

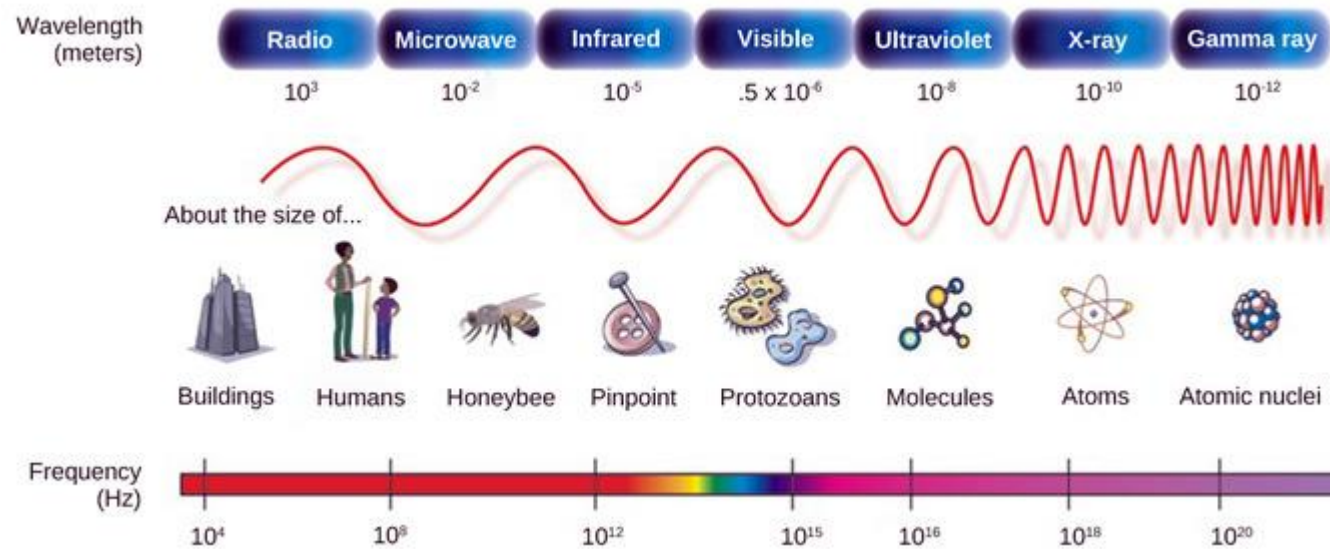
The background features abstract, overlapping green geometric shapes, primarily triangles and polygons, in various shades of green, creating a modern and dynamic visual effect.

Graphics Programming Lecture 2

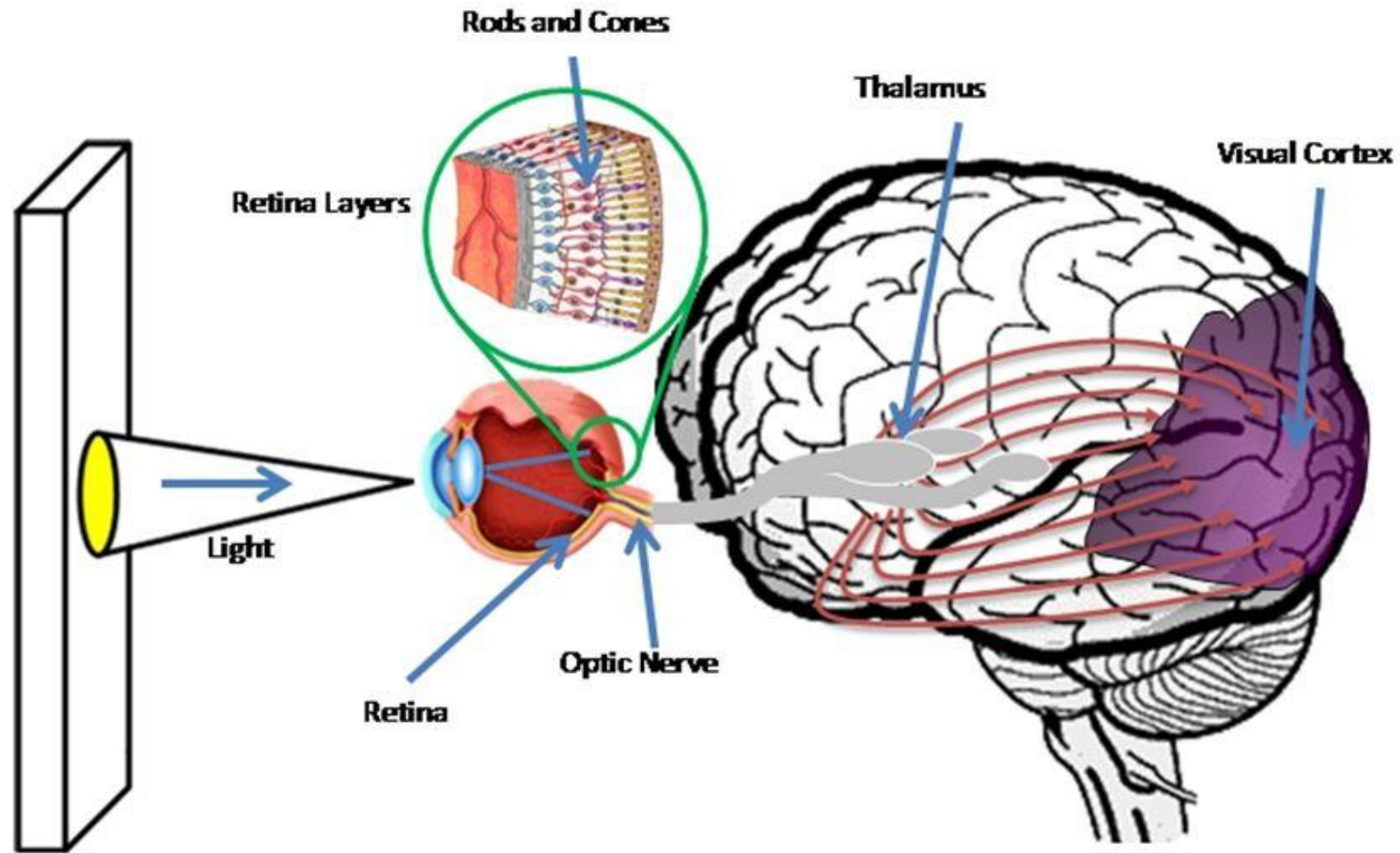
Light and Vision

- ▶ 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

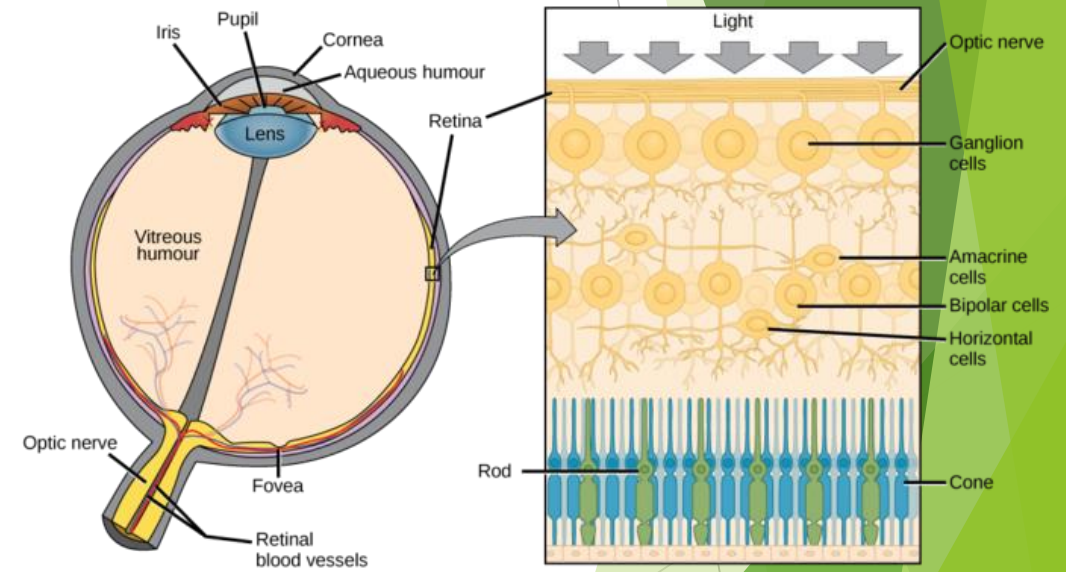


Human Visual System

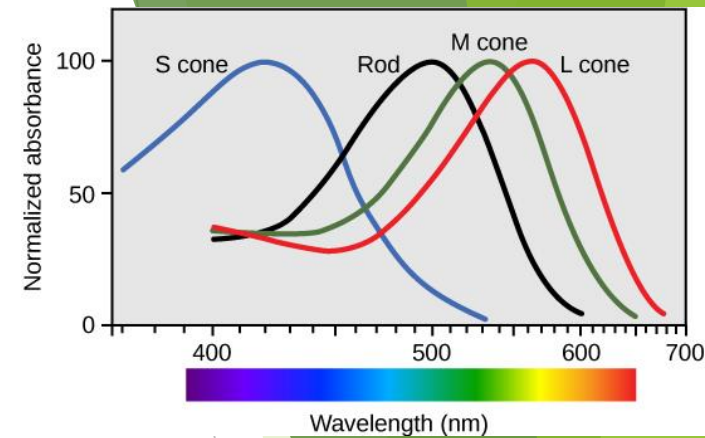


Rods and Cones

- ▶ Rods are used for peripheral and night-time vision
 - ▶ **Rod:** a rod-shaped cell located in the outer retina of the eye that is extremely sensitive to light
- ▶ Cones are used for daytime and colour vision.
 - ▶ **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.



Cones and Colour Vision



- ▶ There are 3 types of cones that differ in the wavelength to which they are most sensitive.
 - ▶ 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, colour vision would not be possible; a two-cone (dichromatic) system has limitations.
- ▶ Primates use a three-cone (trichromatic) system, resulting in full colour vision.

Human Visual System

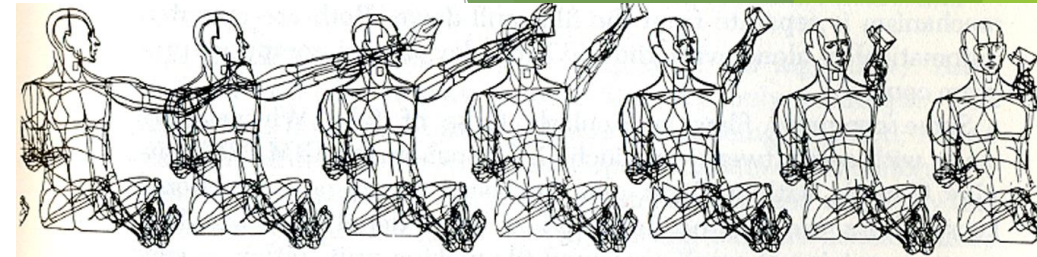


- ▶ Have you ever tried to swat a fly
 - ▶ They can only move at <5mph
- ▶ Animals see the world around them like a continuous video.
 - ▶ In reality, they piece together images sent from the eyes to the brain in distinct flashes a set number of times per second.
 - ▶ Humans average 60 flashes per second, turtles 15, and flies 250.
 - ▶ Killer fly (catches and eats other flies) >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?



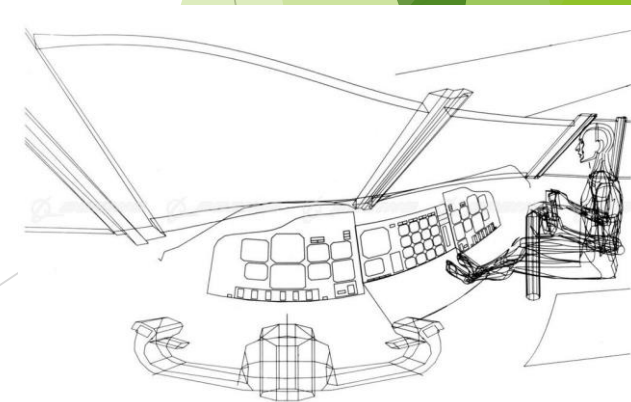
Above: Mechanical analogue plotter draws pilot for computer-animated film by William Fetter of the Boeing Company in Seattle, Washington. Below: Animated sequence from the film. Photo: Boeing Company.

- ▶ 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?

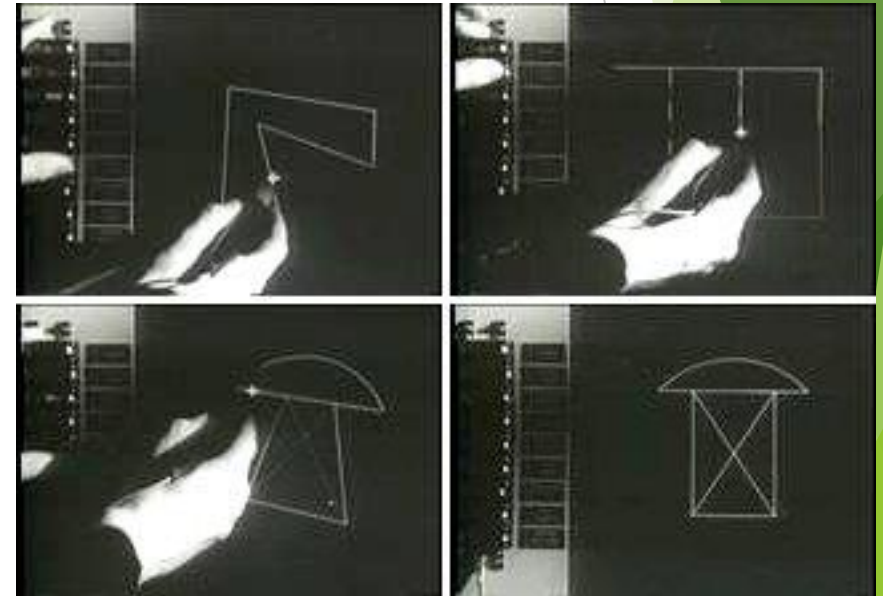
- ▶ User controls content, structure, and appearance of objects and their displayed images via rapid visual feedback
- ▶ Basic components of an interactive graphics system
 - ▶ input (e.g., mouse, stylus, multi-touch, in-air fingers...)
 - ▶ processing (and storage of the underlying representation/model)
 - ▶ 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?

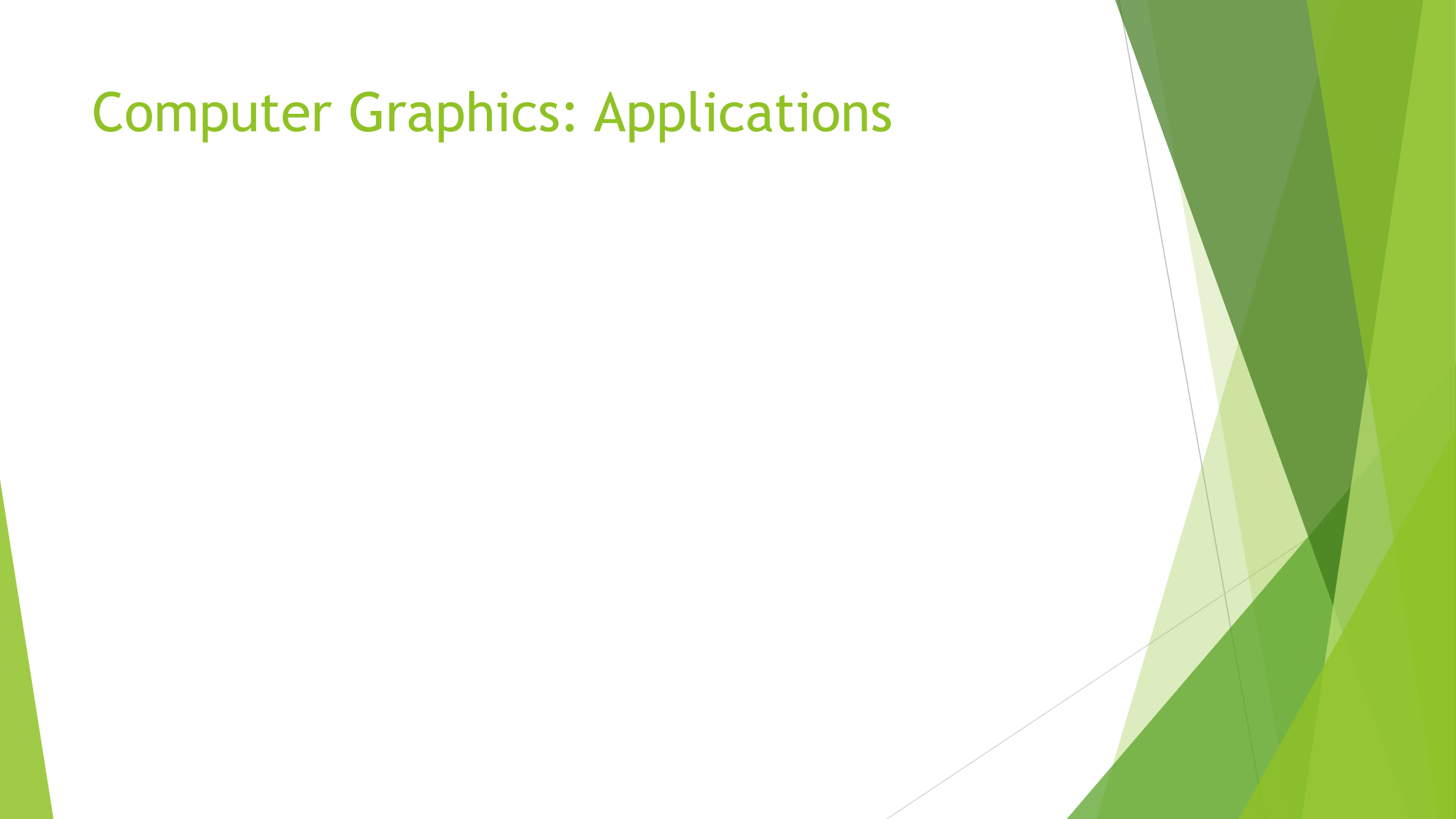
- ▶ Today, non-interactive batch mode (aka offline) rendering is still used for final production-quality content (special effects - FX).
- ▶ Applications - TV, films and game cut-sequences
- ▶ Rendering a single frame of The Good Dinosaur (2015, a 24 fps movie) averaged 48 hours on a 30,000-core render farm!



Computer Graphics: Definitions

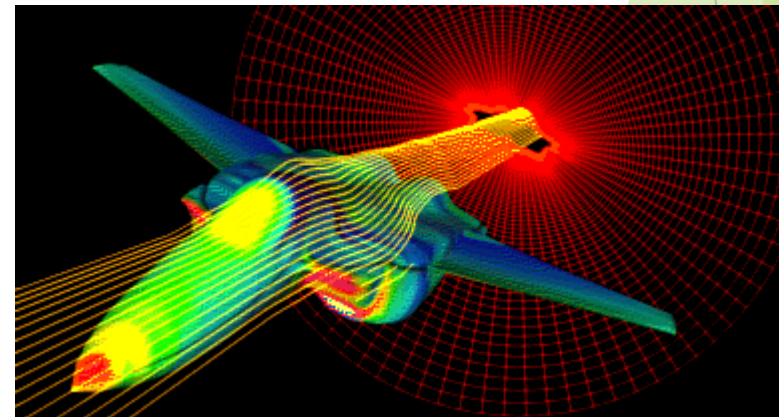
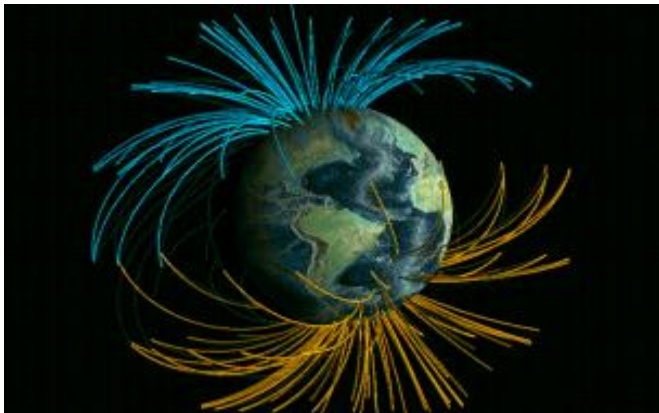
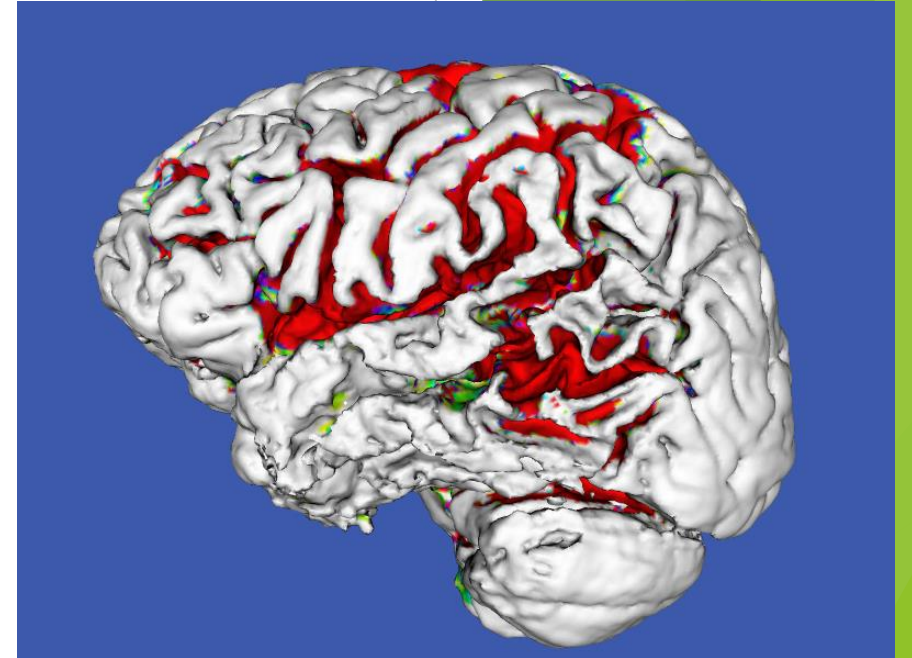
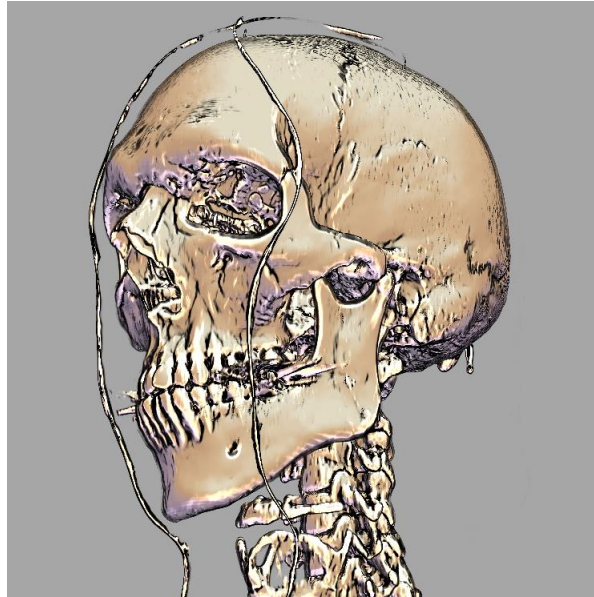
- ▶ Computer Graphics:
 - ▶ Producing pictures or images using a computer
 - ▶ Computer graphics generally means creation, storage and manipulation of models and images
 - ▶ Such models come from diverse and expanding set of fields including physical, biological, mathematical, artistic, and conceptual/abstract 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

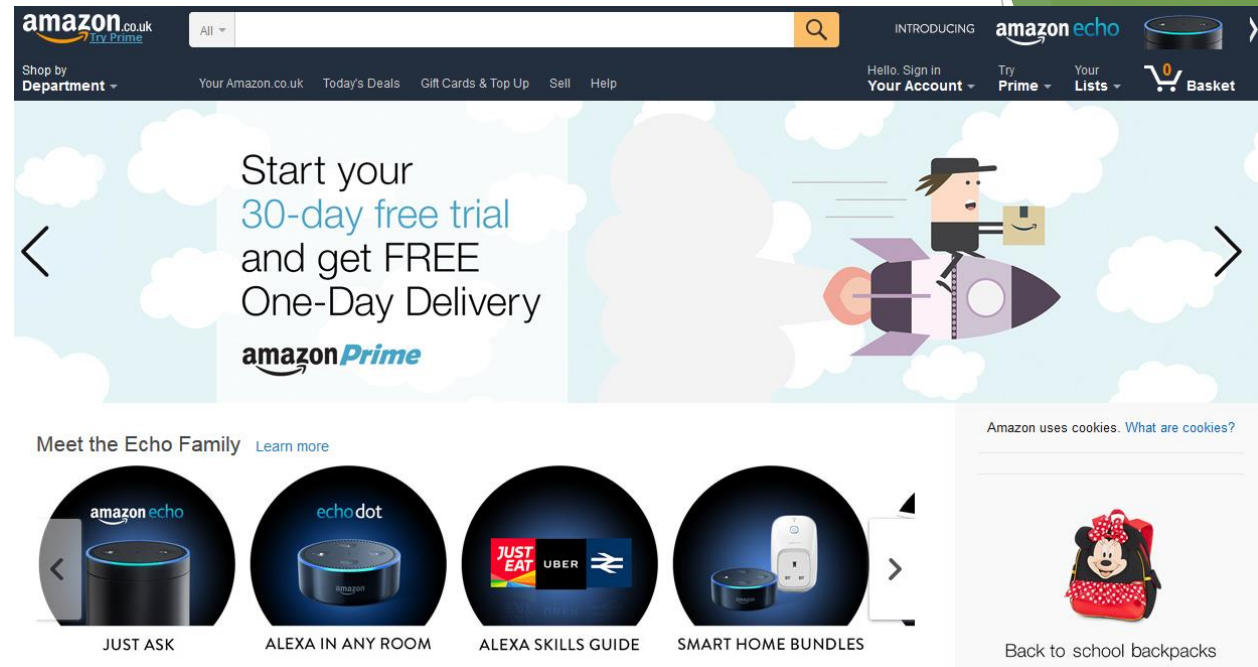


Scientific Visualisation

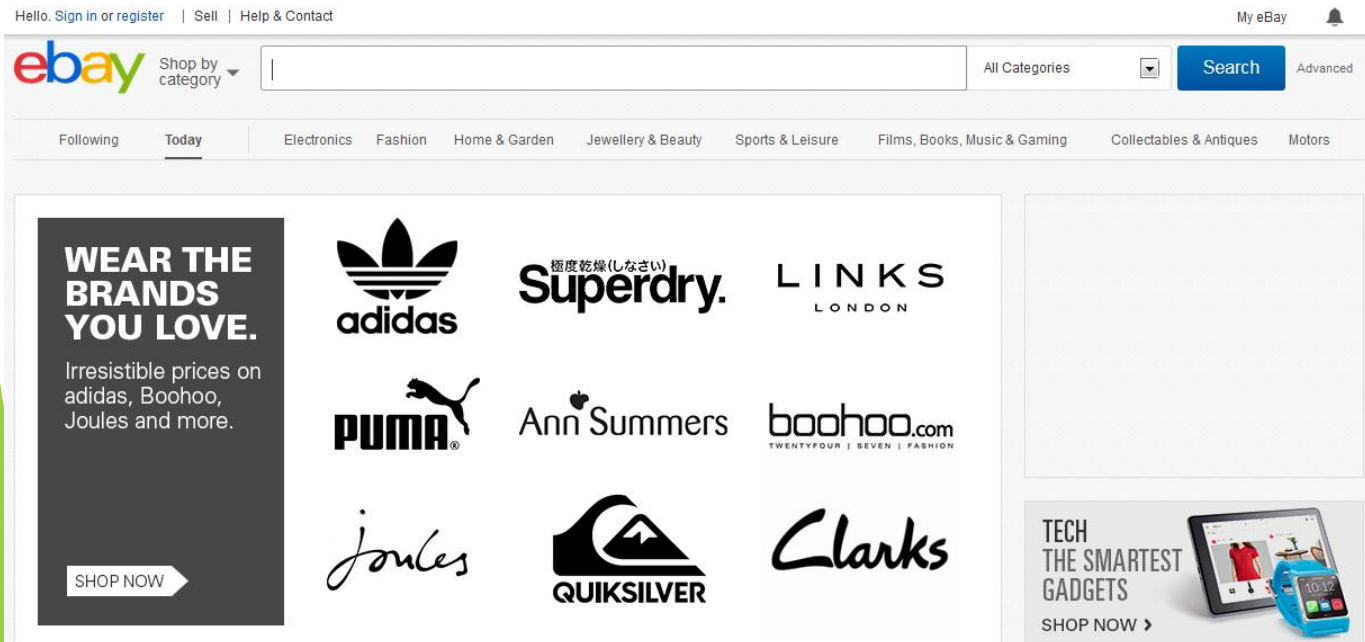
- Data analysis



E-Commerce



The screenshot shows the Amazon.co.uk homepage. At the top is a navigation bar with the Amazon logo, a search bar, and links for 'INTRODUCING amazon echo', 'Hello, Sign in Your Account', 'Try Prime', 'Your Lists', and a shopping basket. Below the navigation bar is a large banner for Amazon Prime, featuring the text 'Start your 30-day free trial and get FREE One-Day Delivery' and an illustration of a delivery person on a rocket. Underneath the banner is a section titled 'Meet the Echo Family' with four circular icons: 'JUST ASK' (Amazon Echo), 'ALEXA IN ANY ROOM' (Echo Dot), 'ALEXA SKILLS GUIDE' (with logos for Just Eat, Uber, and others), and 'SMART HOME BUNDLES'. To the right of this section is a small box titled 'Amazon uses cookies. What are cookies?' with a Minnie Mouse backpack icon and the text 'Back to school backpacks'.



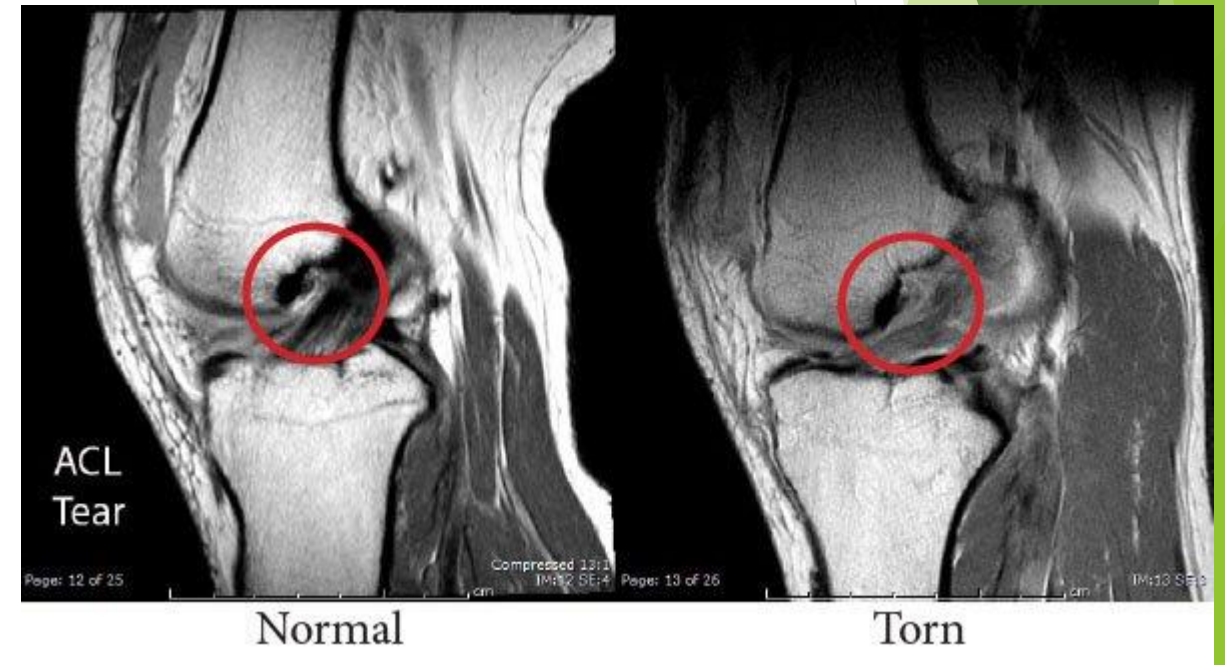
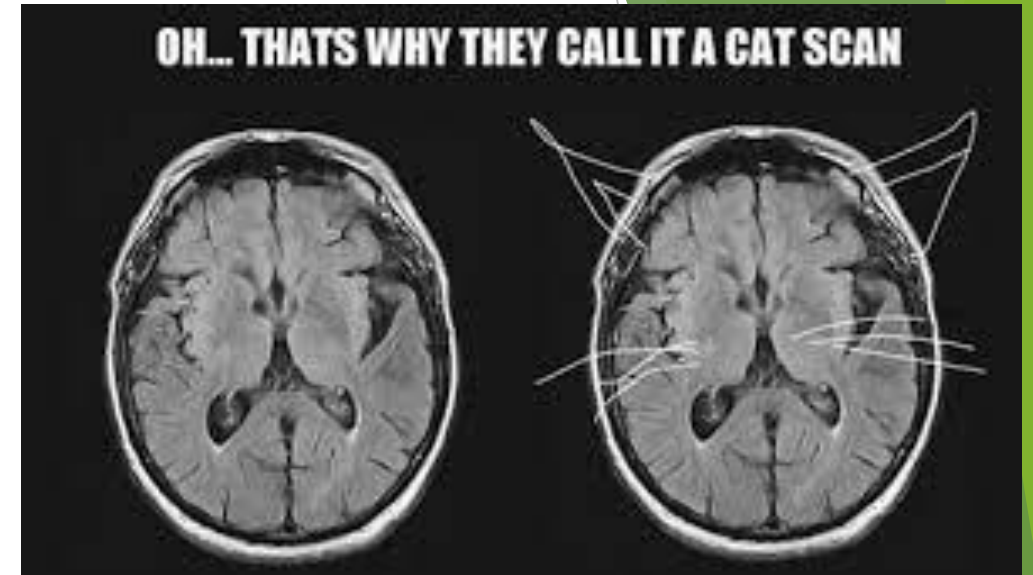
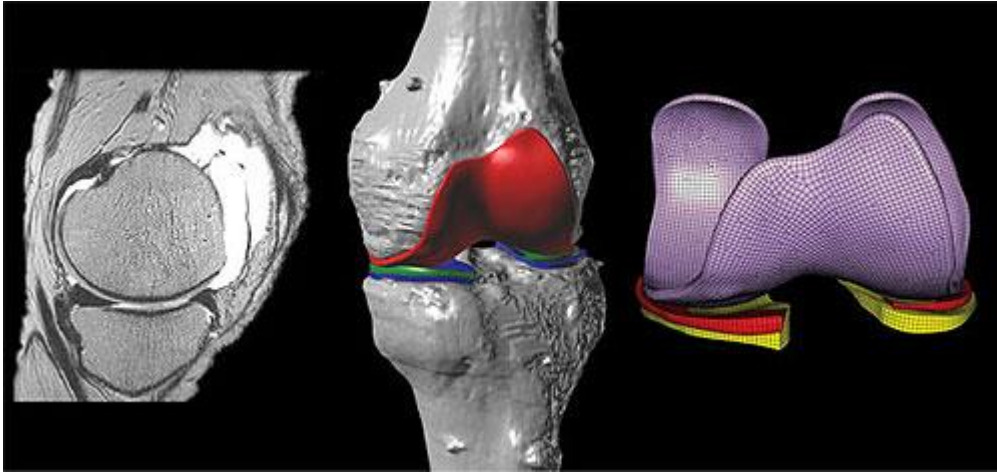
The screenshot shows the eBay homepage. At the top is a navigation bar with the eBay logo, a search bar, and links for 'Hello, Sign in or register', 'Sell', and 'Help & Contact'. Below the navigation bar is a section titled 'Shop by category' with a dropdown menu. To the right of the search bar is a section titled 'All Categories' with a dropdown menu and a 'Search' button. Below the search bar is a horizontal menu with categories: 'Following', 'Today', 'Electronics', 'Fashion', 'Home & Garden', 'Jewellery & Beauty', 'Sports & Leisure', 'Films, Books, Music & Gaming', 'Collectables & Antiques', and 'Motors'. The main content area features a large advertisement for 'WEAR THE BRANDS YOU LOVE.' with the text 'Irresistible prices on adidas, Boohoo, Joules and more.' and a 'SHOP NOW' button. To the right of the advertisement is a grid of brand logos: adidas, Superdry, LINKS LONDON, PUMA, Ann Summers, boohoo.com, Joules, QUIKSILVER, and Clarks. At the bottom right of the main content area is a section titled 'TECH THE SMARTEST GADGETS' with a 'SHOP NOW' button and an illustration of a tablet and a smartphone.

3D personalized avatars e.g. teleconferencing



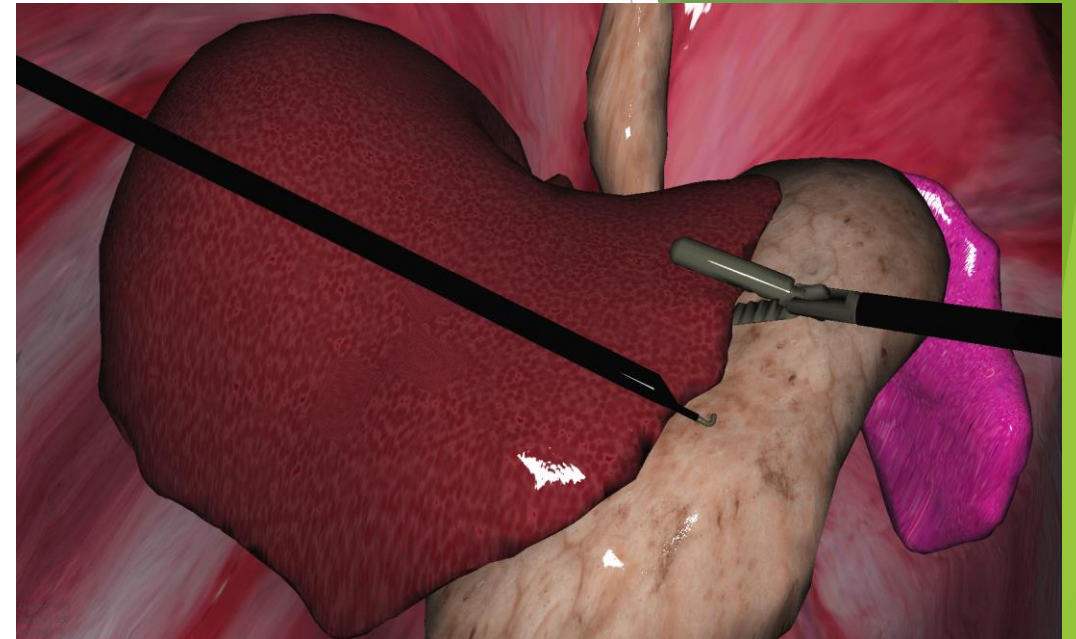
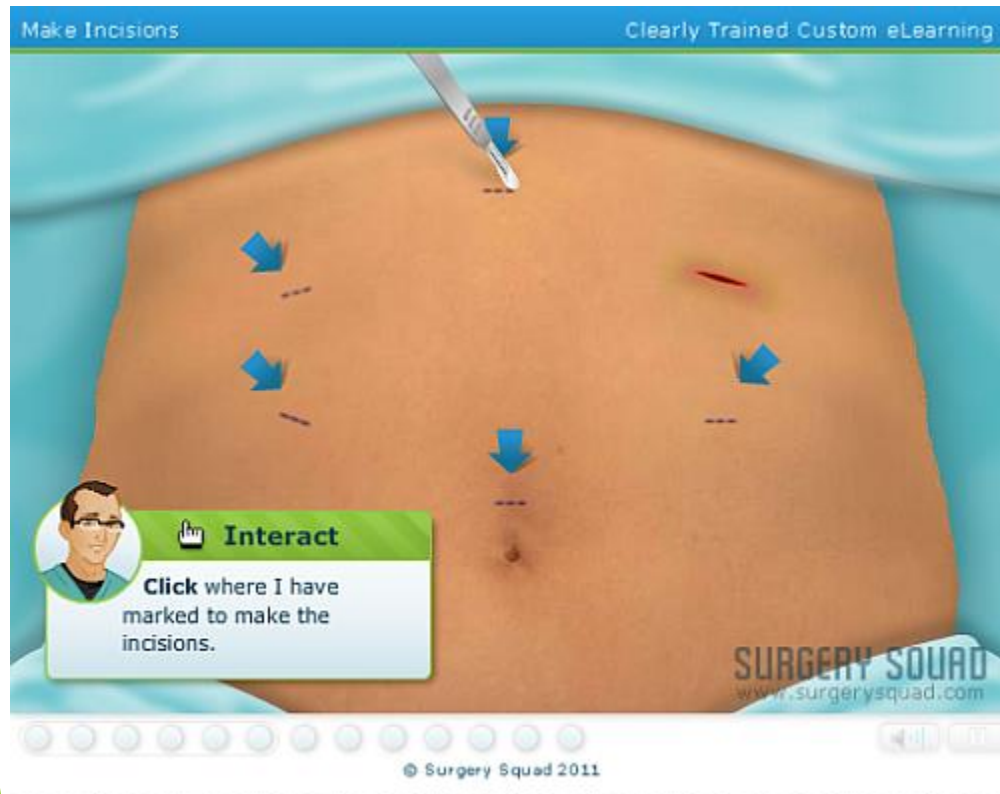
Medical applications

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



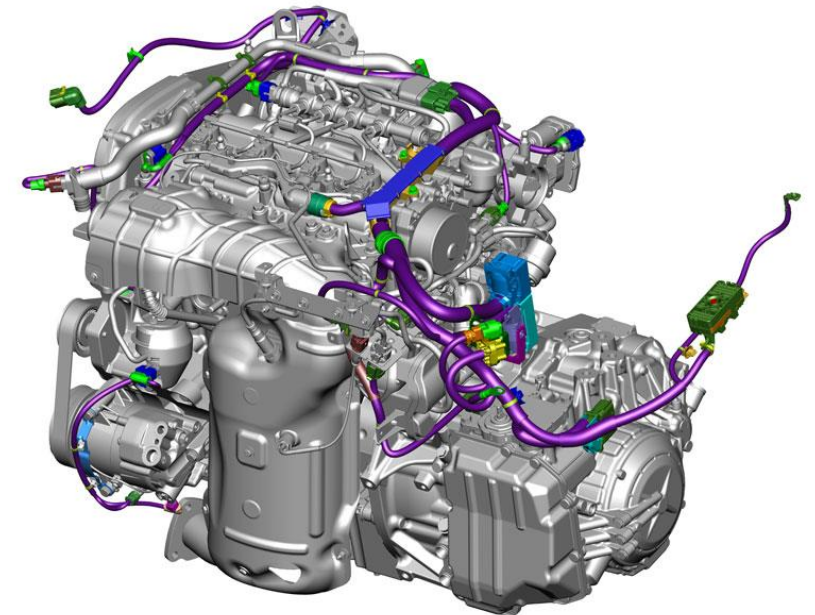
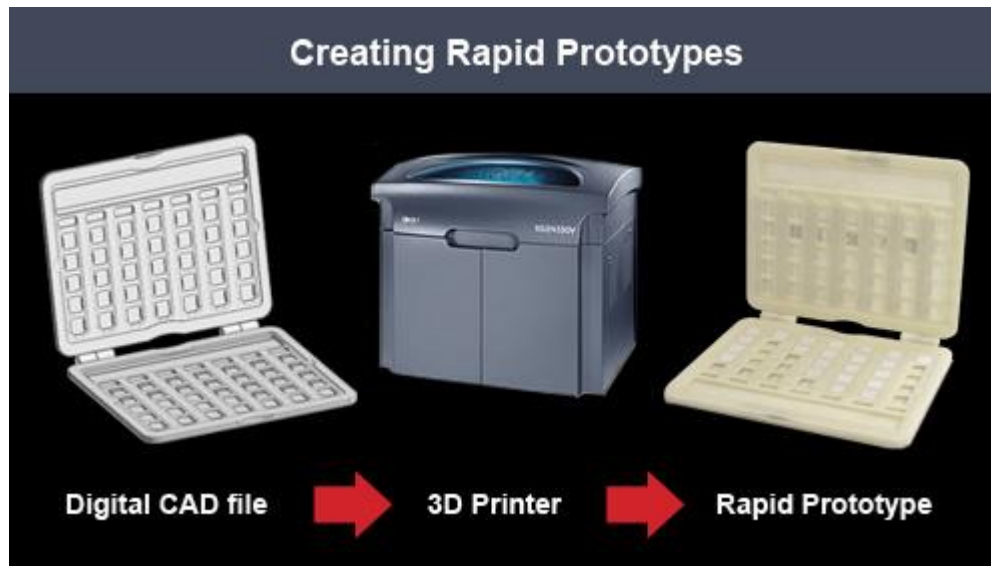
Medical applications

► Virtual/tele surgery



Manufacturing

- CAD
- Rapid Prototyping



Cultural heritage

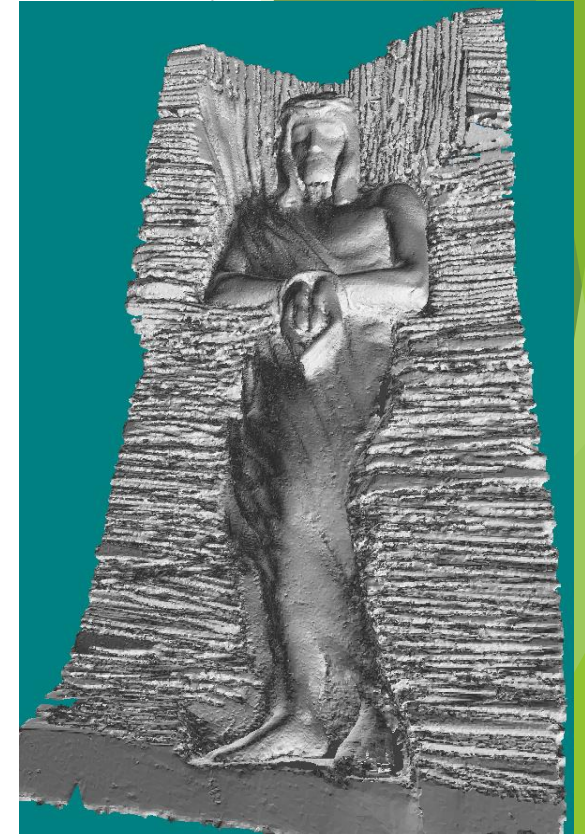
- ▶ Exhibition
 - ▶ Virtual Museums
 - ▶ Catalogues
 - ▶ Educational Tools
- ▶ Restoration
 - ▶ 3D Modelling
 - ▶ Simulations



Oriental Museum in Chicago

Cultural heritage

- Restoration
- First step is *3D Acquisition*



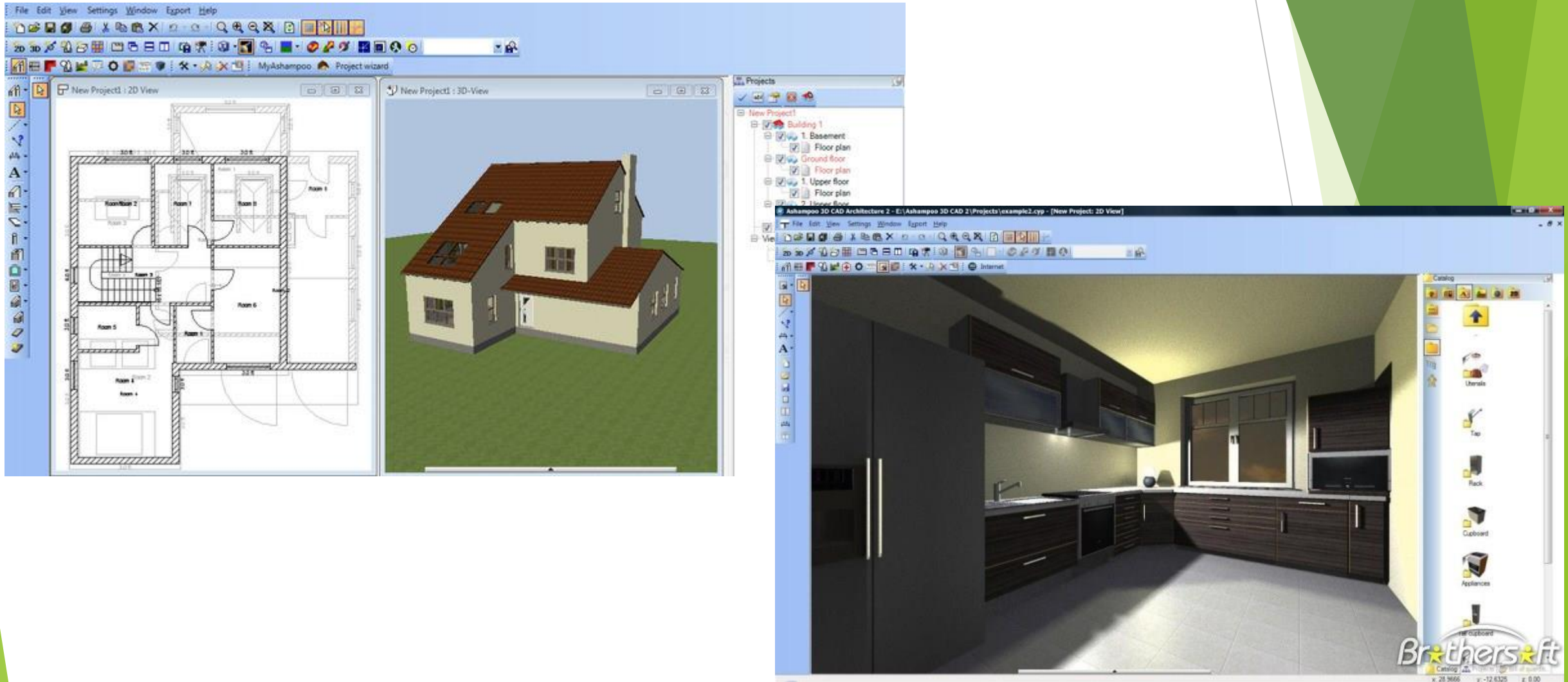
Cultural heritage

- ▶ 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



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



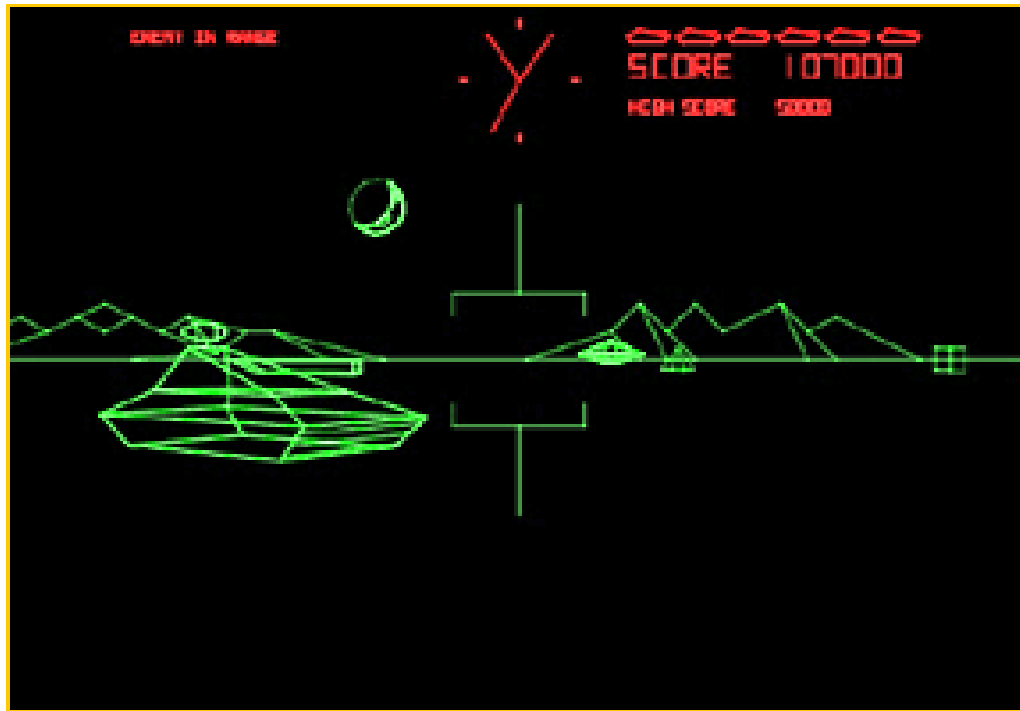
Flight Simulator



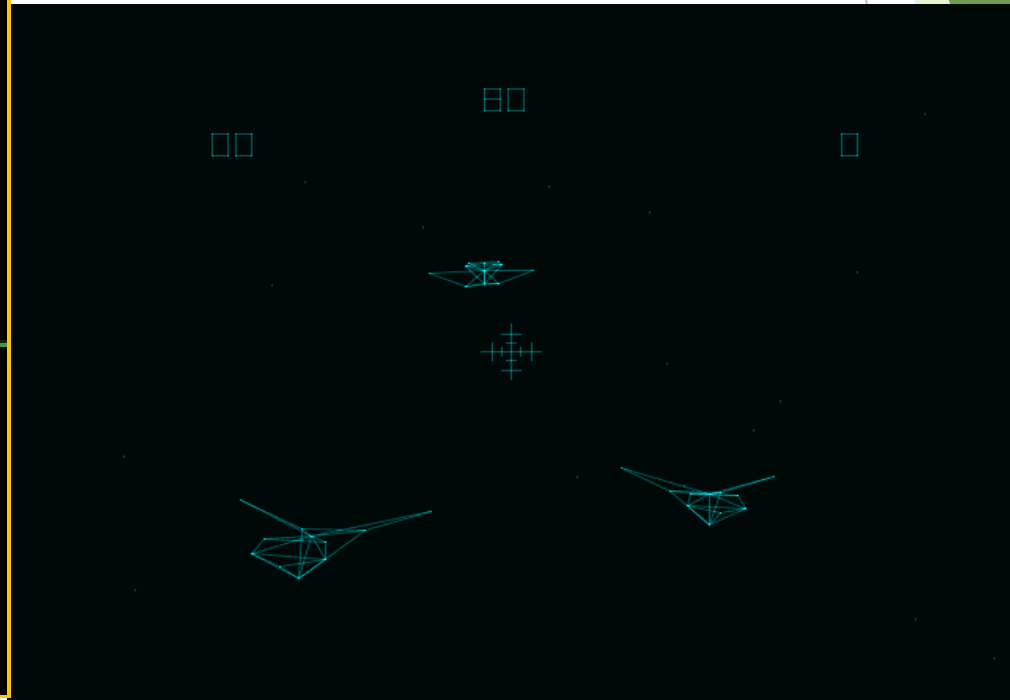
Mars Rover Simulator

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



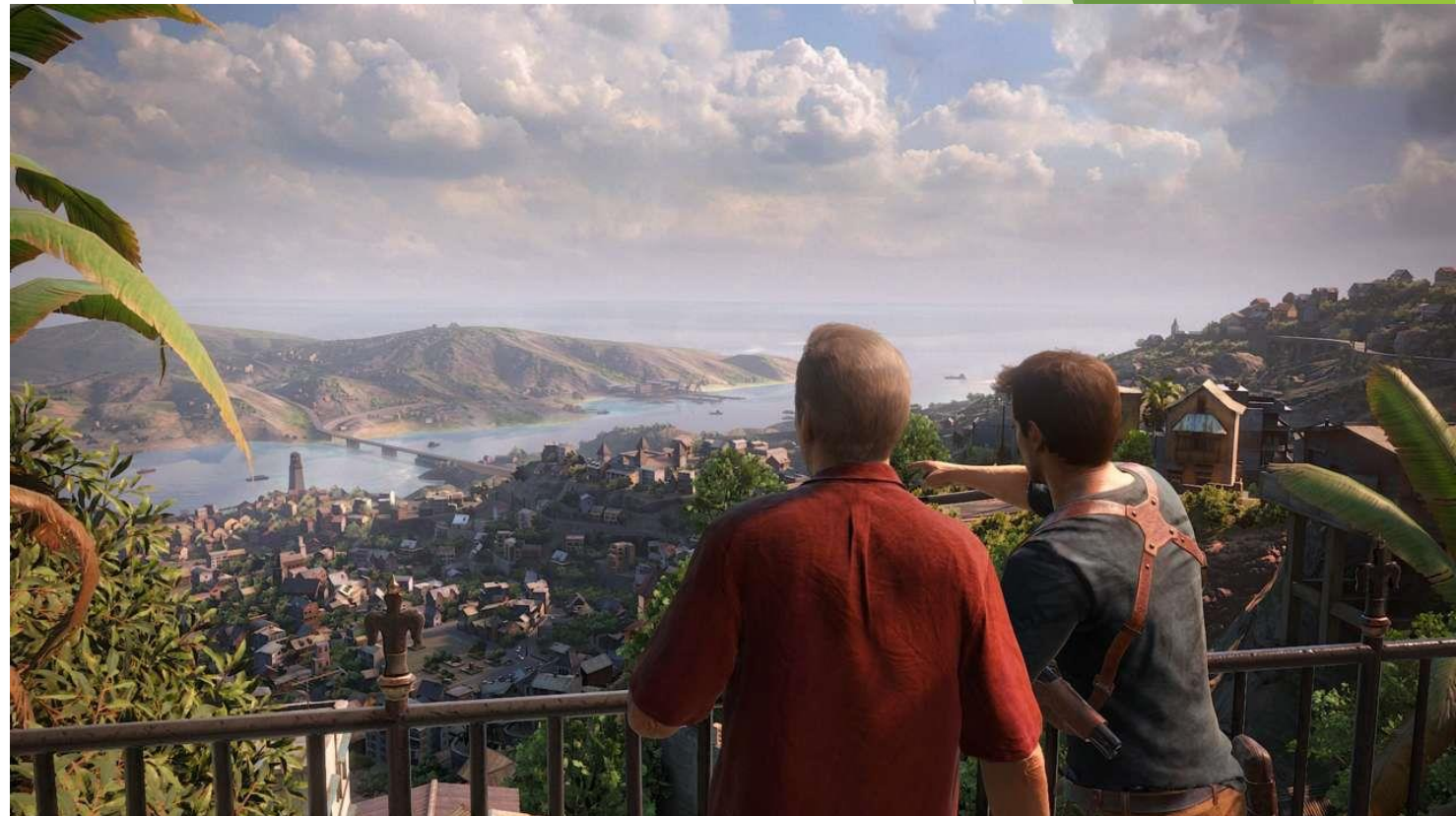
**World of Warcraft,
Blizzard Entertainment 2004**

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
 - ▶ 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.




Graphics



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

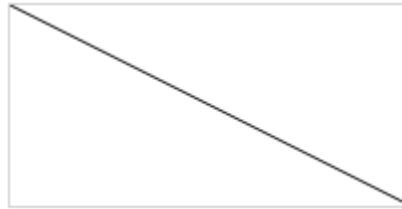
Element					
<canvas>	4.0	9.0	2.0	3.1	9.0

- ▶ 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

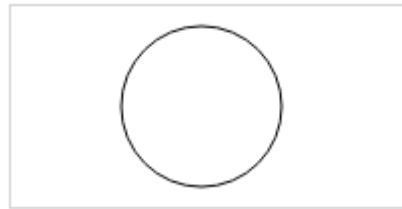
►

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



►

```
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);
```

A rectangular canvas with a thin black border. Inside, the text "Hello World" is rendered in a bold, black, sans-serif font. The text is positioned in the upper-left corner of the canvas.

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();
```

A rectangular canvas with a thin black border. Inside, the text "Hello World" is rendered in a black, sans-serif font. The text is positioned in the upper-left corner of the canvas, and it appears to be drawn with a stroke, giving it a slightly outlined appearance.

Hello World