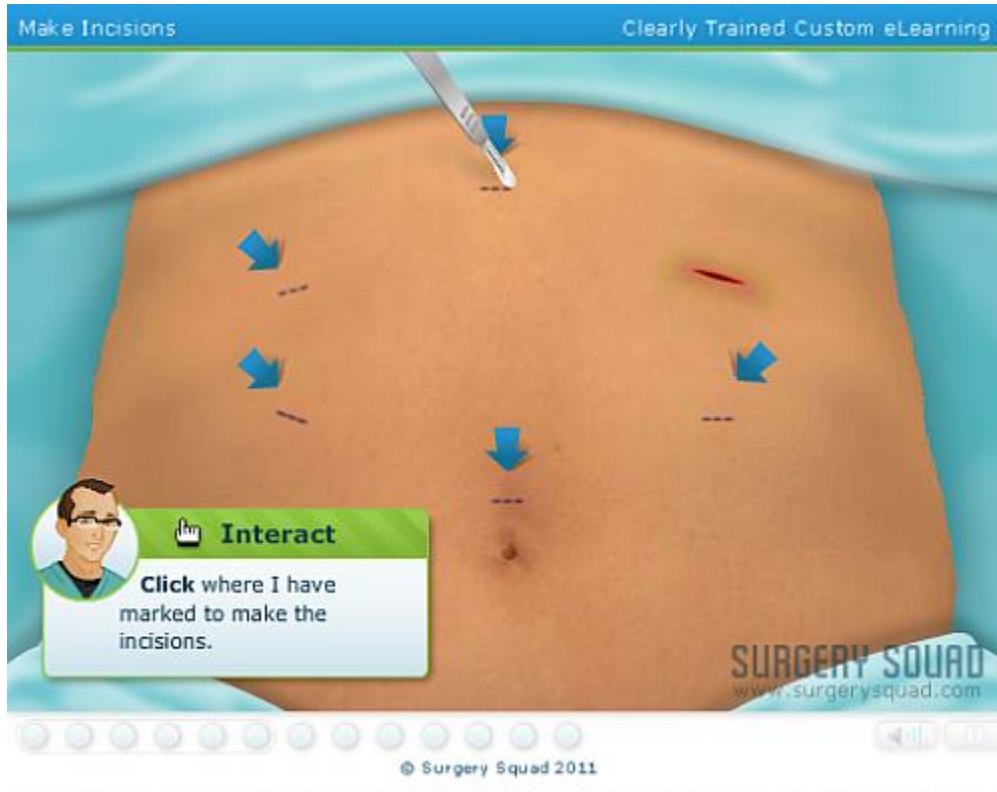- Diagnosis support
  - e.g. Visualisation of CAT/MRI scans
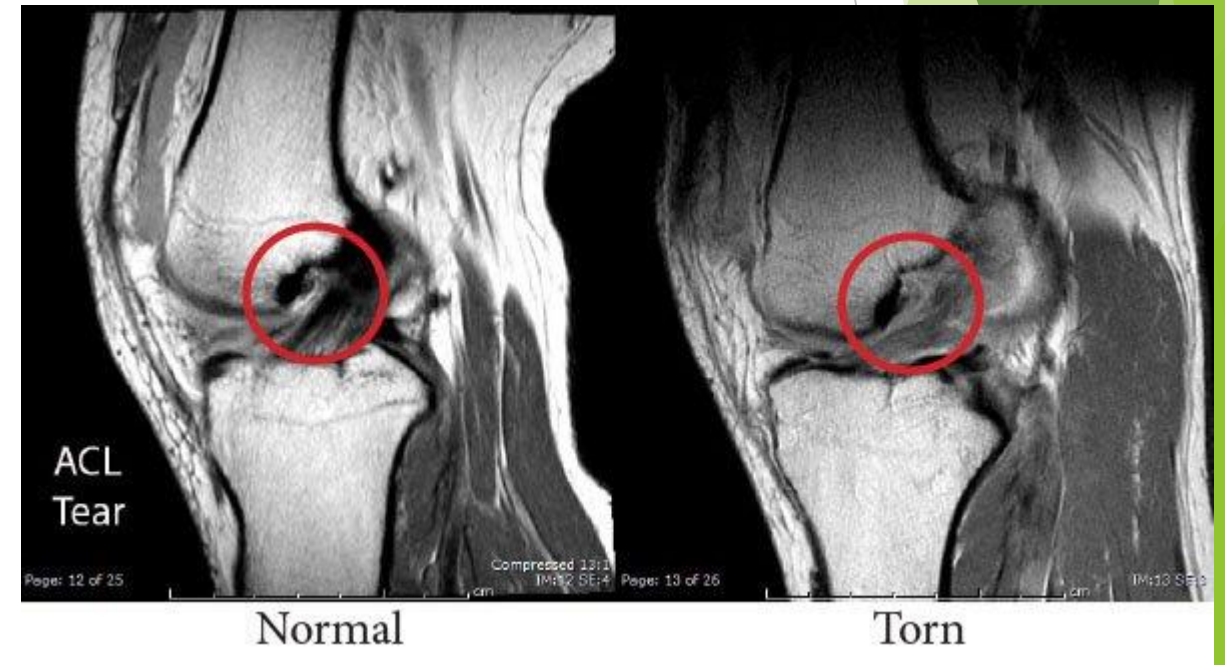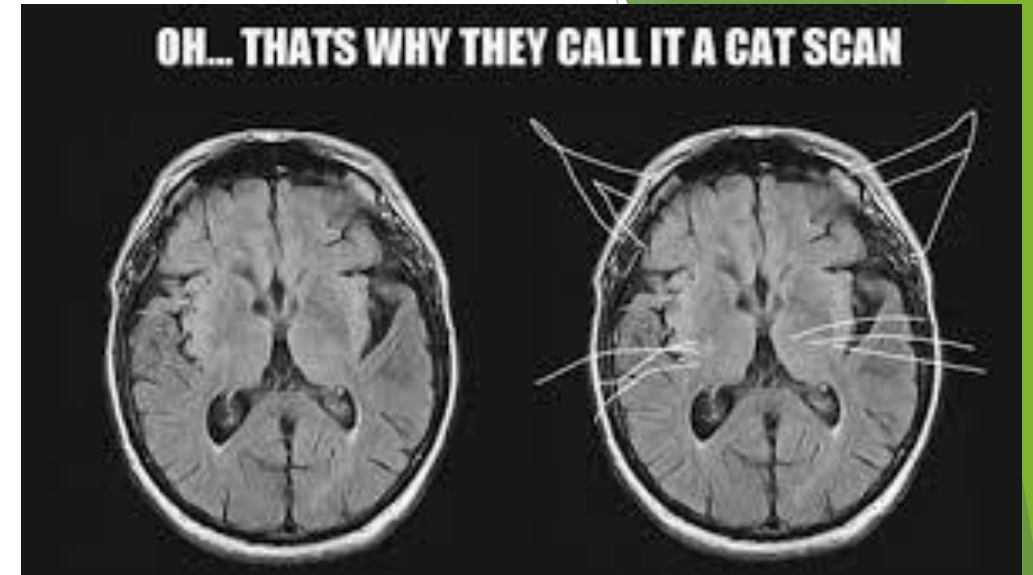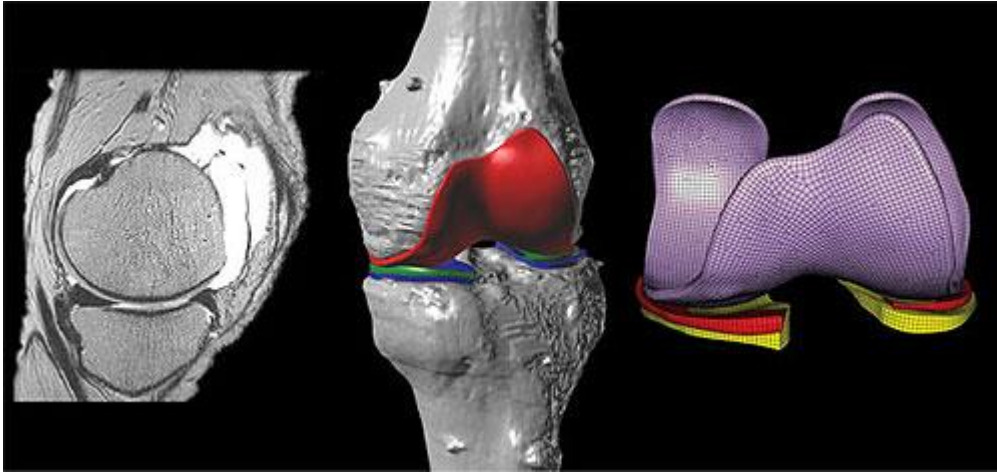
Medical applications

▶ Virtual/tele surgery

Manufacturing

- CAD

- Rapid Prototyping

Creating Rapid Prototypes

Digital CAD file → 3D Printer → Rapid Prototype
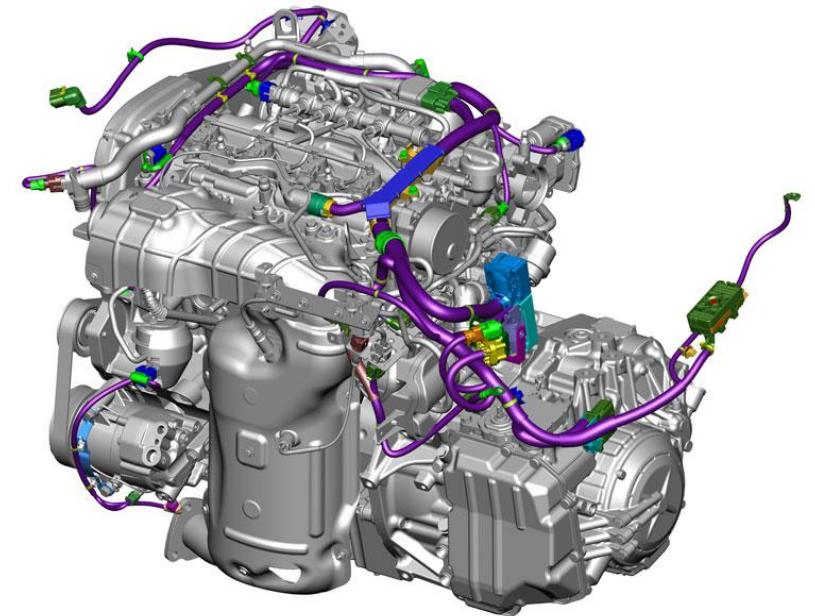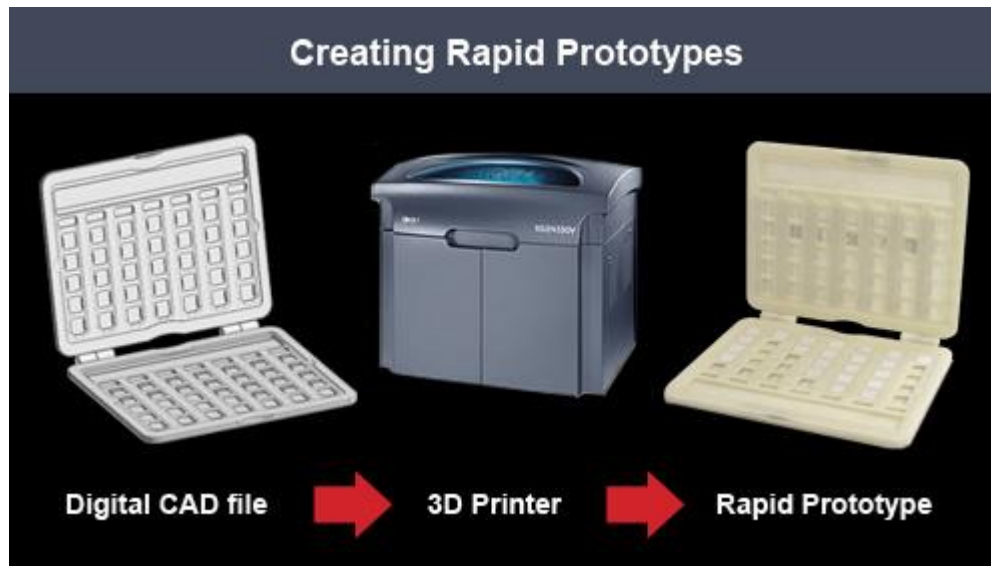
Cultural heritage

- Exhibition
  - Virtual Museums
  - Catalogues
  - Educational Tools
- Restoration
  - 3D Modelling
  - Simulations

Oriental Museum in Chicago

Cultural heritage

- Restoration
- First step is *3D Acquisition*

Visual Computing Lab – Stanford
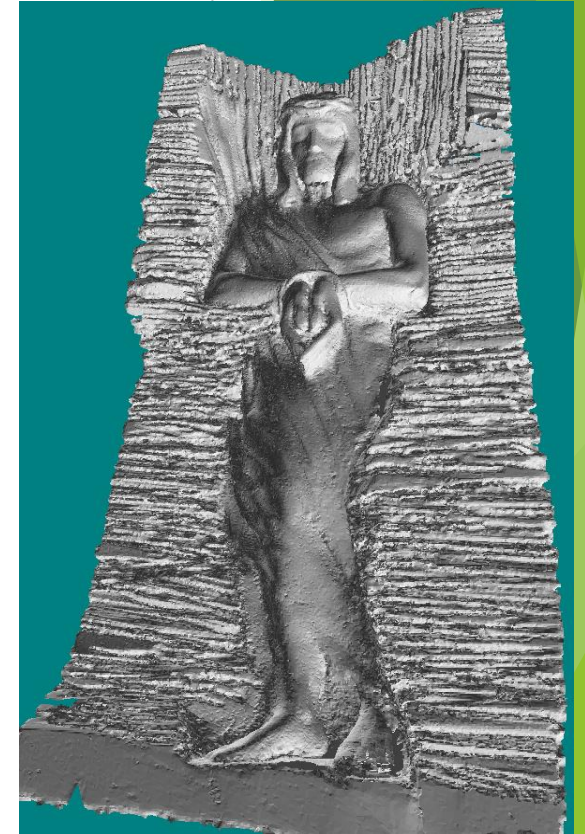
Cultural heritage

- Restoration
- First step is *3D Acquisition*

3D model of the ancient Temple of Bel, at Palmyra, Syria,

Architecture: Design aid tool
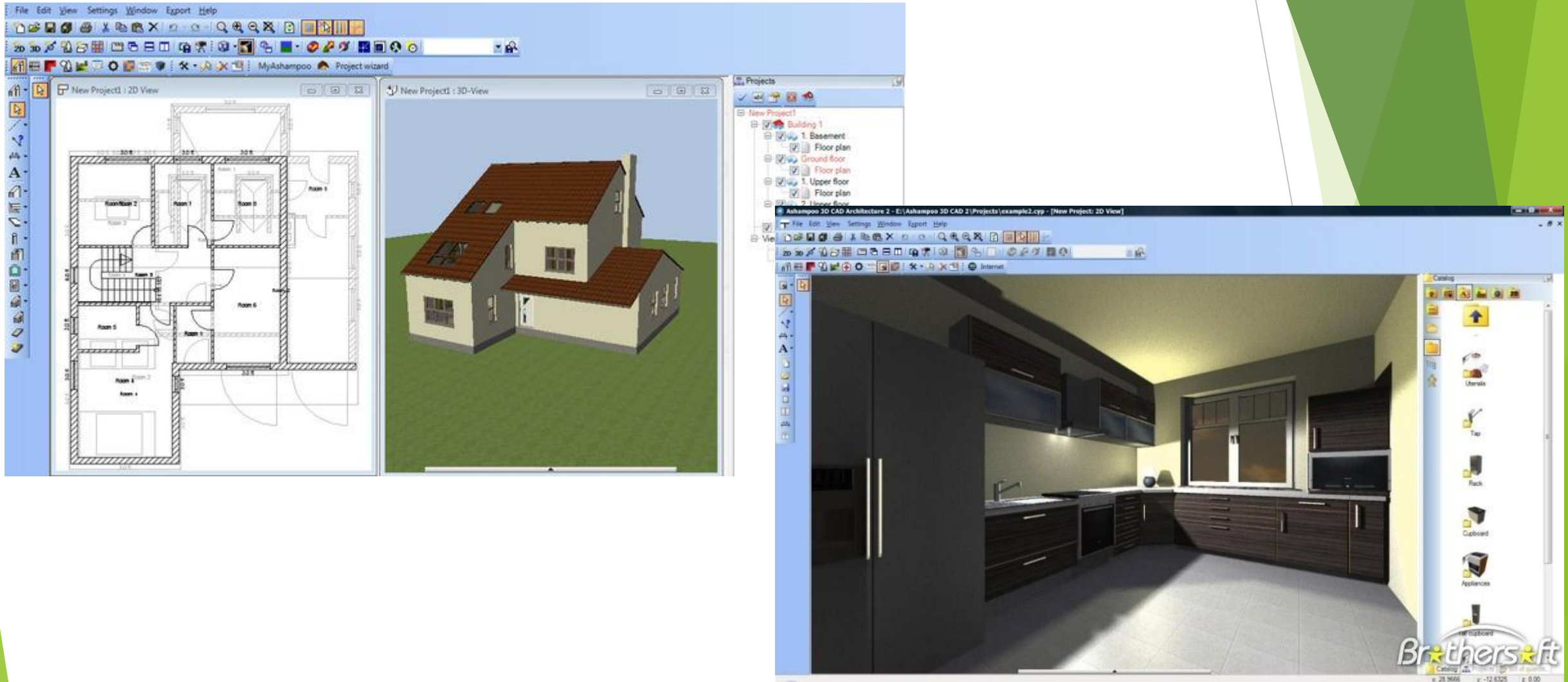
Architecture: Design aid tool

- Architecture:
  - preview:
    - User interaction
    - Design check

Area3D (with VRay)

Brazil – SputterFish

Strata Renderer– (Strata)

Computer-Generated Models of Physical, Financial and Economic Systems for Educational Aids

Flight Simulator

Mars Rover Simulator

Entertainment: Videogames
Most in-demand field of applications
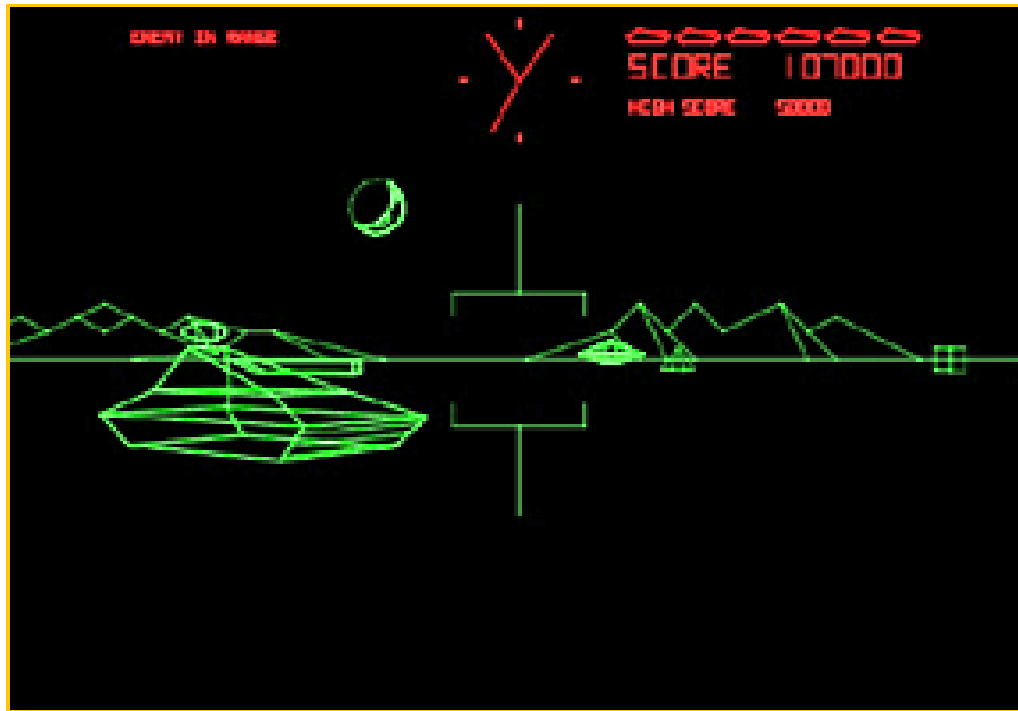
Battlezone – Atari 1980
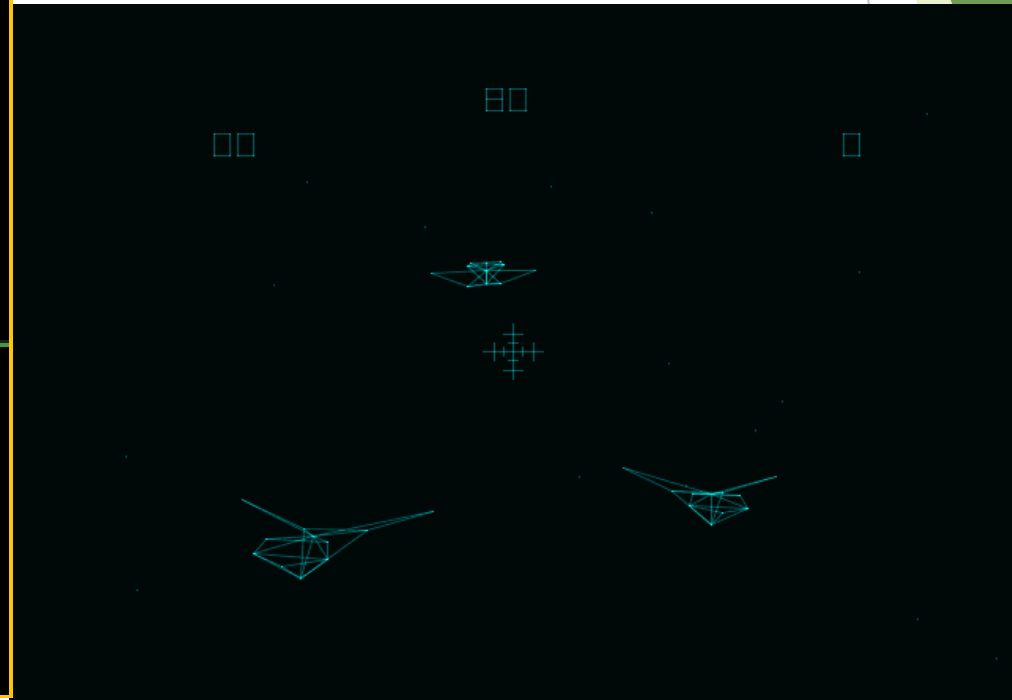
Tailgunner - Cinematronics 1979

Entertainment: Videogames
Most in-demand field of applications

Doom – IDsoft 1993

Virtua Fighter - Sega 1993

Entertainment: Videogames
Most in-demand field of applications

Doom 3- ID soft 2004

World of Warcraft,
Blizzard Entertainment 2004

Entertainment: Videogames
Most in-demand field of applications

Doom 3- ID soft 2004

**World of Warcraft,
Blizzard Entertainment 2004**

Entertainment: Videogames
Most in-demand field of applications

Uncharted 4 – PS4 – 2016
https://www.youtube.com/watch?v=yrN5arZKJok
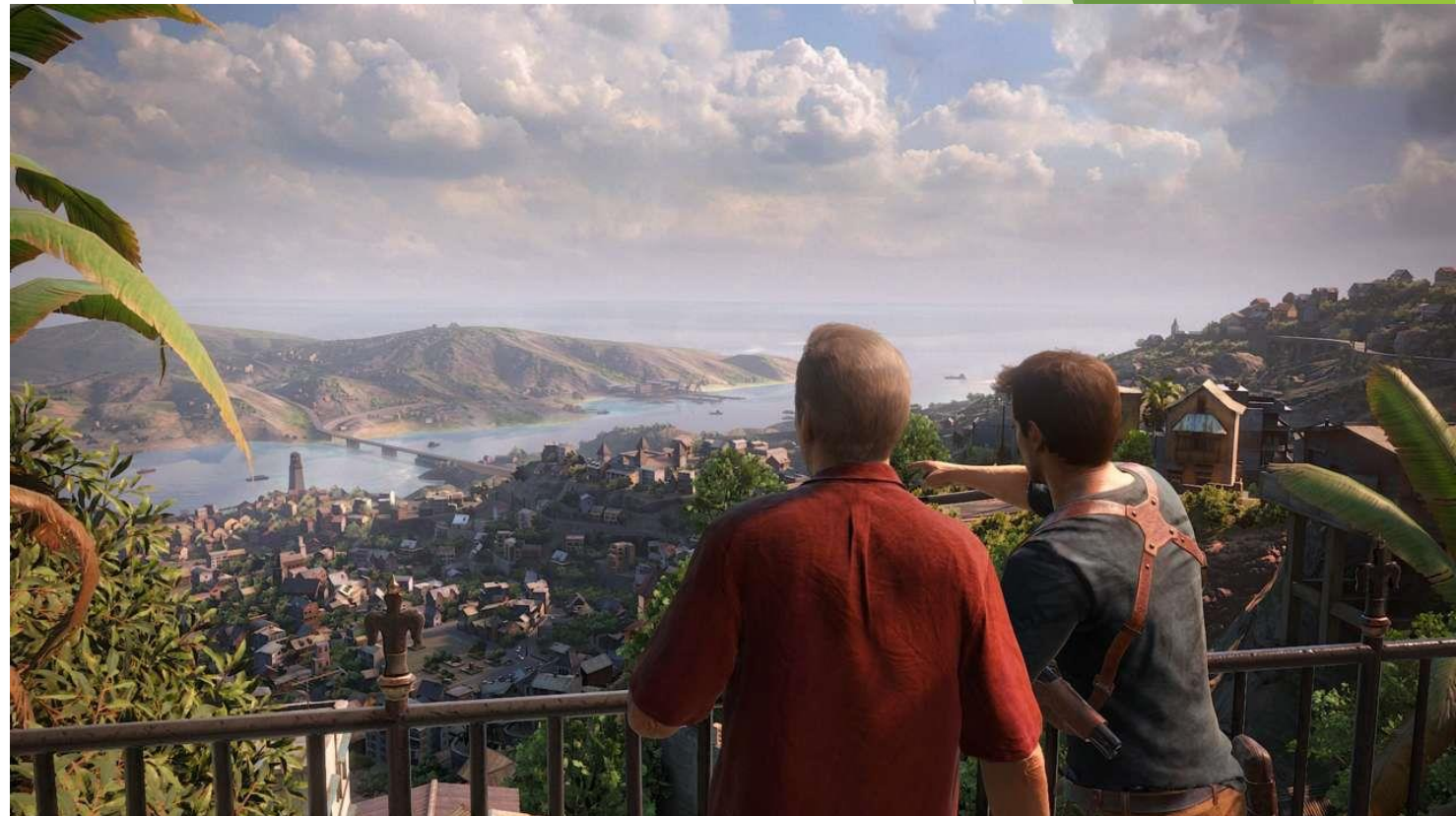
Entertainment: Videogames

- Virtual Reality

Entertainment: Movie Industry
CG Animations

High performance graphics possible at the time with offline rendering (different to real time requirement for games)

Luxo Jr - Pixar 1986

Geri's Game - Pixar 1997

Entertainment: Movie Industry
Visual Effects (not special fx)
Special effects are carried out on set during production and *visual* effects are done in post-production

The Matrix - 1999
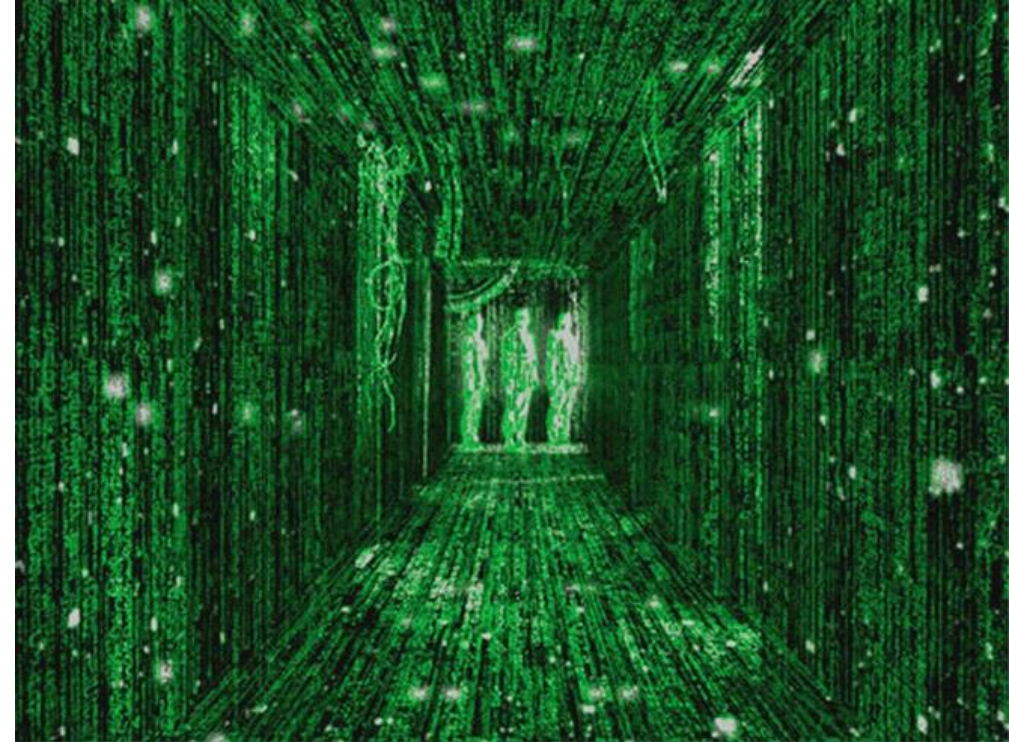
Before and After

- Guardians of the Galaxy

Before and After

- Pirates Of The Caribbean

Before and After

- Hobbit

Before and After

- Twilight Saga: Eclipse

Before and After

▶ Game Of Thrones

Before and After

- Alice In Wonderland

Before and After

- Life Of Pi

Photorealistic feature movies

- Final Fantasy (video is completely computer generated)

HTML5

▶ Latest evolution of the standard that defines HTML

    ▶ New version of HTML - new elements, attributes, and behaviours

    ▶ Larger set of technologies that allows more diverse and powerful websites and applications.

       ▶ Multimedia: Making video and audio first-class citizens in the Open Web.

       ▶ 2D/3D graphics and effects: Allowing a much more diverse range of presentation options.

          ▶ SVG

          ▶ WebGL

          ▶ Canvas

Graphics

       ▶ Performance and integration: Greater speed optimization and better usage of hardware.

       ▶ Styling: Allowing authors write more sophisticated themes – CSS3

       ▶ Device access: allowing for the usage of various input and output devices.

       ▶ Connectivity: allowing you to communicate with the server in new and innovative ways.

       ▶ Offline and storage: allowing webpages to store data on the client-side locally and operate offline more efficiently.

HTML5 Canvas

HTML5
< canvas >

▶ The HTML <canvas> element is used to draw graphics, on the fly, via JavaScript.

  ▶ The <canvas> element is only a container for graphics.

  ▶ Must use JavaScript to actually draw the graphics.

  ▶ Has several methods for drawing paths, boxes, circles, text, and adding images.
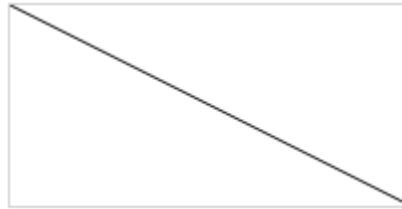
▶ Browser Support

Element					
<canvas>	4.0	9.0	2.0	3.1	9.0

▶ A canvas is a rectangular area on an HTML page. By default, a canvas has no border and no content.

▶ The markup looks like this: `<canvas id="myCanvas" width="200" height="100"></canvas>`
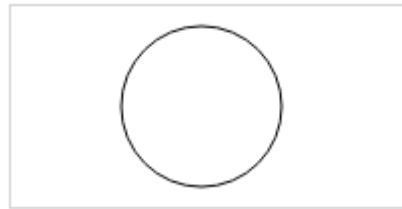
Canvas: Draw a Line/Circle

-
```javascript
var c = document.getElementById("myCanvas");
var ctx = c.getContext("2d");
ctx.moveTo(0,0);
ctx.lineTo(200,100);
ctx.stroke();
```

-
```javascript
var c = document.getElementById("myCanvas");
var ctx = c.getContext("2d");
ctx.beginPath();
ctx.arc(95,50,40,0,2*Math.PI);
ctx.stroke();
```

Canvas: Draw Text/Stroke Text

▶
```
var c = document.getElementById("myCanvas");
var ctx = c.getContext("2d");
ctx.font = "30px Arial";
ctx.fillText("Hello World",10,50);
```

Hello World

▶
```
var c = document.getElementById("myCanvas");
var ctx = c.getContext("2d");
ctx.beginPath();
ctx.arc(95,50,40,0,2*Math.PI);
ctx.stroke();
```

Hello World