UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Centre de la Imatge i la Tecnologia Multimèdia

Introduction to Computer Graphics

Bachelor's Degree in Video Game Design and Development

Summary

- What is Computer Graphics
- Main goals
- CG Overview
  - Image Synthesis
  - Hardware and Architecture
  - Animation
  - Applications
- CG through the years
- Tools

What is Computer Graphics?

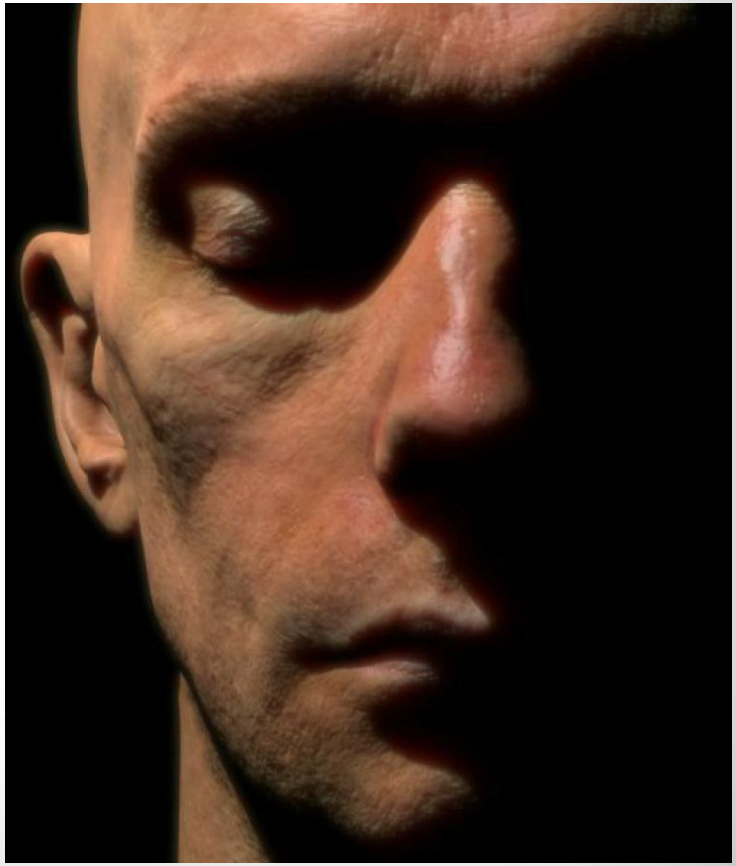
"Using a computer as a rendering tool for the generation (from models/data) and manipulation of images"

"The study of creating, manipulating, and using visual images in the computer"

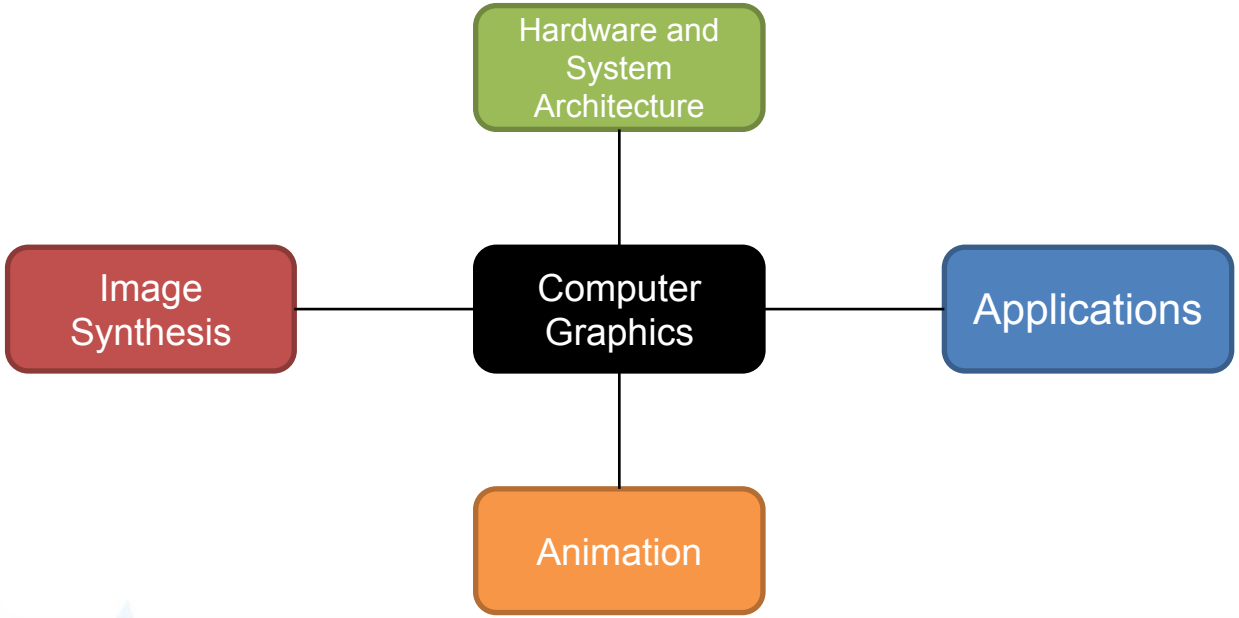
"Mathematics made visible"

Main goals

- **Generate synthetic images**
  - Intricate shapes
  - Complex optical effects
  - Seamless motion
- **Do it in a practical way and scientifically sound**
- **Make them fast**
  - real-time?



CG overview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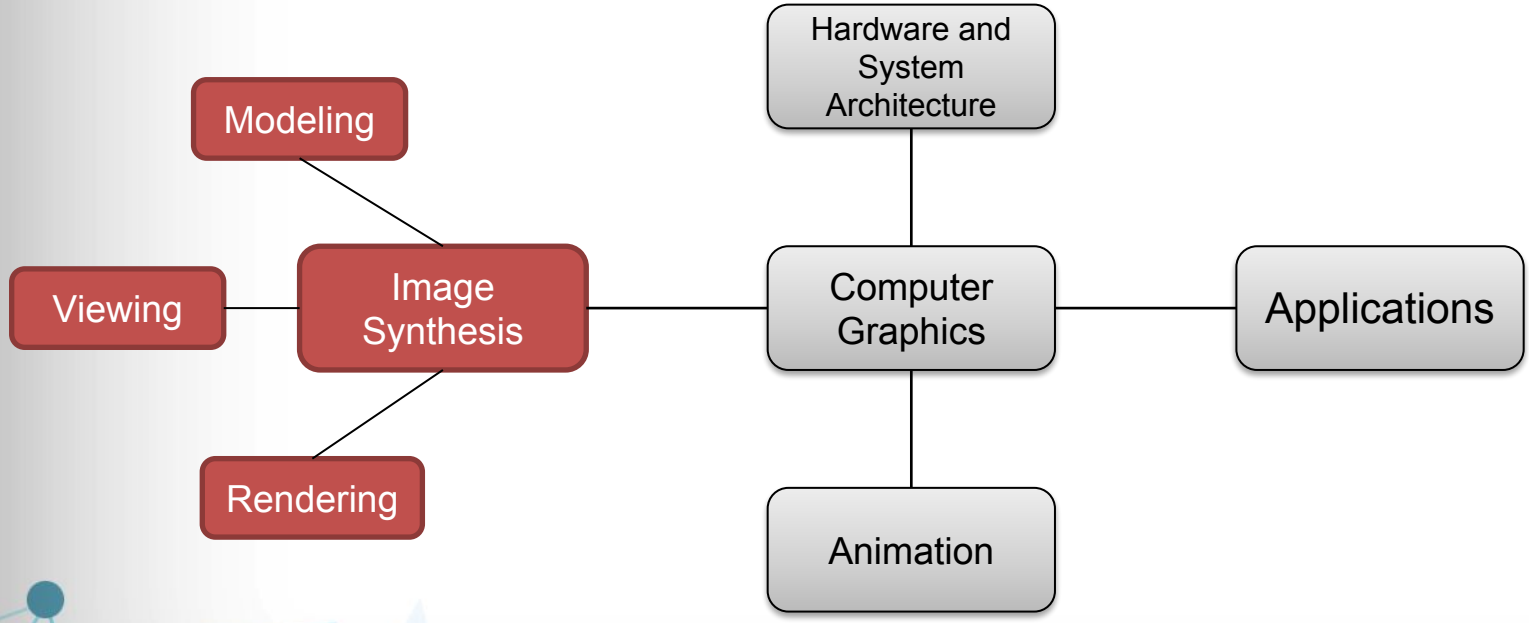
CG overview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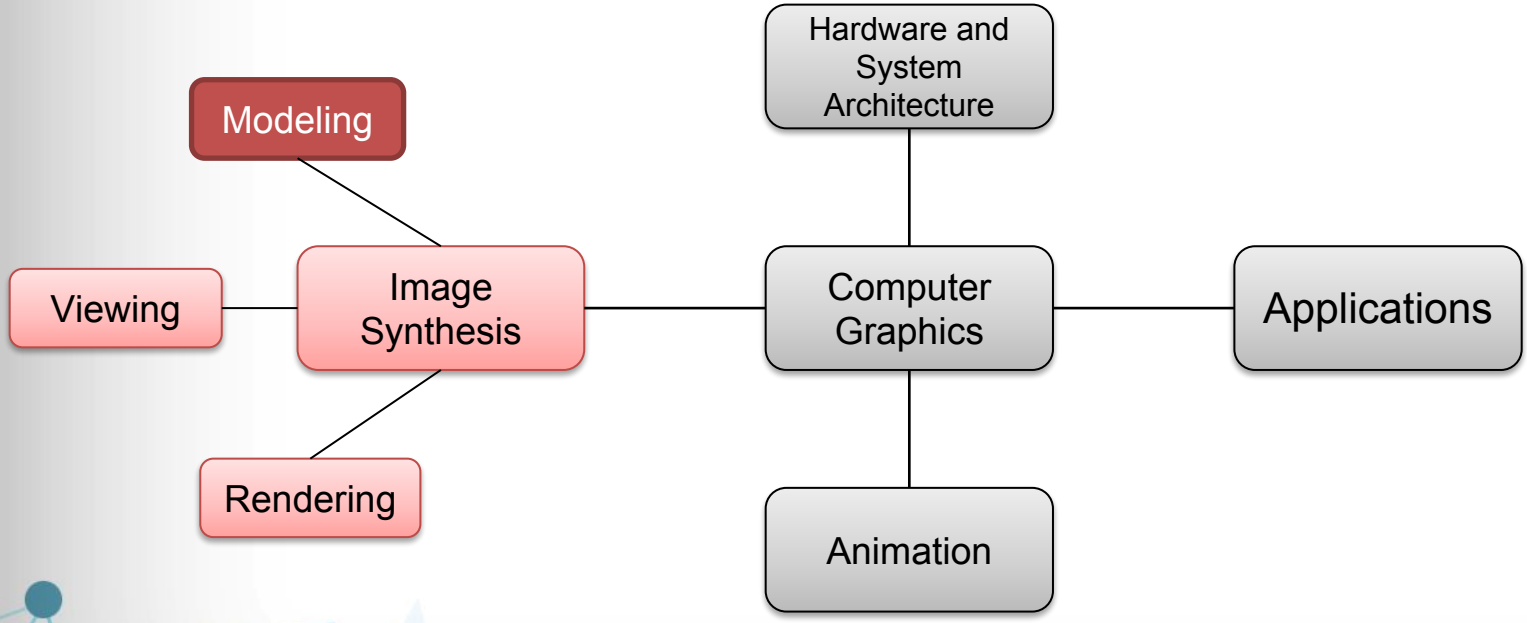
CG overview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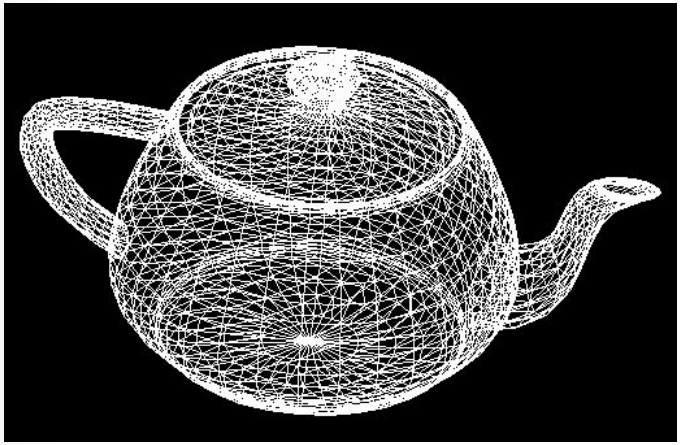
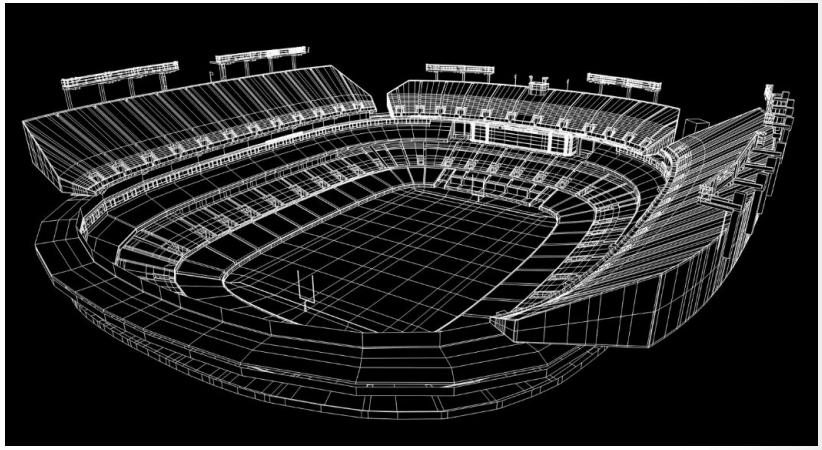
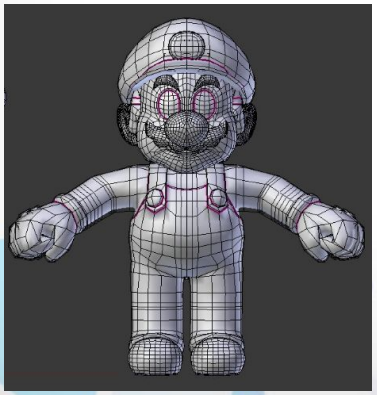
Modeling

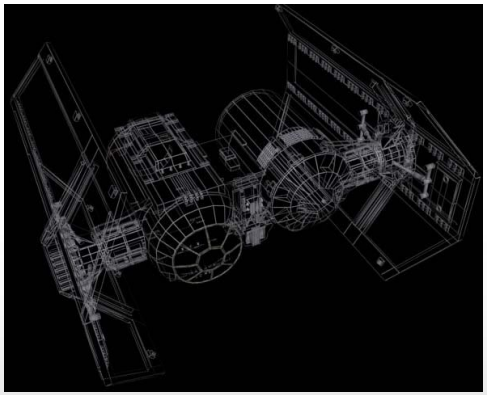
- How to represent real environments
  - Geometry: curves, surfaces, volumes
  - Photometry: light, color, reflectance
- How to build these representations
  - Interactively: 3D models
  - Procedurally: fractals, extraction…
  - Scanning: via 3D scanners
- Primitive generation
  - Lines, triangles, quads…

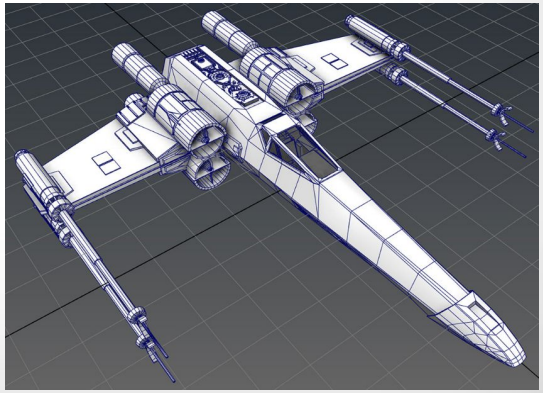
Interactive modeling









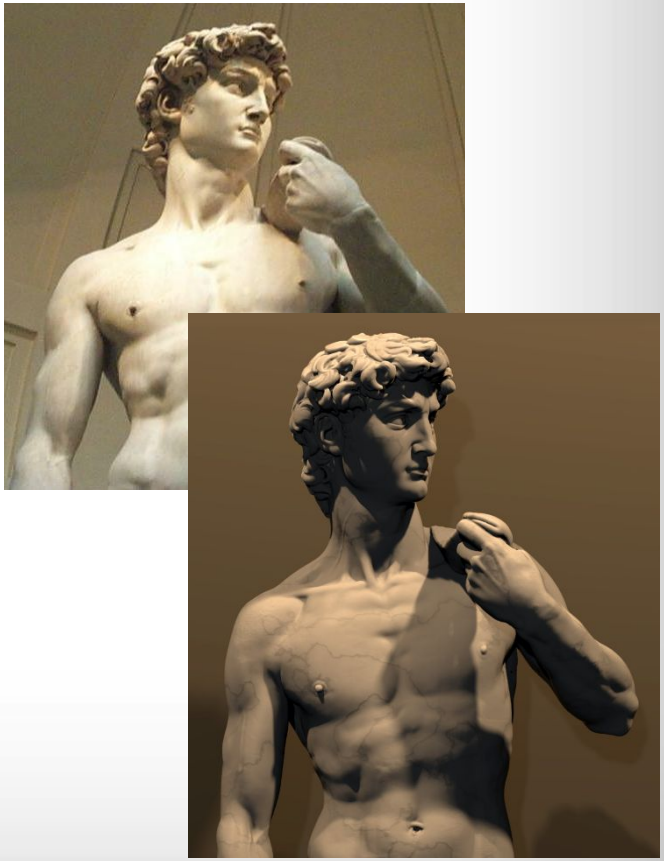


Procedural modeling

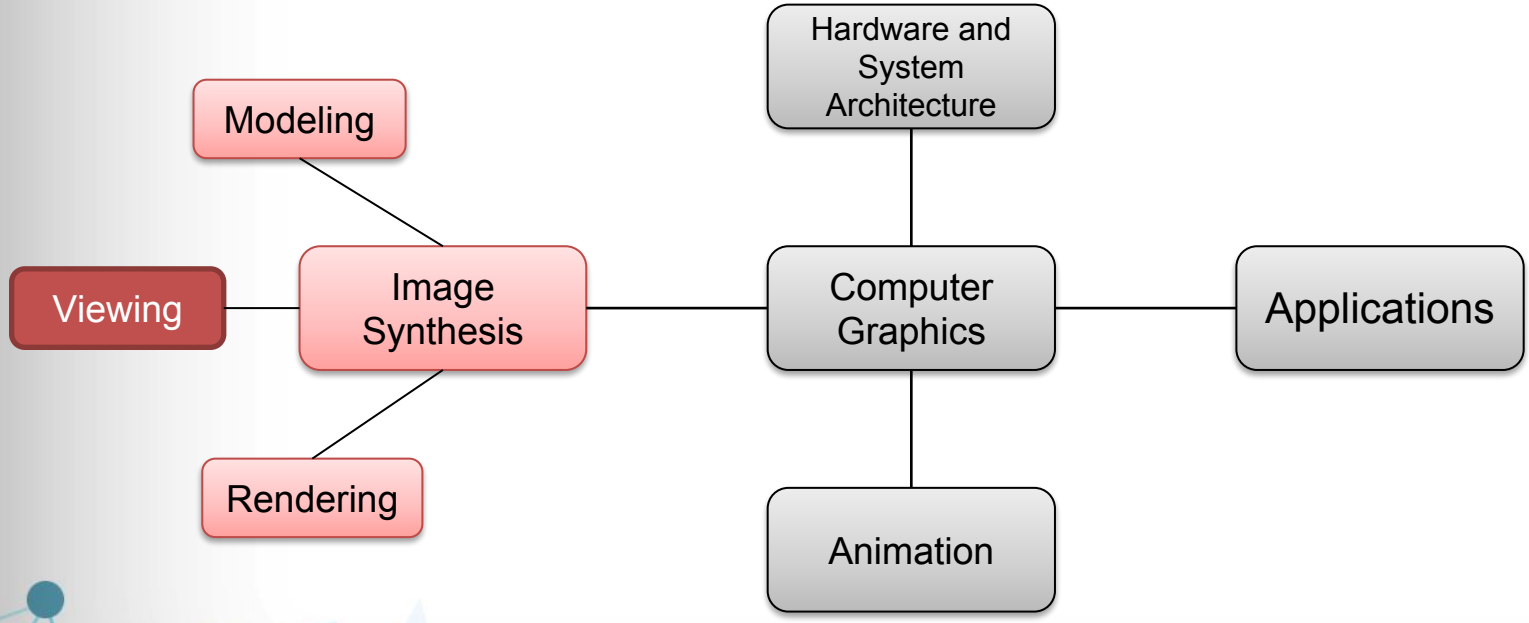
https://www.youtube.com/watch?v=JCsj0v-wmIM

3D scanning

- Acquisition of color and shape of 3D objects with 3D scanners
  - Acquisition of point clouds from the real object
  - Processing to obtain a “correct” polygonal mesh
    - Triangulation
    - Filling holes
    - …
  - Mapping colors and materials to the mesh



CG overview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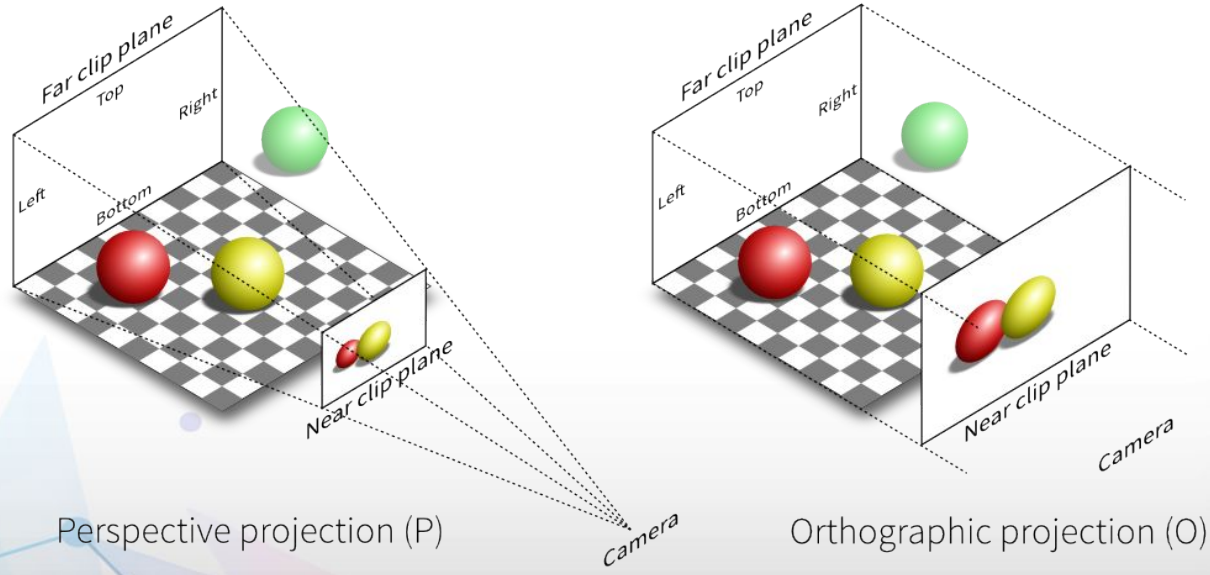
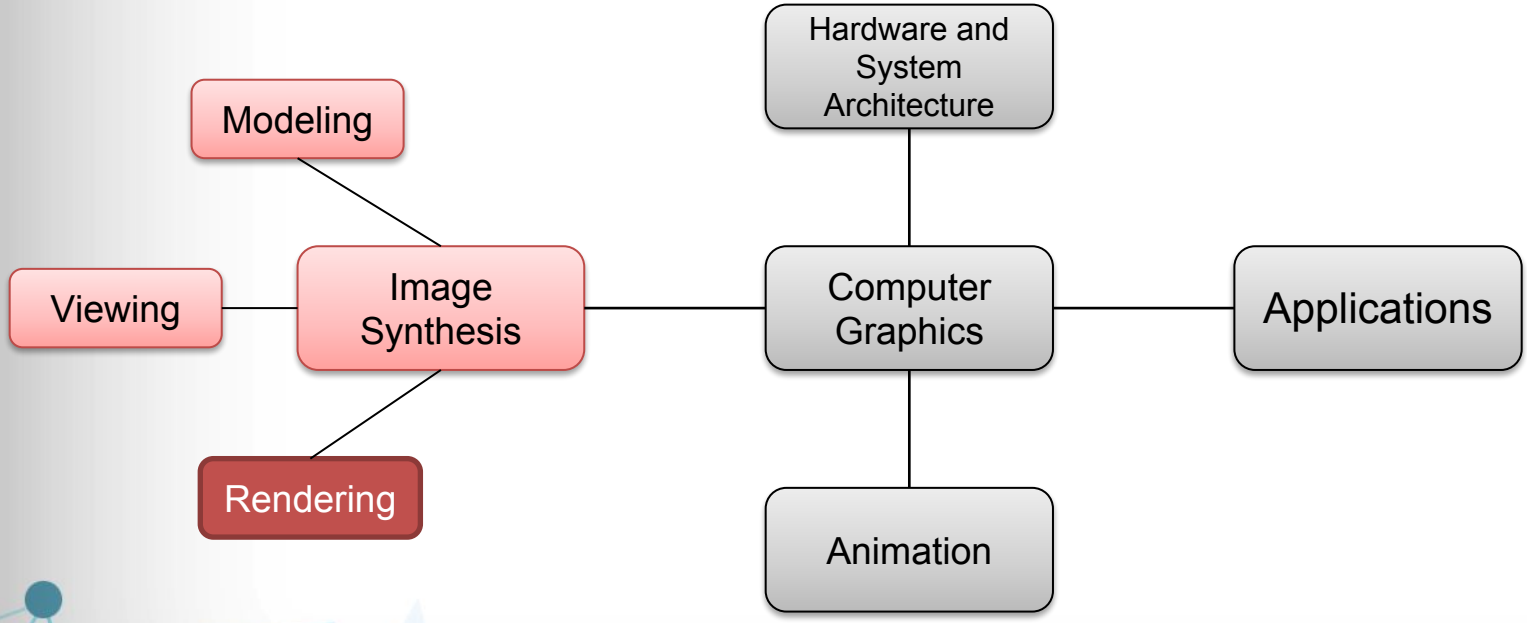
Viewing

- **How the scene (model) is projected onto the screen**
  - **Observer position and viewing direction**
  - **Type of projection: perspective, orthogonal**
  - **Frustum definition**



CG overview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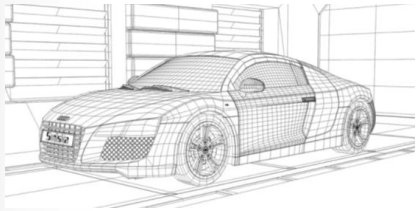
Rendering

- **What is an image?**
  - Distribution of light energy on 2D “canvas”
  - Represented as a matrix of pixels (RGB - RGBA)

- **How do we generate images from scenes?**
  - Scene (model)
  - Viewing parameters
  - Others: visibility, colors, materials, shading, illumination models…
  - Rendering algorithms: rasterization, ray tracing…

Rendering

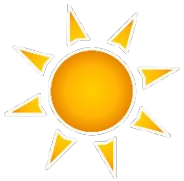


Scene

+

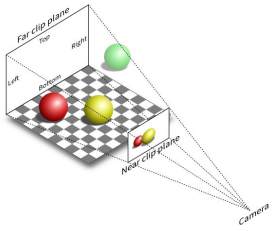
Material

+



Light

+



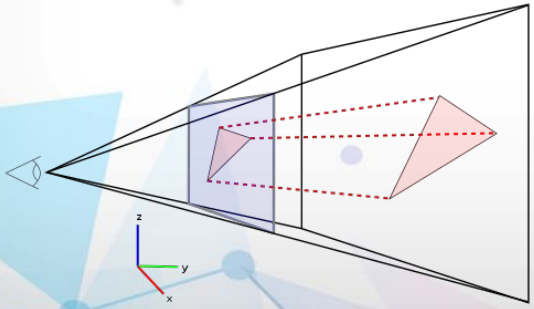
Viewing

Rendering algorithm

Rendering

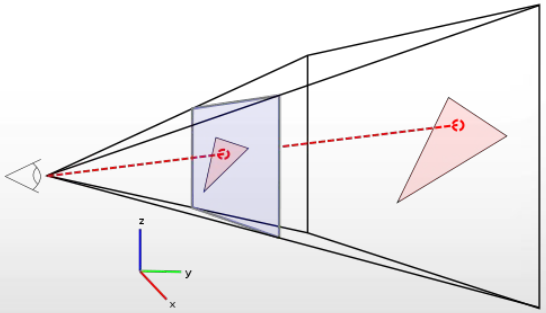
- **Rasterization**
  - **Project the scene to pixels**

For each scene primitive o:
find where **o** falls on screen
rasterize 2D shape
for each produced pixel p:
find color for **o**
color **p** with it

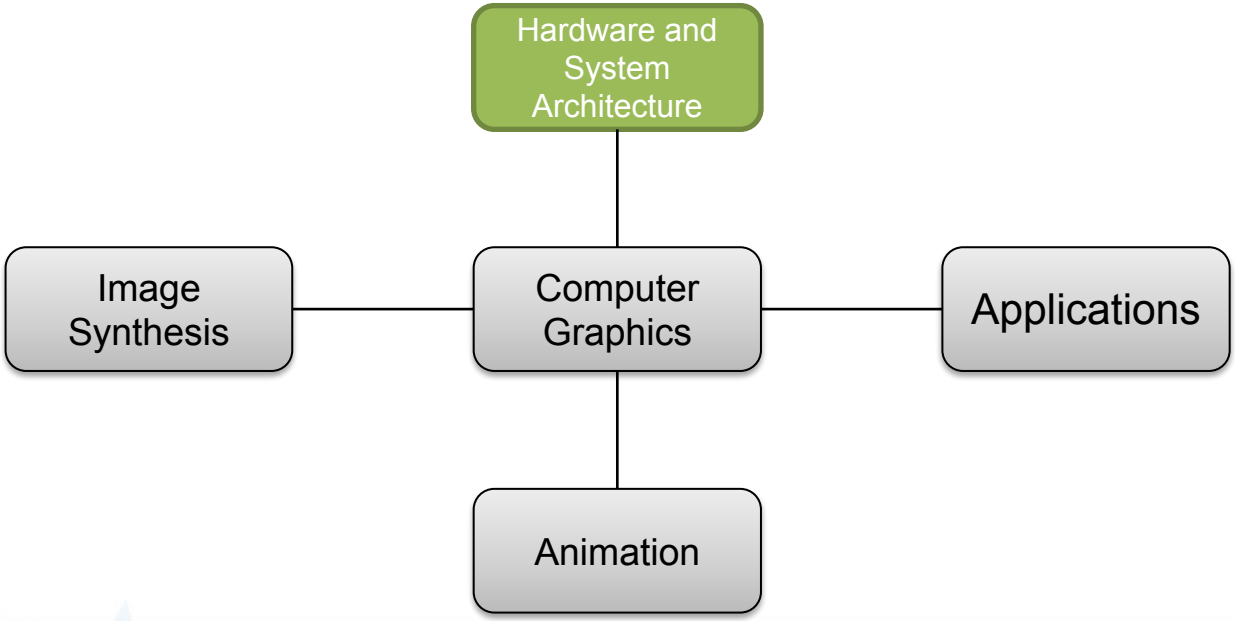


- **Ray Tracing**
  - **Project the pixels to the scene**

For each image pixel p:
make a ray r
For each scene primitive o:
if intersect(**r**,**o**) then
find color for **o**
color **p** with it



CG overview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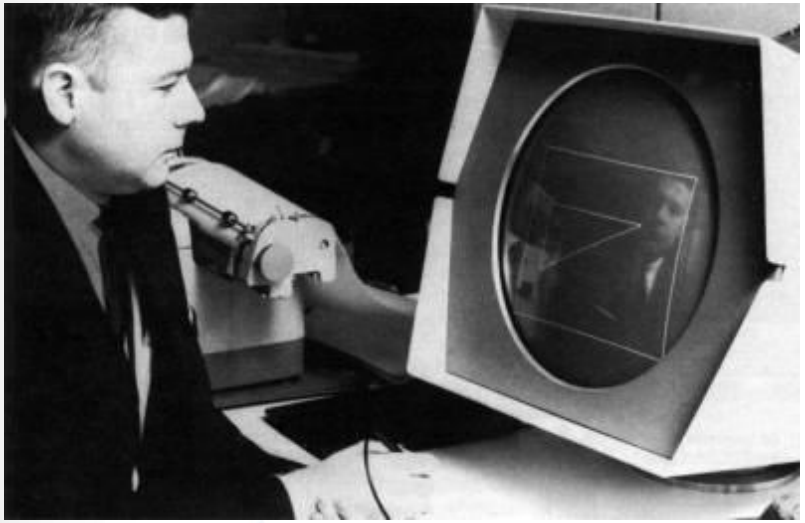
Hardware

- **Computing capabilities to generate images**

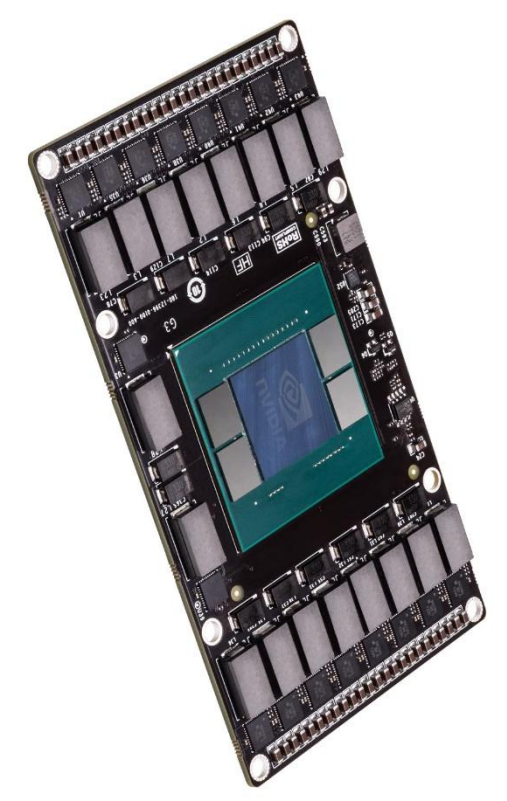


1961

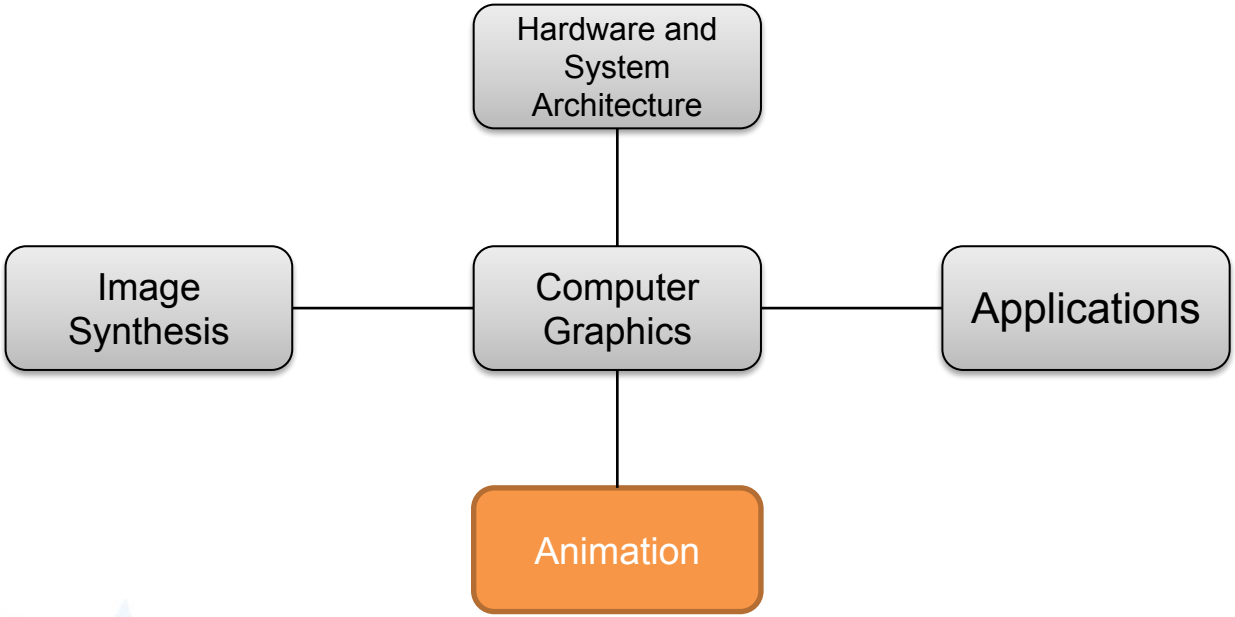
2016

Hardware

- **Nowadays we have…**
  - Special purpose hardware: Graphics Processing Units (GPUs)
  - Enormous performance and power efficiency
  - General and specific purpose programming models
  - Arbitrary dataflow
  - Hardware managing threading and pipelining
  - GPUs power freely used for graphics and computation



CG overview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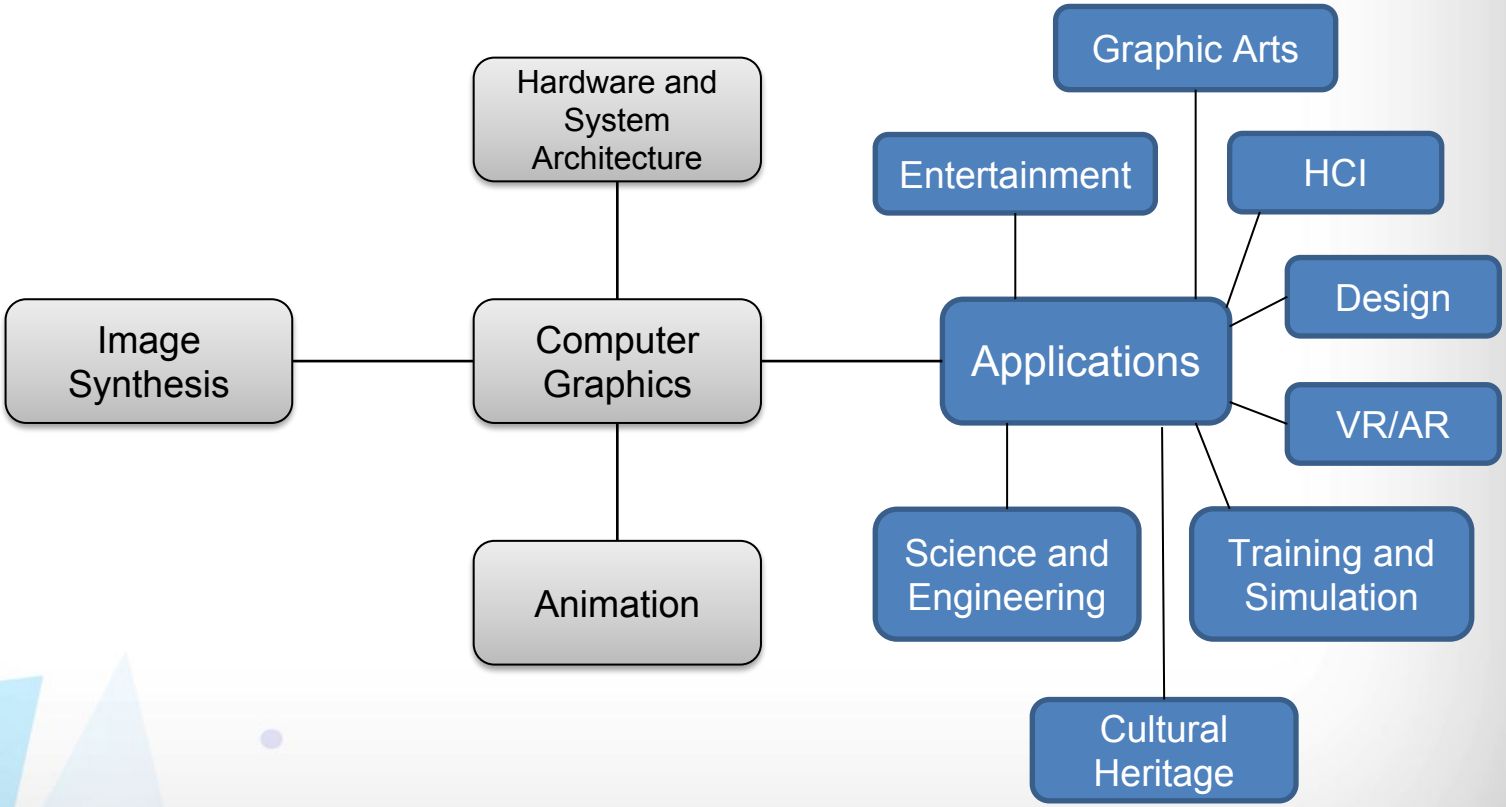
Animation

- **Model how things move**
- **Temporal change of**
  - Objects: position, orientation, size, shape, color…
  - Camera: position, direction, angle, focus…
  - Illumination: position, direction, color, brightness…
- **Represent motion**
  - Keyframe animation
  - Physical simulation

Animation

https://www.youtube.com/watch?v=ureGelZPi3o

CG overview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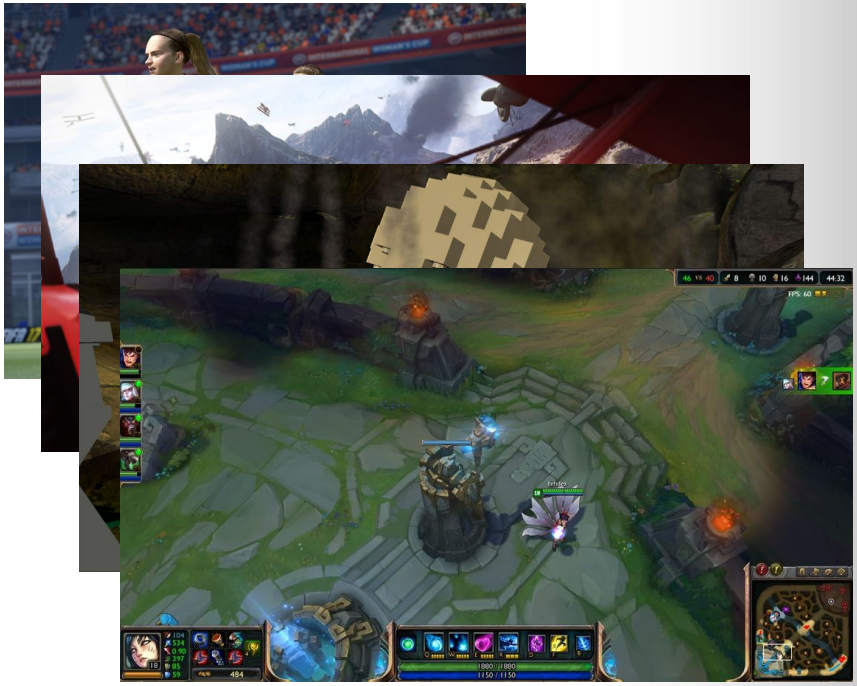
Animation
Applications
Graphic Arts
Entertainment
HCI
Design
VR/AR
Science and Engineering
Training and Simulation
Cultural Heritage

Some examples…

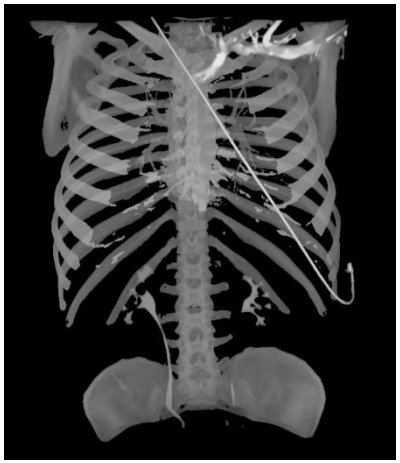
Special effects

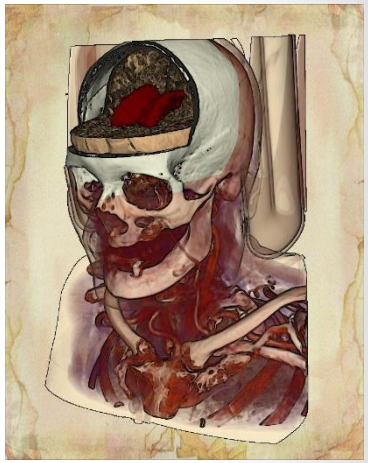


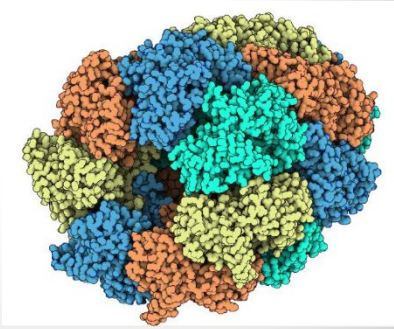
Video games

Some examples…

- Scientific visualization
- Medical Imaging
- Fluid simulations
- Aeronautics
- …

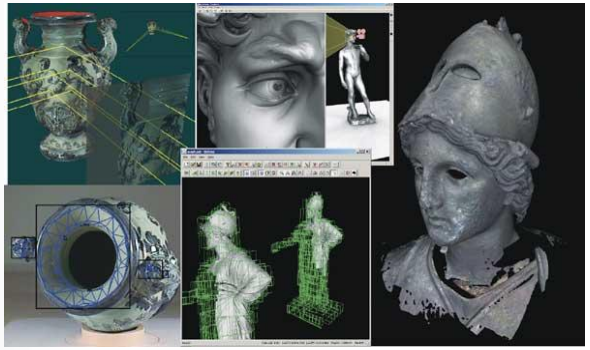






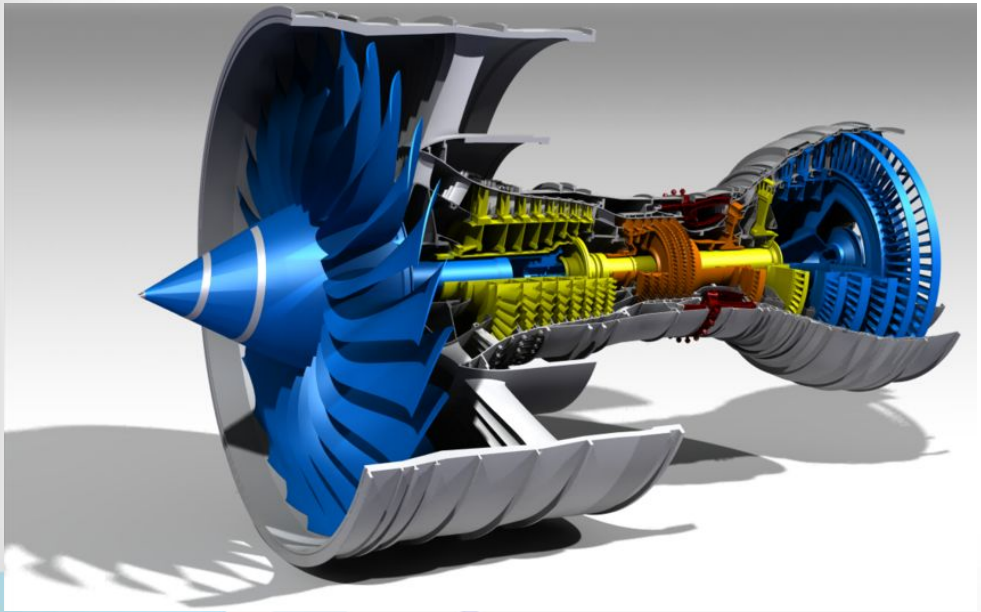
Some examples…

- **Cultural Heritage**

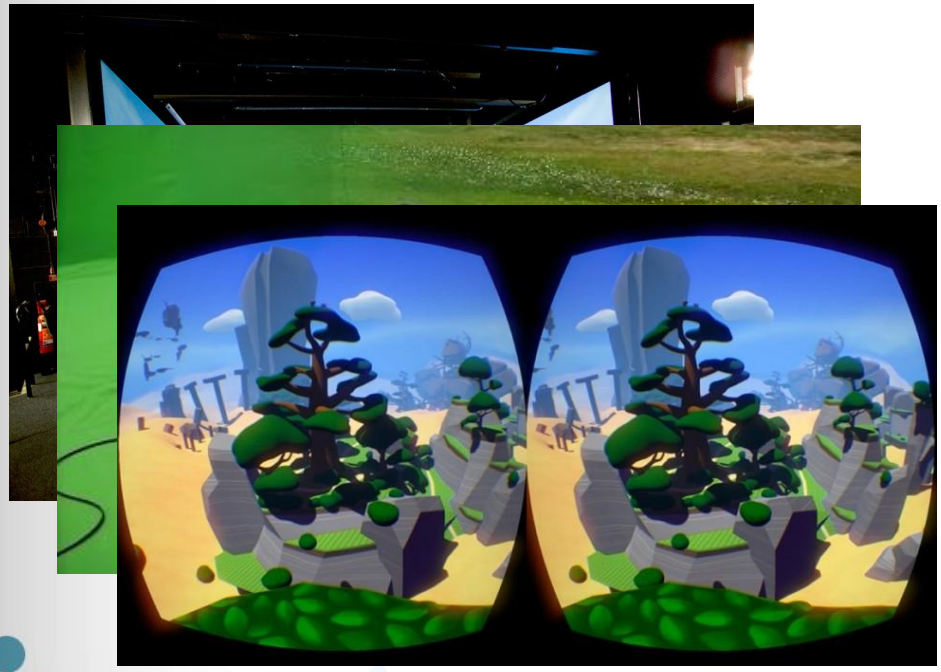


Some examples…

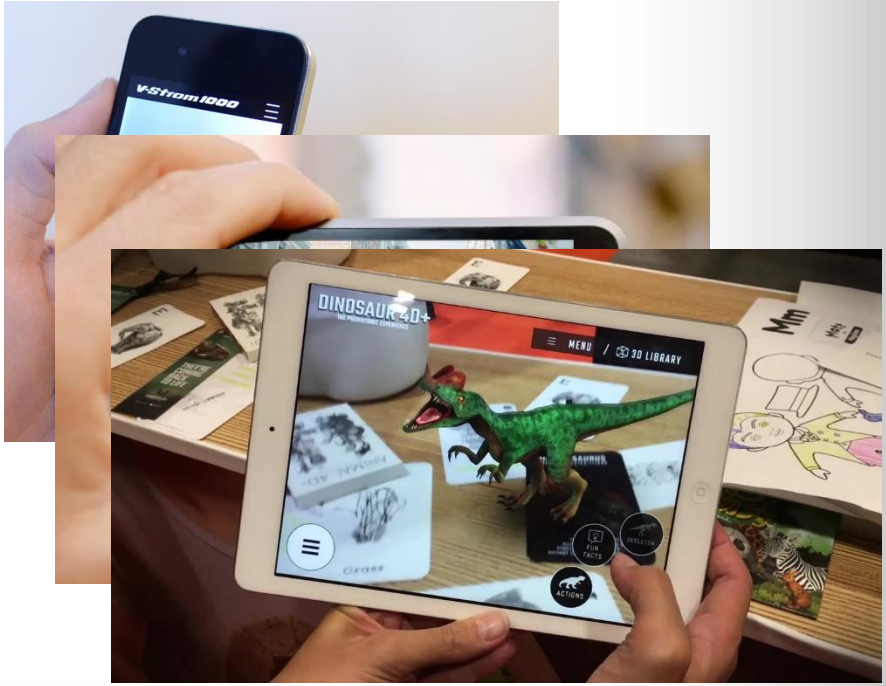
- **CAD 3D models**



Some examples…



Virtual Reality



Augmented Reality

CG through the years

- 1950 • First graphic images (oscilloscope)
- 1951 • Whirlwind computer (MIT): first video display of real-time data
- 1955 • Light pen introduced
- 1958 • William Higinbotham's *Tennis for two* video game

Ben Laposki, 1950

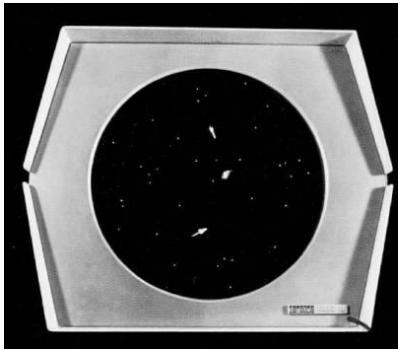
Whirlwind computer

Light pen

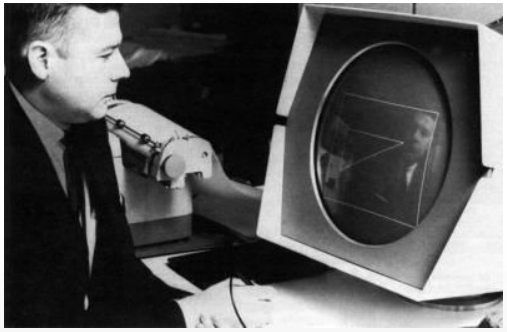
Tennis for two

CG through the years

- **1960** • William Fetter coined the term *Computer Graphics*
- **1961** • Steve Russell's *Space War* video game (MIT)
- **1963** • *SketchPad*: First computer drawing program (I. Sutherland, MIT)
- **1966** • First HMD (I. Sutherland, MIT)
- **1968** • Proposal of the *ray casting* algortihm (A. Appel)
- **1969** • ACM creates the SIGGRAPH (Special Interest Group on Graphics)



Space War



SketchPad

Sutherland's HMD

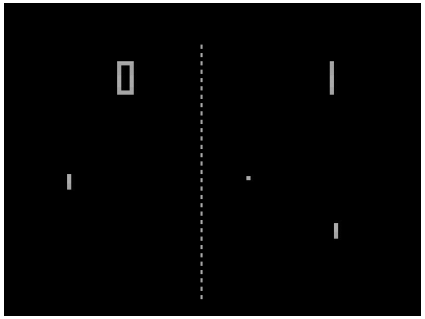
CG through the years

1972
- Pong video game
- Raster displays begin to appear
- Introduction of the CT scanner

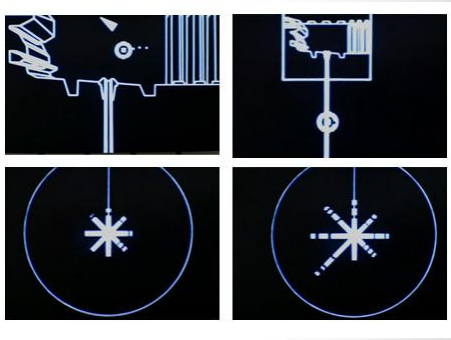
1977
- First CG Standard
- Apple II (first graphics PC)
- Release of Star Wars

1978
- First real boundary representation (Charles Lang, Cambridge)
- Bump mapping (Jim Blinn)

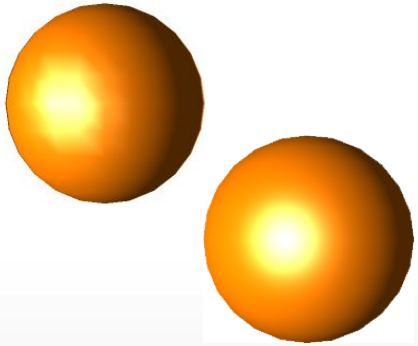
70's
- First CG animations (University of Utah)
- First visibility algorithm
- First shading algorithms (Gouraud, Blinn-Phong)



Pong



Star Wars CG



Gouraud and Phong shading

Apple II

CG through the years

Early 80's
- Modernization and commercialization of CG thanks to PCs (Commodore 64, Lisa…)

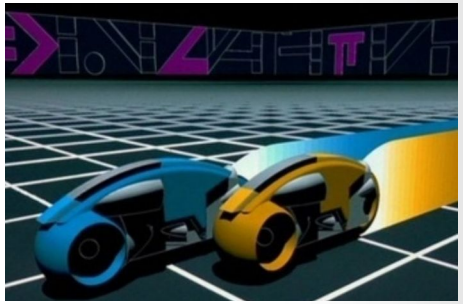
1982
- LINKS-1 computer for realistic 3D CG
- Release of TRON (extensive use of CG)
- AutoCAD 1.0 is released

1986
- General Rendering Equation (Kajiya)
- Pixar is created

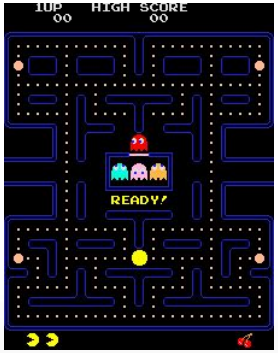
Late 80's
- VGA standard (87)
- First shaders (88)
- SVGA standard (89)

80's
- Expansion of CG in films (Lucasarts and ILM)
- Golden era of video games (Nintendo, Sega, Atari, John Carmac games…)

Commodore 64



TRON



Boom in the video games industry

CG through the years

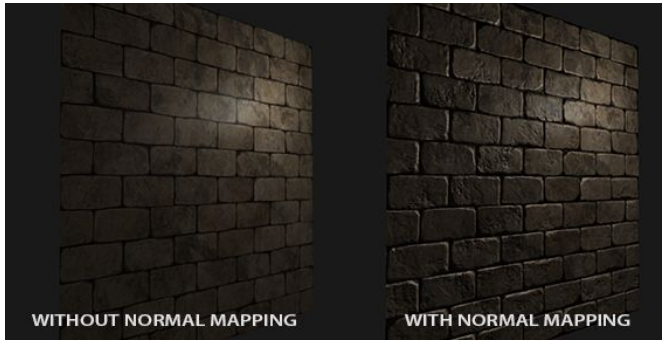
1992
- Release of OpenGL
- Popularization of 3D polygonal graphics for videogames with Virtua Racing (SEGA)

1995
- Release of Toy Story
- Release of DirectX

1996
- Normal mapping

1999
- Nvidia GeForce 256: first home video card (GPU)

90's
- Emerging of 3D modeling
- Impressive rise of CG quality
- High popularity in gaming, multimedia and animation



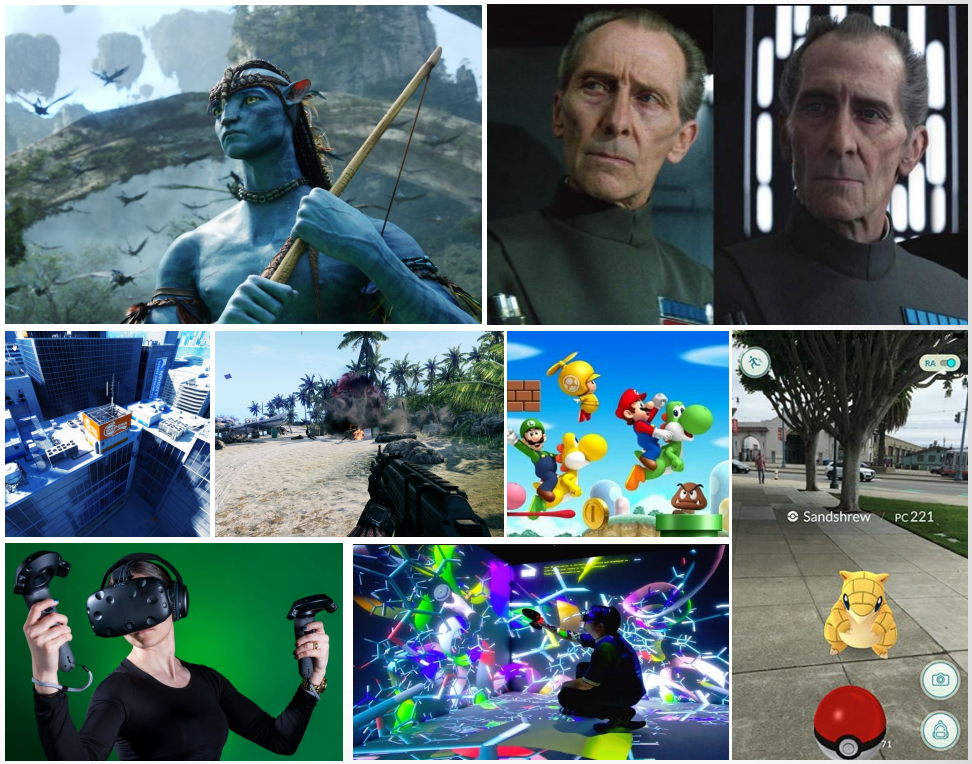
GeForce 256

Toy Story and Jurassic Park

CG through the years

XXI century

- Widely-used in cinema, video games, design, science, arts…
- Ever-increasing computing capabilities thanks to modern hardware
- Graphics quality allows us to bring actors back to life!



2016 SIGGRAPH technical papers

Tools

- **There are different programming languages, libraries and tools we can use to develop CG apps**
  - OpenGL, WebGL
  - Direct3D (DirectX)
  - Vulkan
  - GLSL
  - CG
  - CUDA
  - Unity 3D
  - …

…so, let’s the fun begin!!

Questions?

www.citm.upc.edu