



CG apes from Dawn of the Planet of the Apes, 2014

Computer Graphics

Εισαγωγή στα Γραφικά Υπολογιστών

Andreas Aristidou

andarist@ucy.ac.cy

<http://www.andreasaristidou.com>

Hi!

■ Andreas Aristidou



Assistant Professor

Office: FST01, Room B113

Office hours: Tuesday 09:00– 10:30

Friday 09:00 – 10:30

Only after appointment

email: andarist@ucy.ac.cy

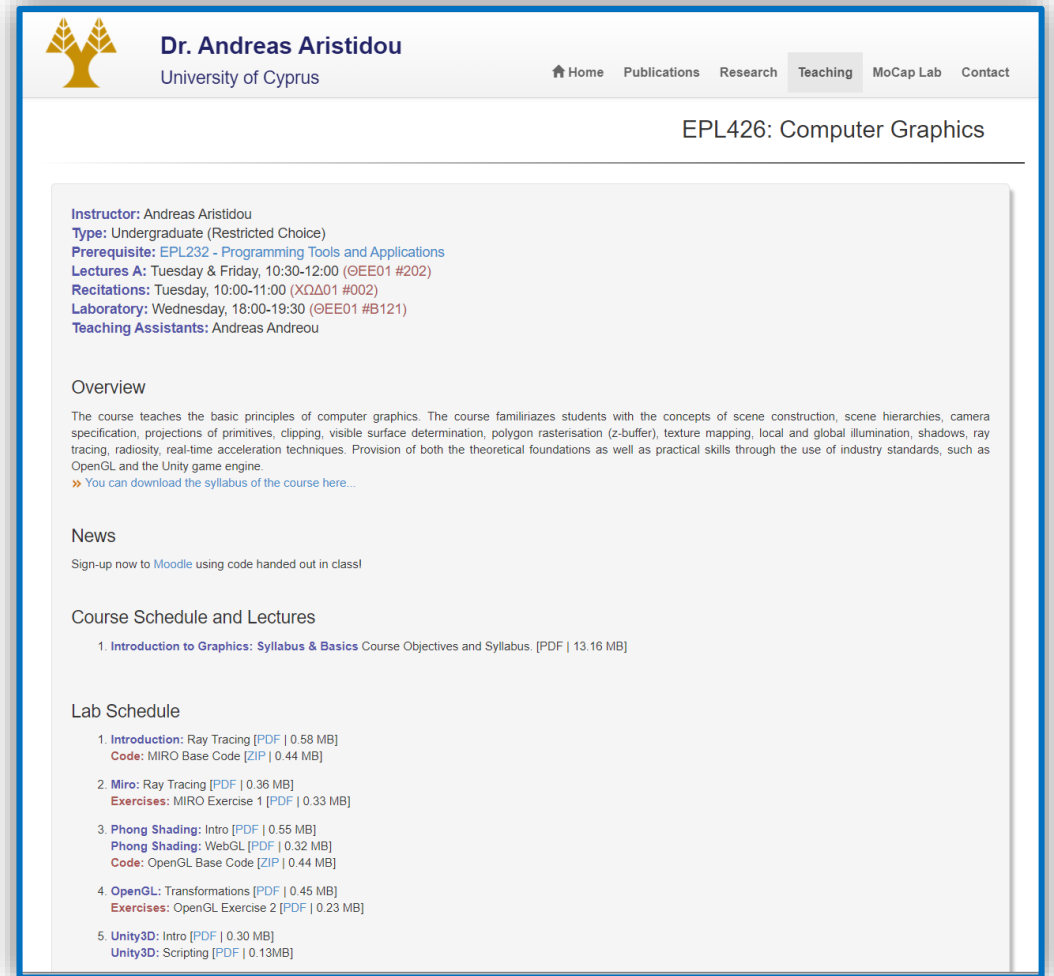
■ Andreas Andreou



Teaching Assistant

Office hours: Only after appointment

email: aandre01@cs.ucy.ac.cy

A screenshot of a web page for the course EPL426: Computer Graphics. The page has a blue header with the University of Cyprus logo and navigation links: Home, Publications, Research, Teaching (selected), MoCap Lab, and Contact. The course title "EPL426: Computer Graphics" is displayed. The main content area lists course details: Instructor (Andreas Aristidou), Type (Undergraduate), Prerequisite (EPL232), Lectures (Tuesday & Friday), Recitations (Tuesday), Laboratory (Wednesday), and Teaching Assistants (Andreas Andreou). It includes an Overview section describing the course content, a News section with a Moodle link, and a Course Schedule and Lectures section listing five topics with associated PDFs and code files. A Lab Schedule section lists five topics with associated PDFs and code files.

Dr. Andreas Aristidou
University of Cyprus

Home Publications Research **Teaching** MoCap Lab Contact

EPL426: Computer Graphics

Instructor: Andreas Aristidou
Type: Undergraduate (Restricted Choice)
Prerequisite: [EPL232 - Programming Tools and Applications](#)
Lectures A: Tuesday & Friday, 10:30-12:00 (ΘΕΕ01 #202)
Recitations: Tuesday, 10:00-11:00 (ΧΩΔ01 #002)
Laboratory: Wednesday, 18:00-19:30 (ΘΕΕ01 #B121)
Teaching Assistants: Andreas Andreou

Overview

The course teaches the basic principles of computer graphics. The course familiarizes students with the concepts of scene construction, scene hierarchies, camera specification, projections of primitives, clipping, visible surface determination, polygon rasterisation (z-buffer), texture mapping, local and global illumination, shadows, ray tracing, radiosity, real-time acceleration techniques. Provision of both the theoretical foundations as well as practical skills through the use of industry standards, such as OpenGL and the Unity game engine.

» You can download the syllabus of the course [here](#)...

News

Sign-up now to [Moodle](#) using code handed out in class!

Course Schedule and Lectures

1. [Introduction to Graphics: Syllabus & Basics](#) Course Objectives and Syllabus. [PDF | 13.16 MB]

Lab Schedule

1. [Introduction: Ray Tracing](#) [PDF | 0.58 MB]
[Code:](#) MIRO Base Code [ZIP | 0.44 MB]

2. [Miro: Ray Tracing](#) [PDF | 0.36 MB]
[Exercises:](#) MIRO Exercise 1 [PDF | 0.33 MB]

3. [Phong Shading: Intro](#) [PDF | 0.55 MB]
[Phong Shading: WebGL](#) [PDF | 0.32 MB]
[Code:](#) OpenGL Base Code [ZIP | 0.44 MB]

4. [OpenGL: Transformations](#) [PDF | 0.45 MB]
[Exercises:](#) OpenGL Exercise 2 [PDF | 0.23 MB]

5. [Unity3D: Intro](#) [PDF | 0.30 MB]
[Unity3D: Scripting](#) [PDF | 0.13MB]

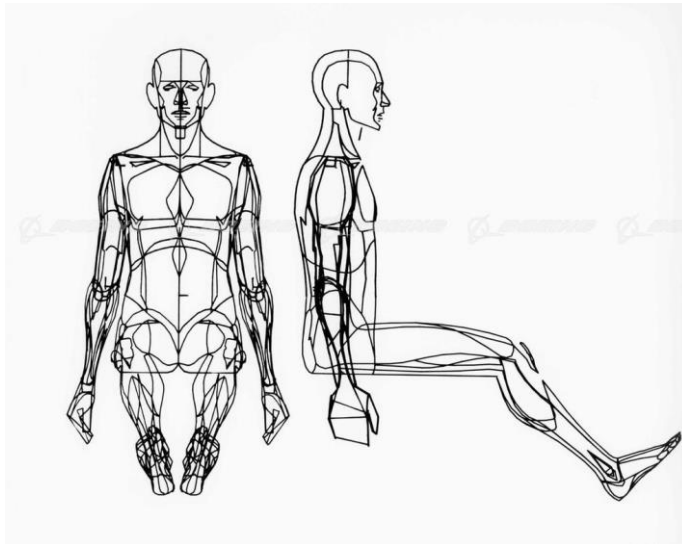
<https://www.cs.ucy.ac.cy/courses/EPL426/>

Computer Graphics: *Introduction*

- **Computer Graphics**
 - What's It All About?
 - Application Areas
 - Interactive Computer Graphics
- **How do graphics work**
 - Modeling
 - Animation
 - Rendering
- **Course Outline**
 - Lectures, Exams, Evaluation
 - Books
 - Miscellanea

Computer Graphics: *Introduction*

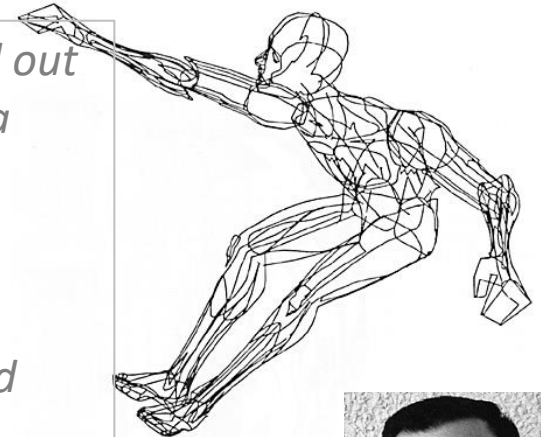
- **com•put•er graph•ics** /kəm'pyŭdər 'grafiks/ *n.* The use of computers to synthesize and manipulate visual information.
- The creation, storage and manipulation of models and images. Such models come from diverse and expanding set of fields including physical, biological, mathematical, artistic, and conceptual/abstract structures.



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.

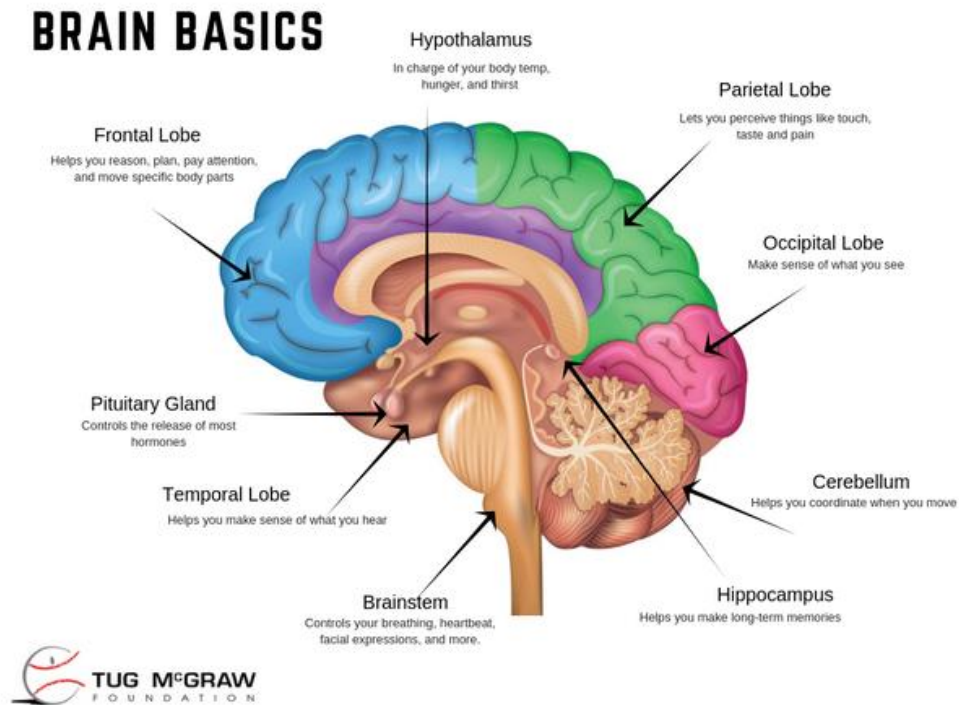
*Computer graphics is all these – a consciously managed and documented technology directed toward **communicating information** accurately and descriptively.”*

Computer Graphics, by William A. Fetter, 1966



Computer Graphics: *Why Visual Information?*

- About 30% of brain dedicated to visual processing...



Sources: Duke Medicine, John Hopkins Mayo Clinic, National Cancer Institute, WebMD

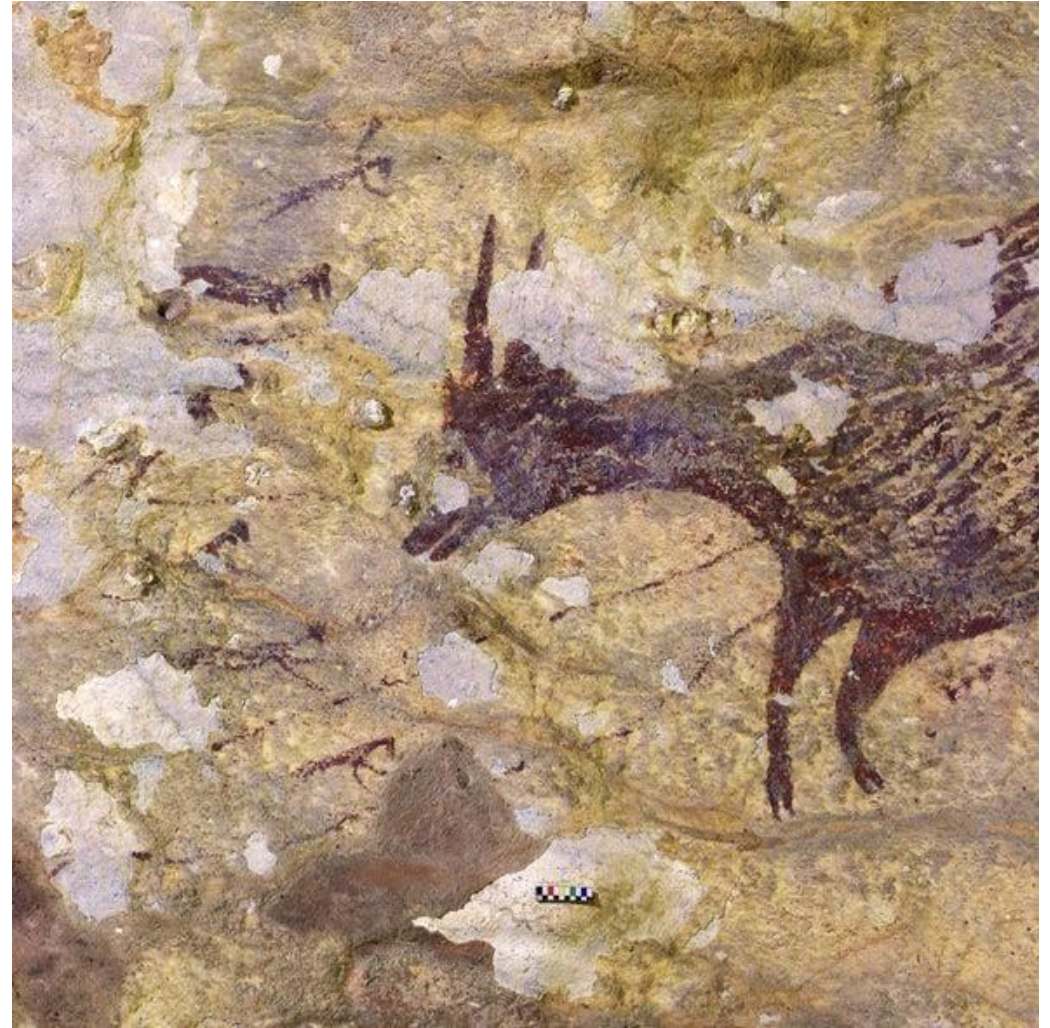


© Petar Milošević

- ...eyes are highest-bandwidth port into the head!

Computer Graphics: *History of visual depiction*

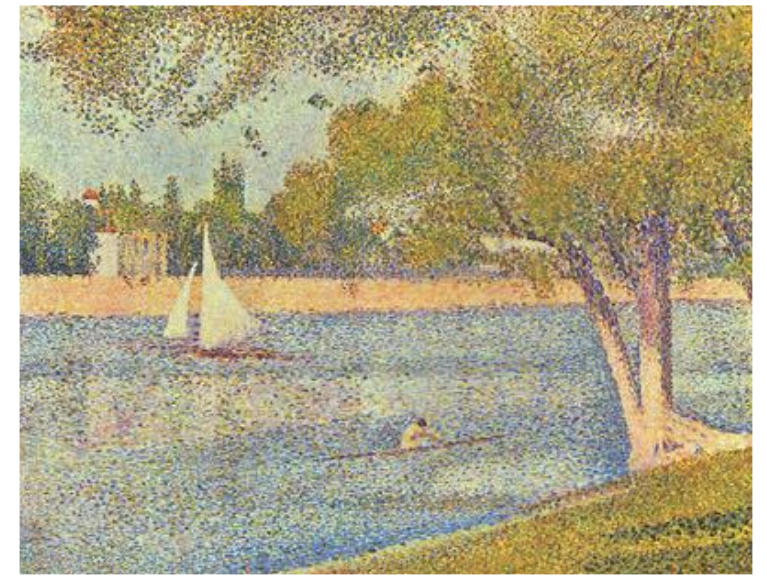
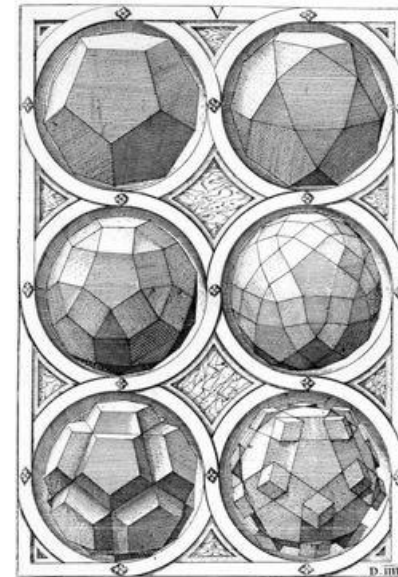
- Humans have always been visual creatures!



Indonesian cave painting (~38,000 BCE)

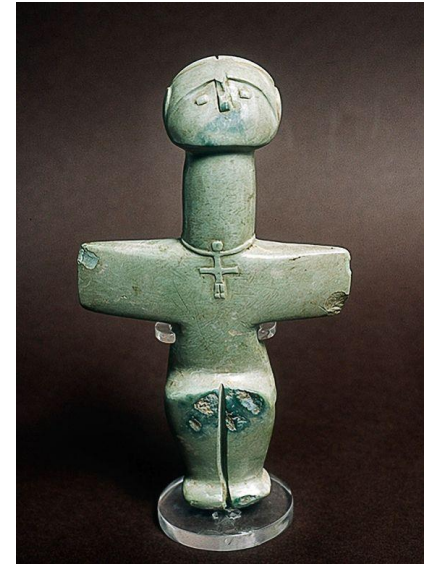
Computer Graphics: *History of visual depiction*

- Humans have always been visual creatures!
- Not purely representational: ideas, feelings, data, ...



Computer Graphics: *History of visual depiction*

- Humans have always been visual creatures!
- Not purely representational: ideas, feelings, data, ...
- Carving / sculpture



Computer Graphics: *History of visual depiction*

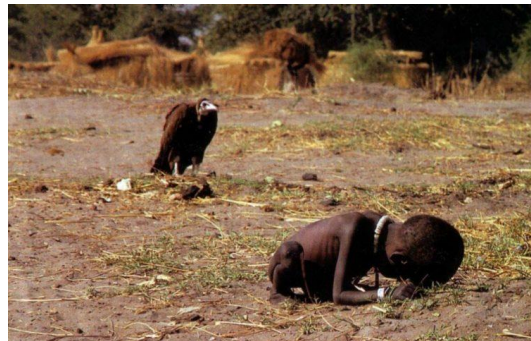
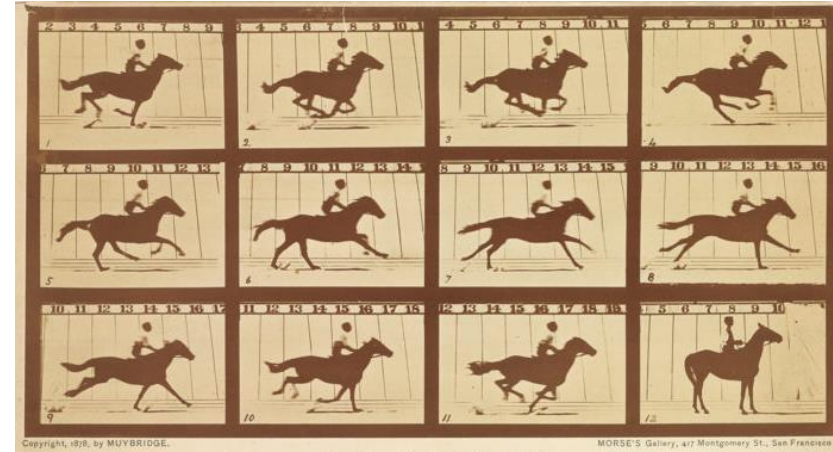
- Humans have always been visual creatures!
- Not purely representational: ideas, feelings, data, ...
- Carving / sculpture
- Processing of visual data no longer happening in the head!



Joseph Niépce, "View from the Window at Le Gras" (1826)

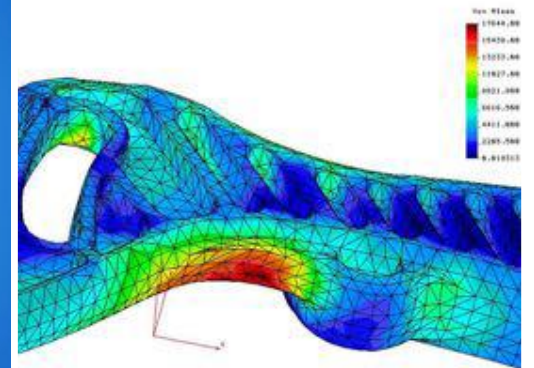
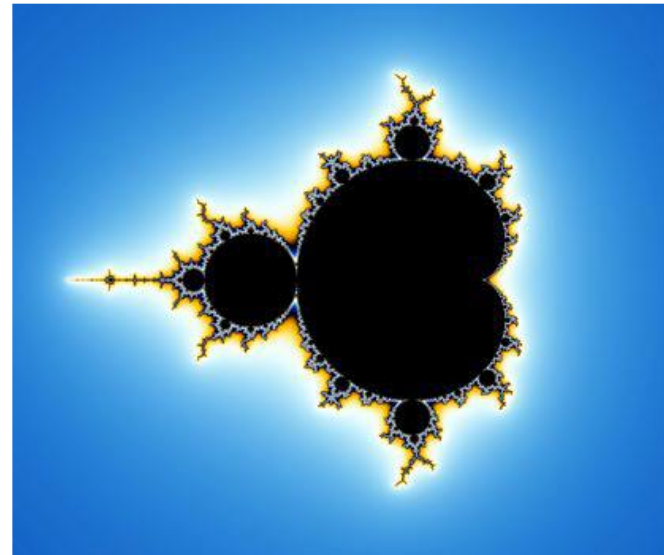
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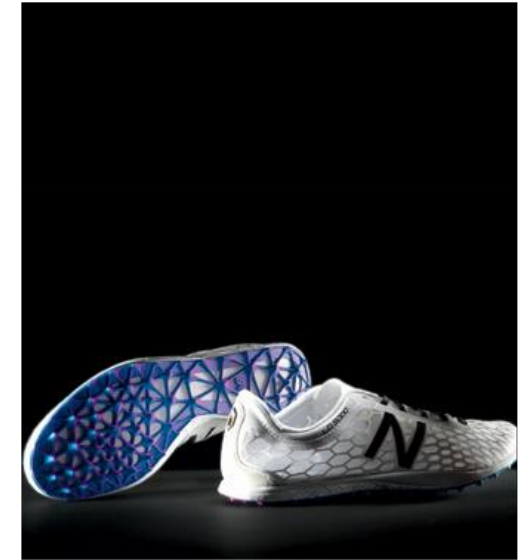
Computer Graphics: *History of visual depiction*

- Humans have always been visual creatures!
- Not purely representational: ideas, feelings, data, ...
- Carving / sculpture
- Processing of visual data no longer happening in the head!
- **Digital imagery**
 - Intersection of visual depiction & computation



Computer Graphics: *History of visual depiction*

- Humans have always been visual creatures!
- Not purely representational: ideas, feelings, data, ...
- Carving / sculpture
- Processing of visual data no longer happening in the head!
- **Digital imagery**
- **3D fabrication**
 - Create physical realization of digital shape



Computer Graphics: *Introduction*

- **com•put•er graph•ics** /kəm'pyʊdər 'ɡrafiks/ *n.* The use of computers to synthesize and manipulate visual information.

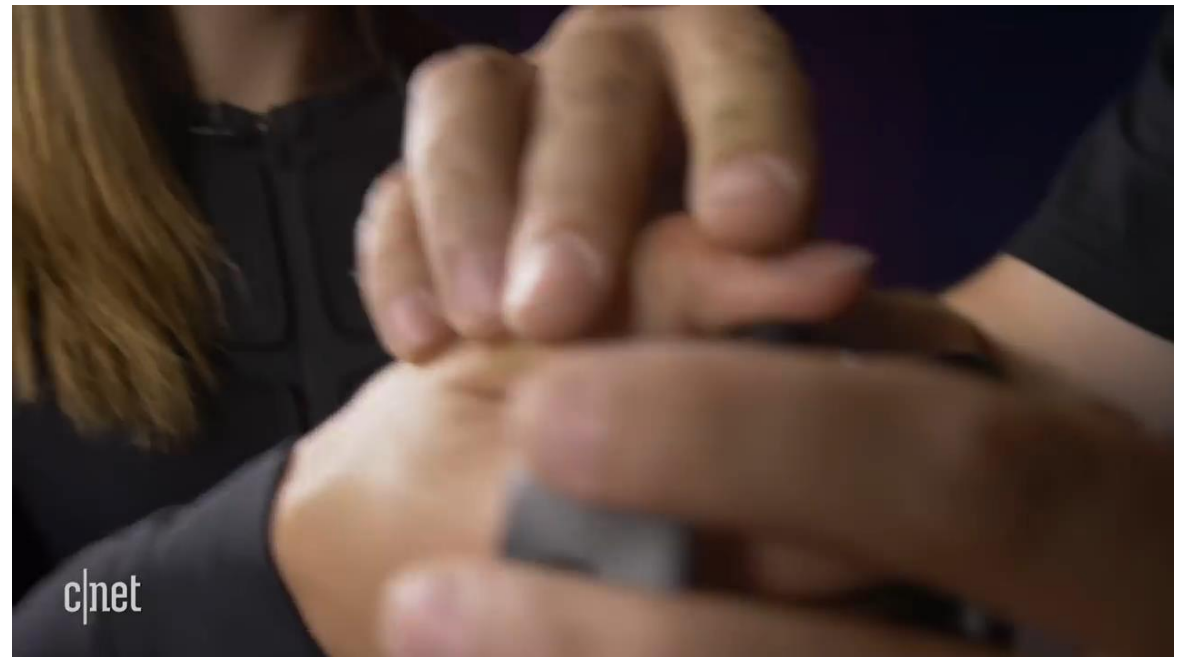


3D Computer Graphics: Not image processing!

Computer Graphics: *Introduction*

- **com•put•er graph•ics** /kəmˈpyʊtər ɡræfˌɪks/. The use of computers to synthesize and manipulate visual information.

Why only visual?



© TeslaSuit

9D Cinemas

|

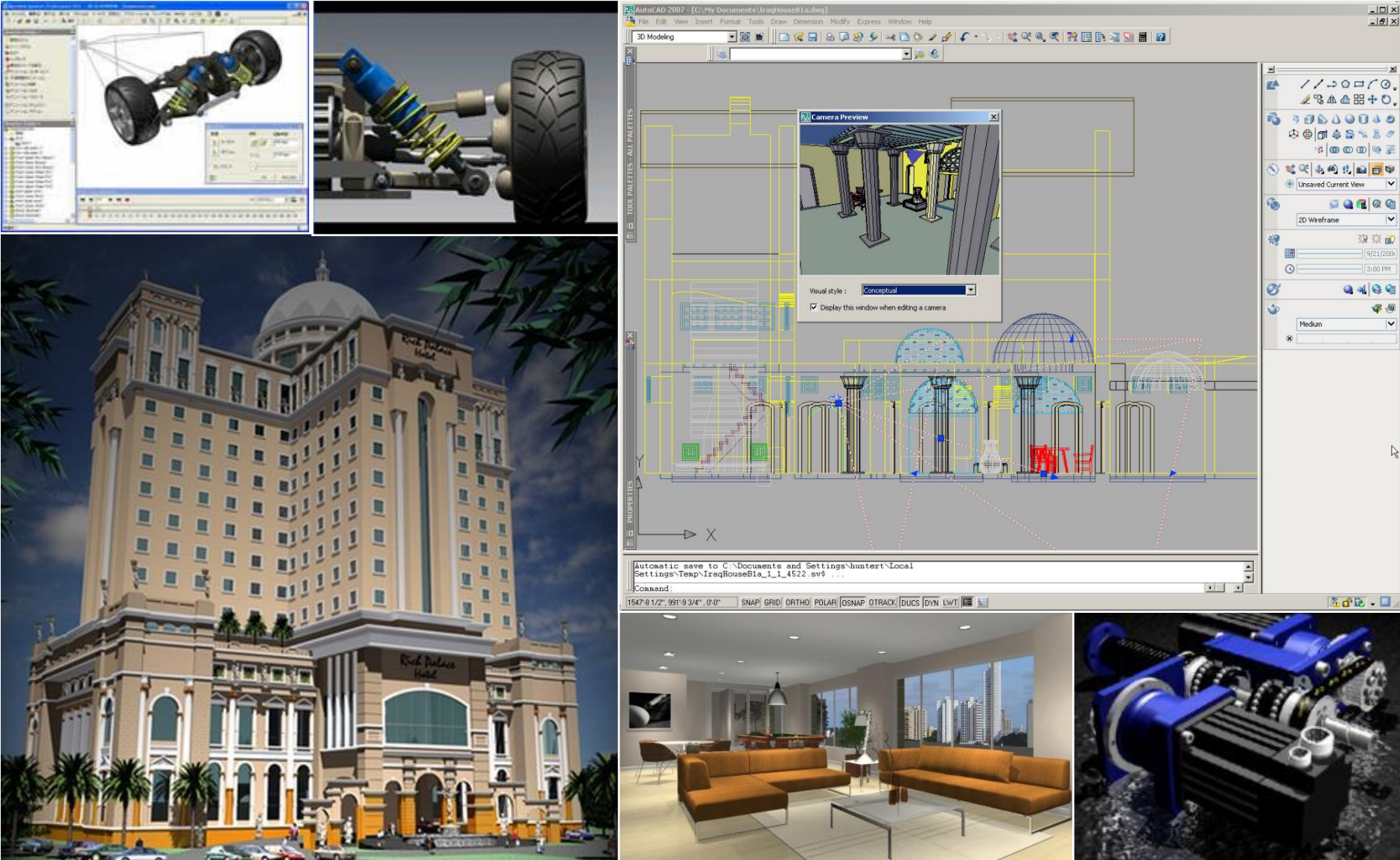
(...What about taste? Smell?!)

Computer graphics are everywhere!

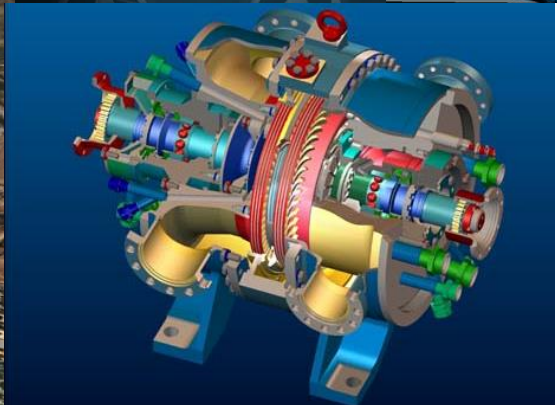
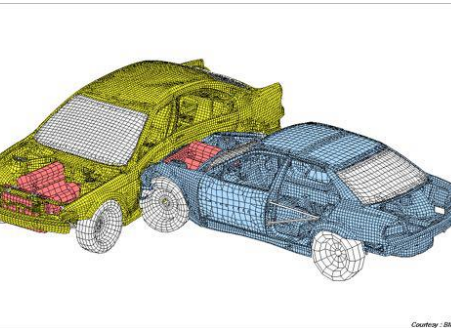
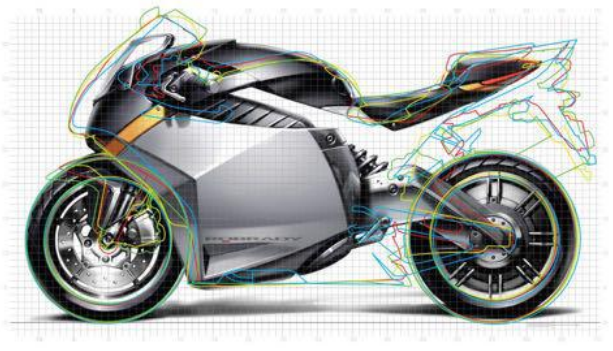
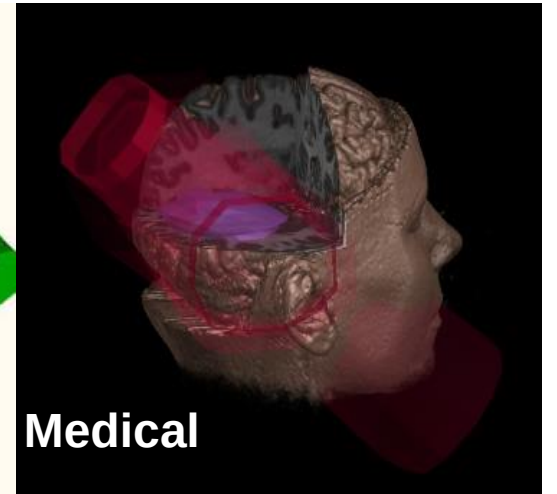
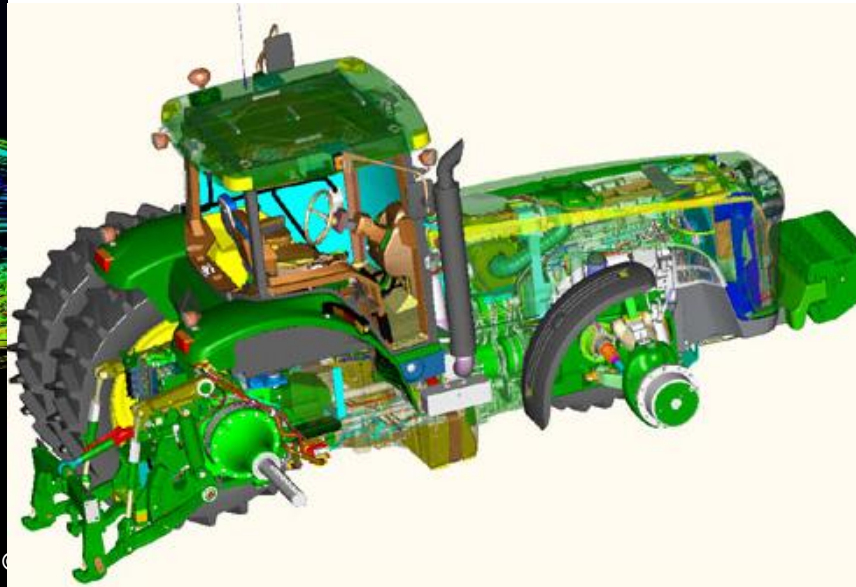
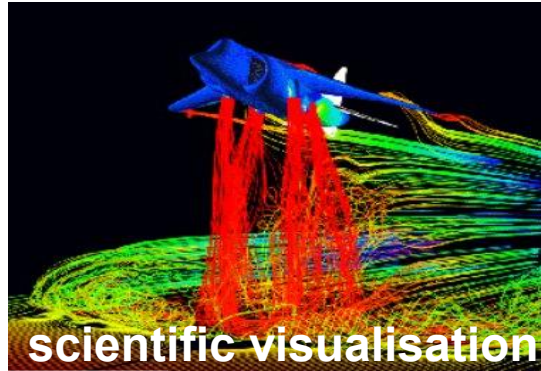
Some Applications of Computer Graphics

- Some of the application areas which make heavy use of computer graphics are:
 - Computer aided design
 - Scientific visualisation
 - Films
 - Games
 - Virtual/Augmented Reality
- **NOTE:** There are lots more and there is huge overlap between these different areas

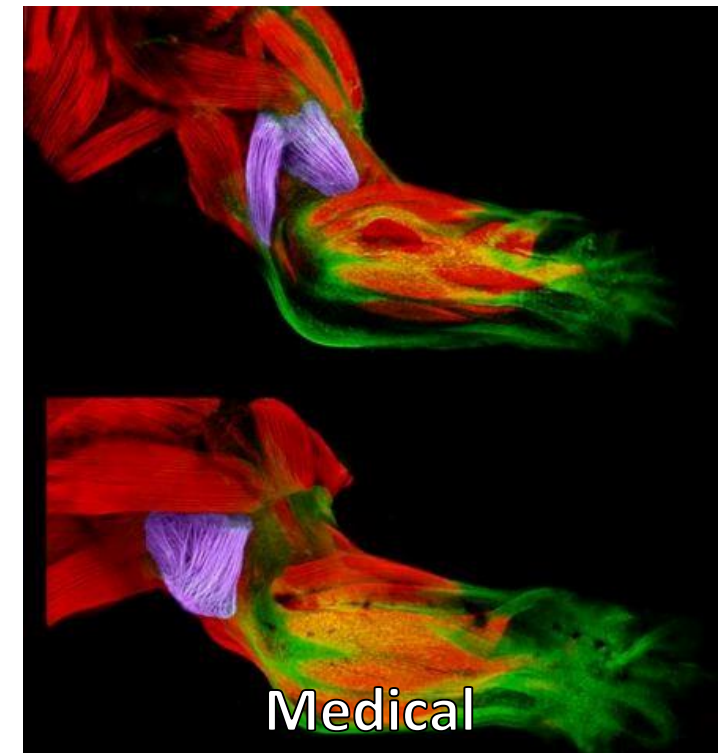
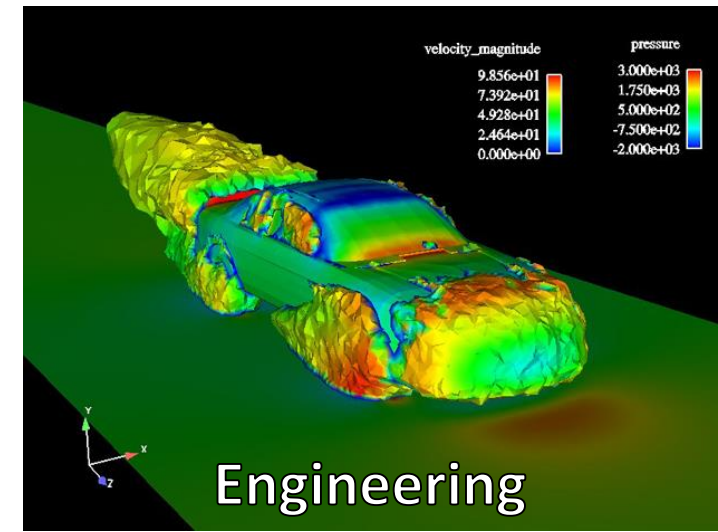
Computer Aided Design



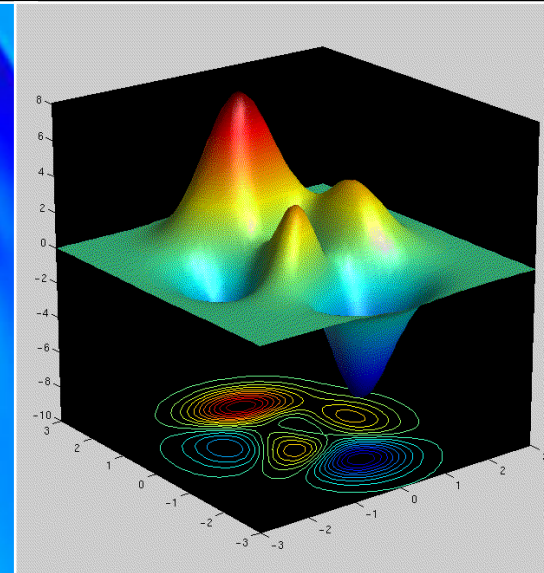
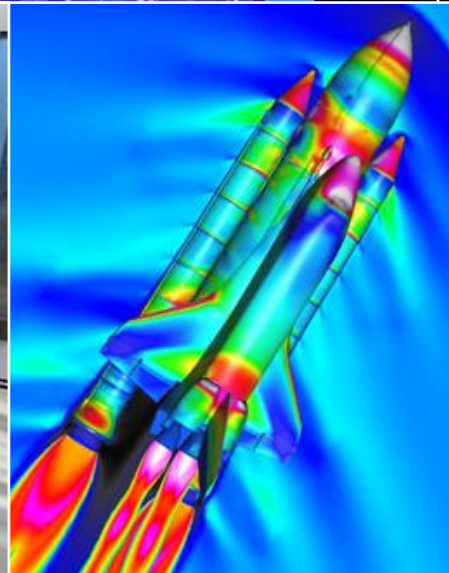
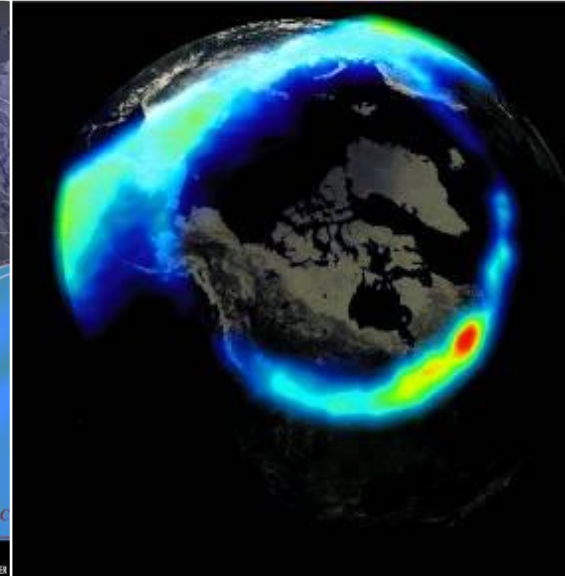
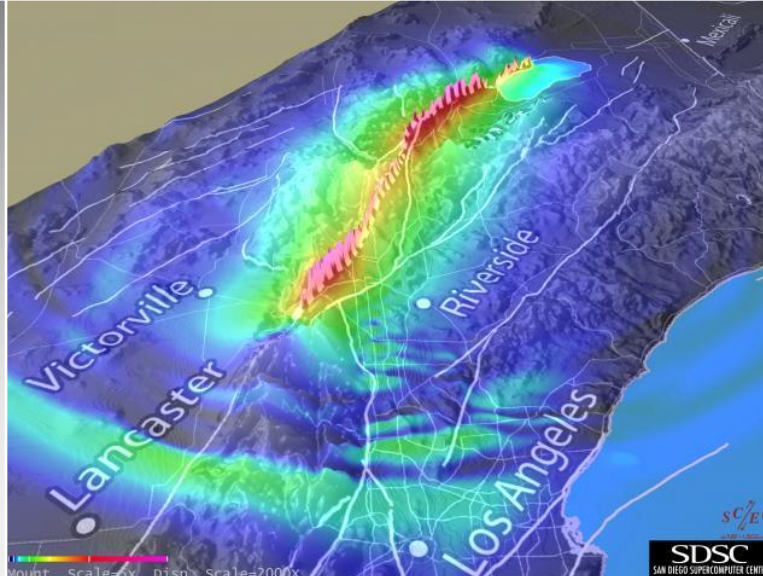
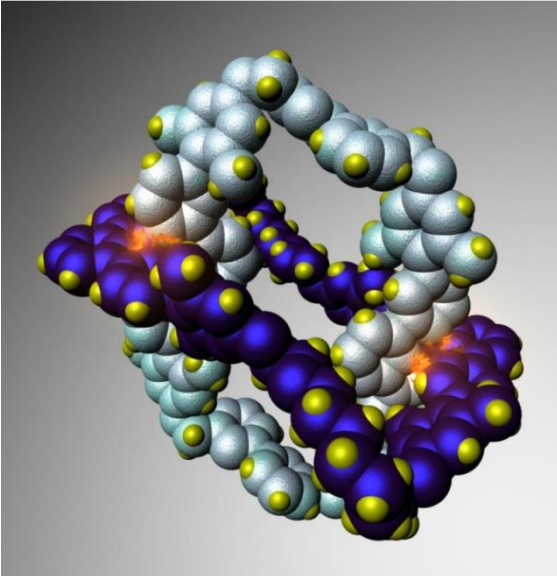
Computer Aided Design



Computer Aided Design



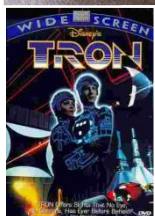
Scientific Visualisation



Navigation



Films



Films



Games



Games



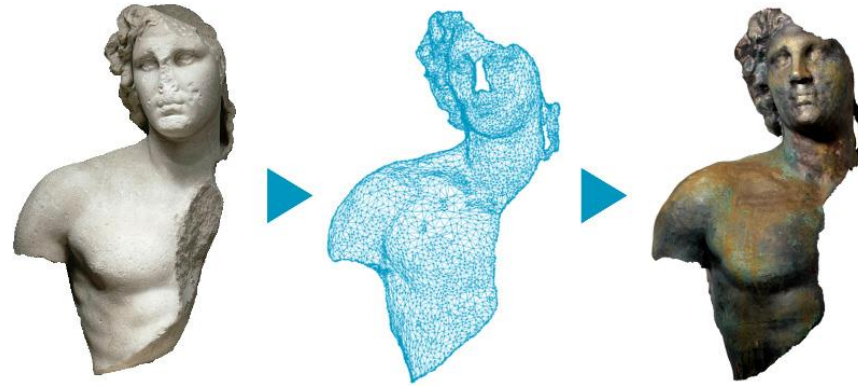
Games



Virtual/Augmented Reality



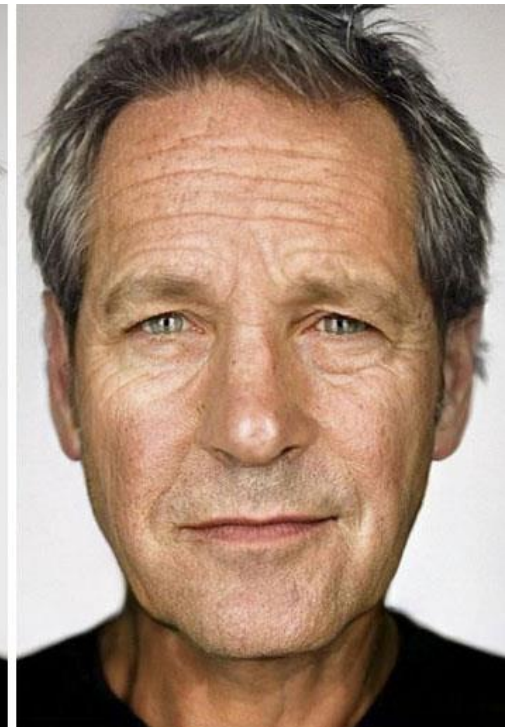
Cultural Heritage



3D printable files are shared online so anyone can print their own



Entertainment

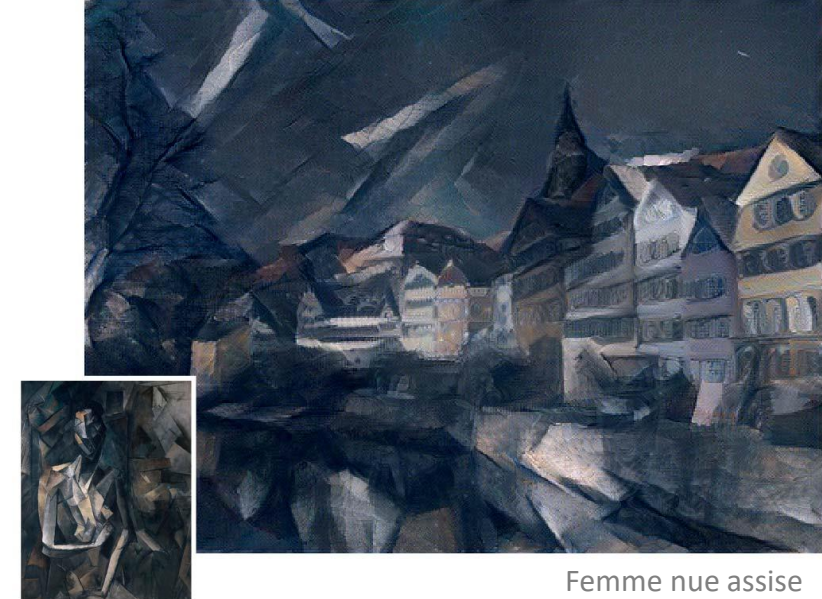




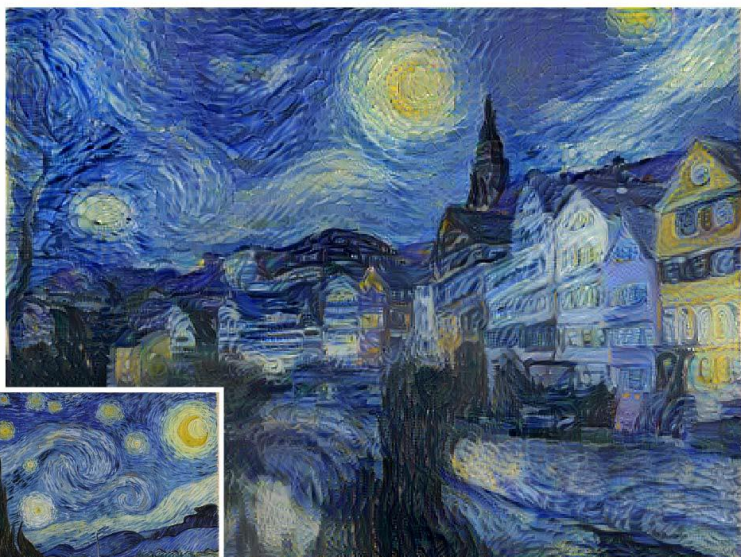
Neckarfront in Tübingen,
Germany ©Andreas Praefcke



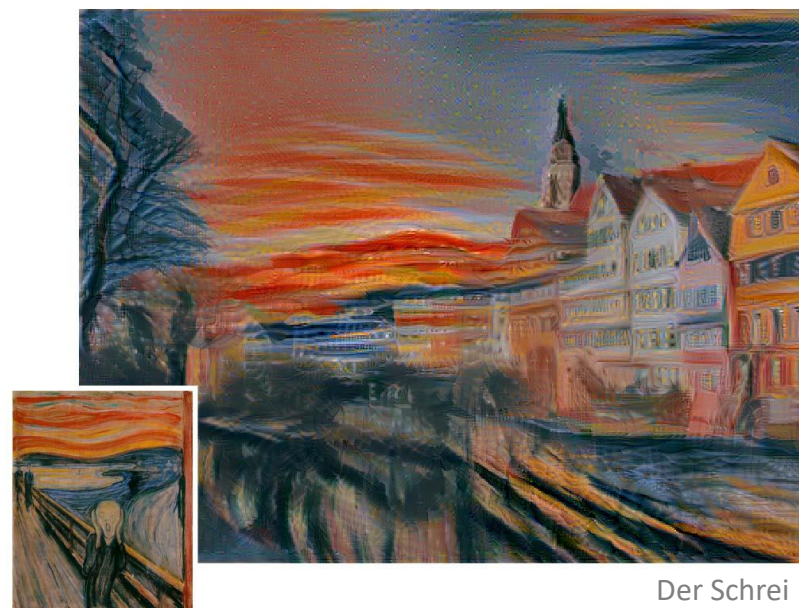
The Shipwreck of the Minotaur
by J.M.W. Turner, 1805



Femme nue assise
by Pablo Picasso, 1910



The Starry Night
by Vincent van Gogh, 1889



Der Schrei
by Edvard Munch, 1893

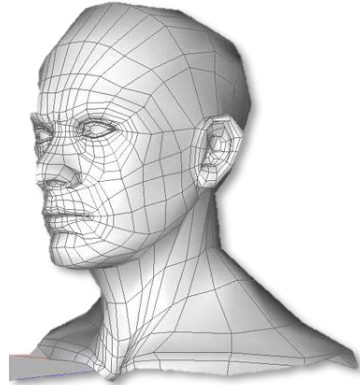


Composition VII
by Wassily Kandinsky, 1913

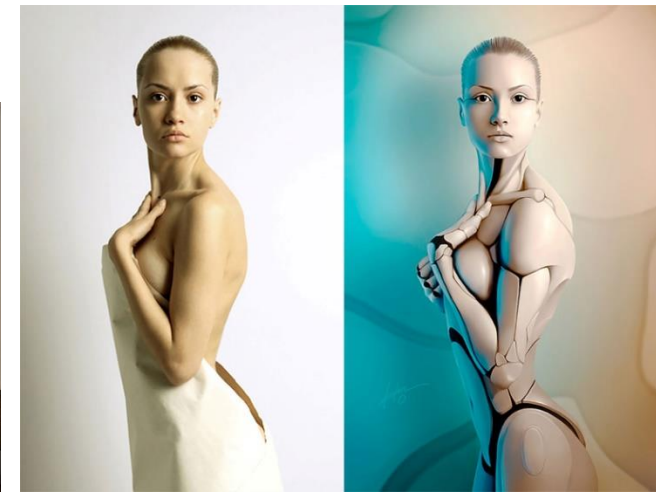
Gatys et al. 2016. Image Style Transfer Using Convolutional Neural Networks. Proc. CVPR 2016.

Foundations of computer graphics

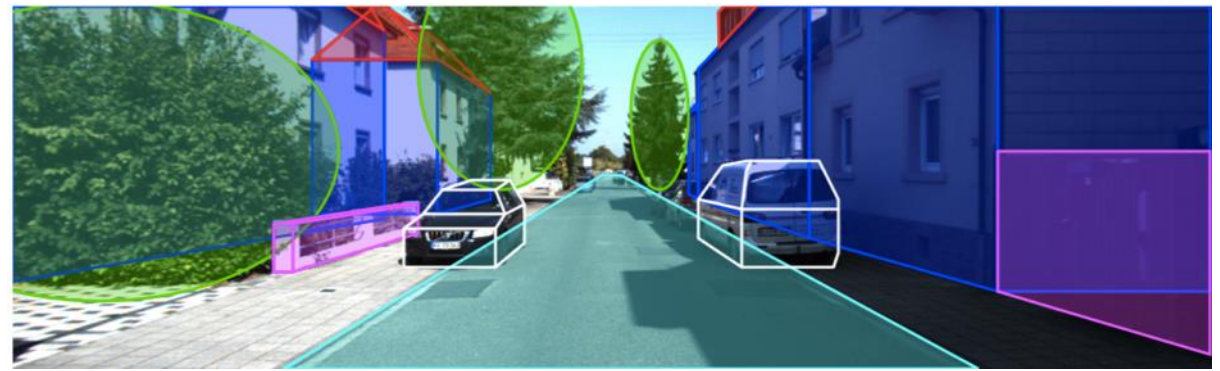
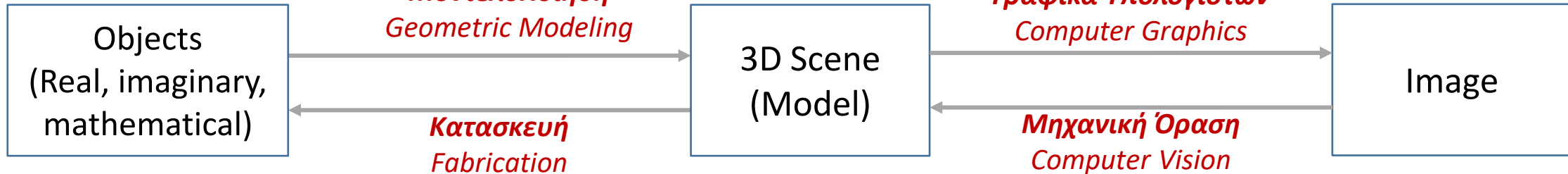
Visual Computing



**Γεωμετρική
Μοντελοποίηση**
Geometric Modeling

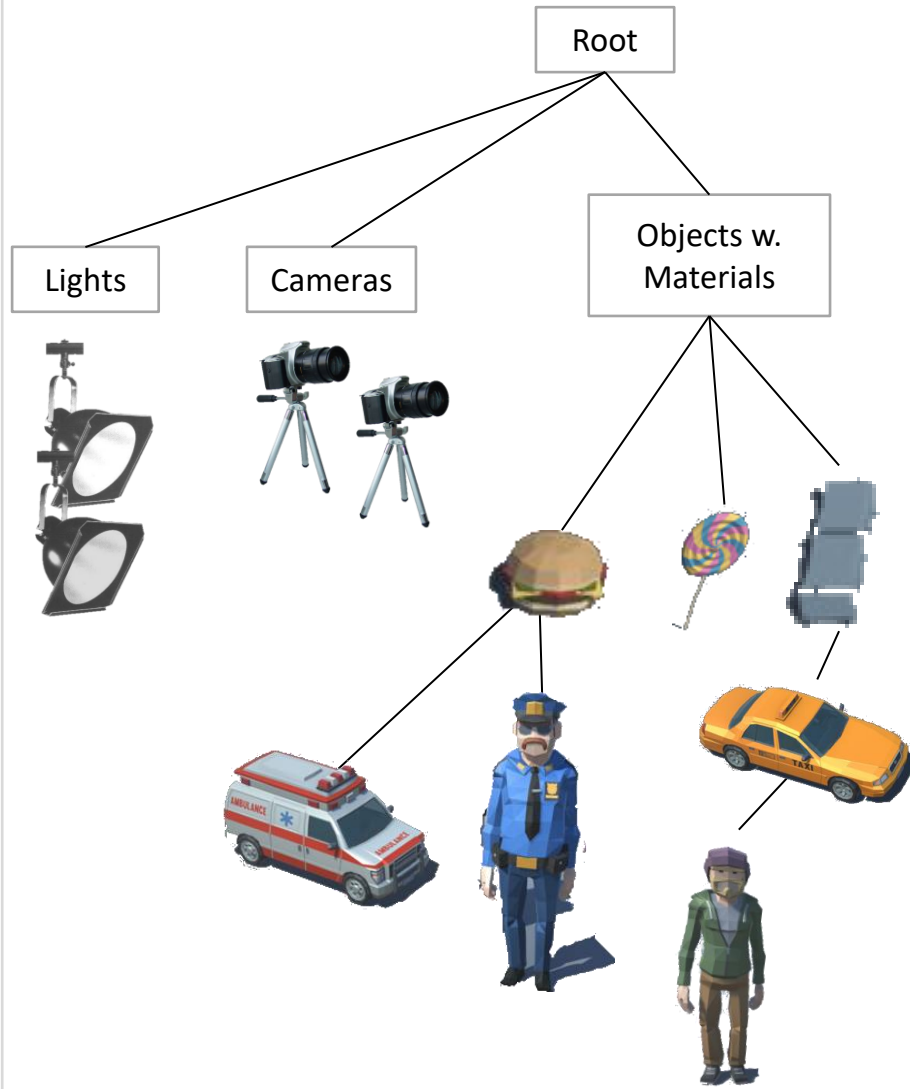


Επεξεργασία Εικόνας
Image Processing



Computer Graphics

Scene Description



Rendering
Algorithm

Image

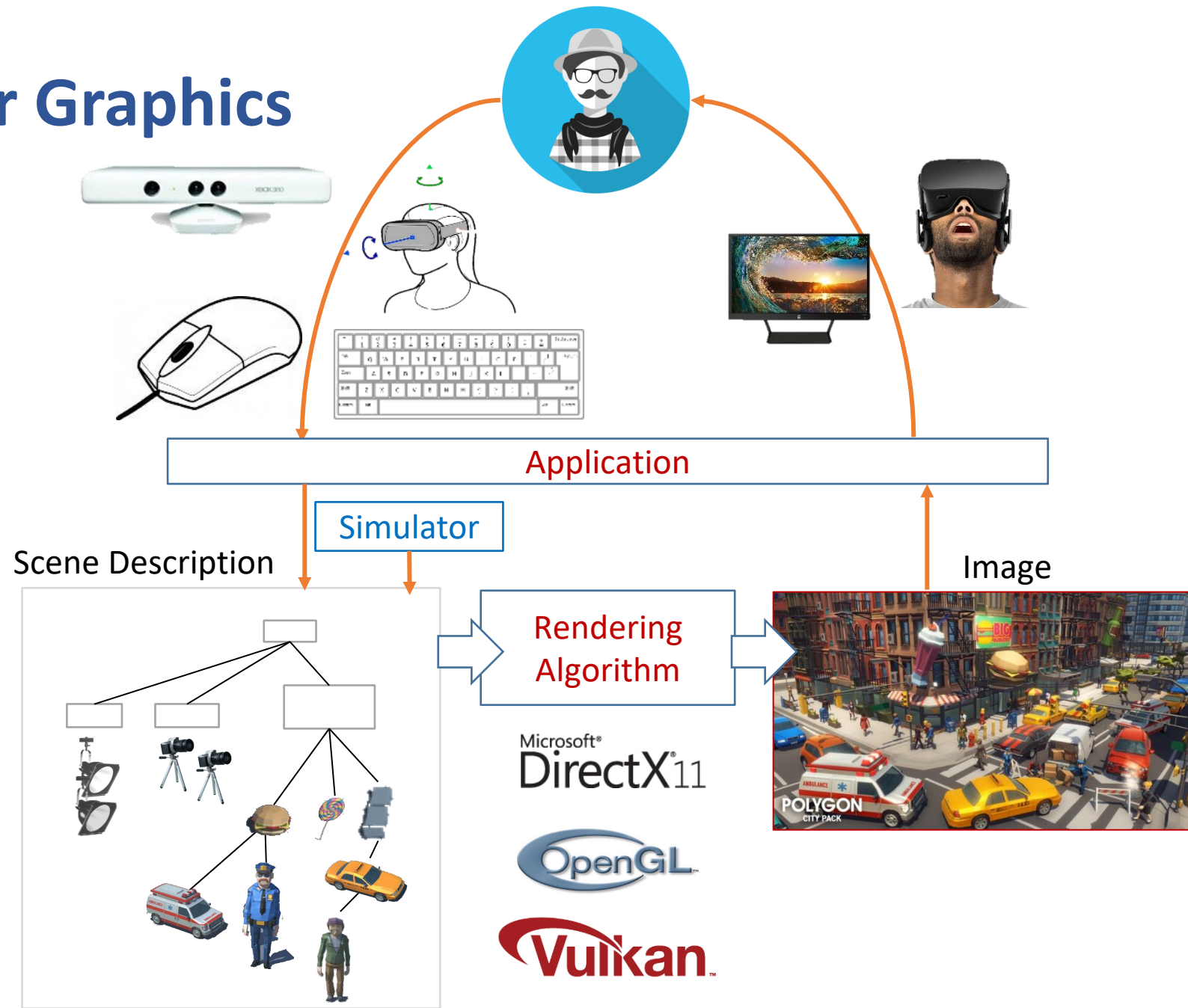


Polygon City Pack for Unity

<https://www.assetstore.unity3d.com/en/#!/content/95214>

Interactive Computer Graphics

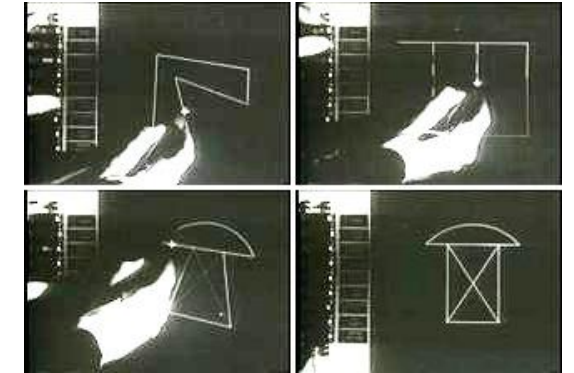
- User controls content, structure, and appearance of objects and their displayed images via rapid visual feedback
- **Interactive**: 15-120 frames per second depending on application
- Users and/or simulations modify the scene state



Basic components of an interactive graphics system

Interactive Computer Graphics

- a.k.a. Real-time Computer Graphics, Real-time Rendering.
- 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...)



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...

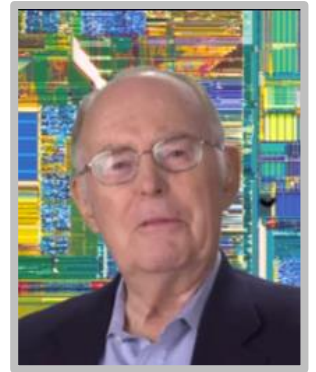
Ivan Sutherland (1963)

Ph.D. thesis: *Sketchpad, A Man-Machine Graphical Communication System*
<http://youtu.be/546ADZFMBT8>

Enabling Modern Computer Graphics

Hardware revolution

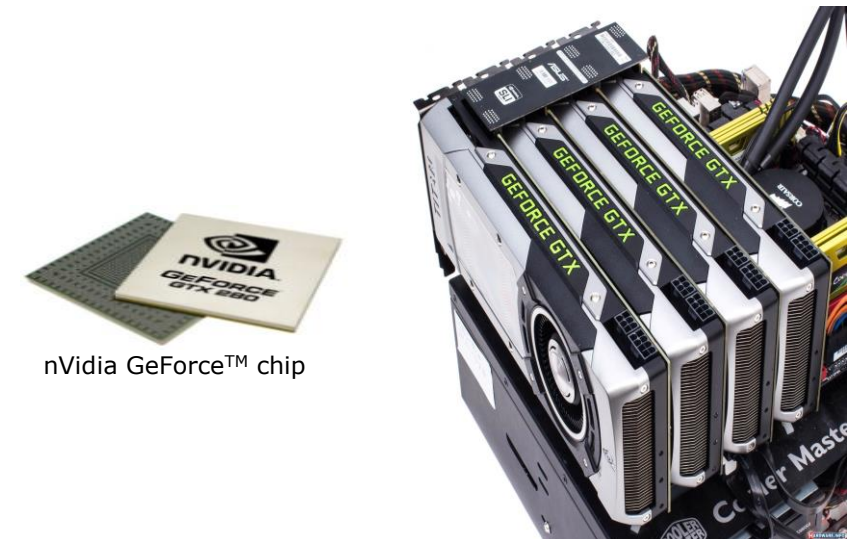
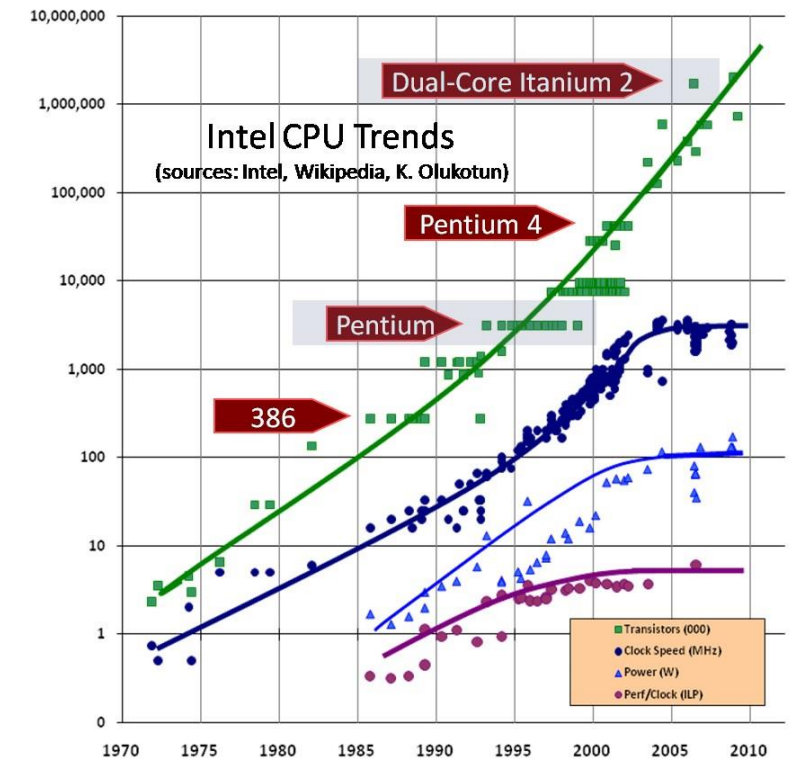
- **Moore's Law:** every 18-24 months, computer power improves by factor of 2 in price / performance as feature size shrinks
 - Newest processors are 64-bit and many-core



Enabling Modern Computer Graphics

Hardware revolution

- Significant advances in commodity graphics chips (GPUs) every 6 months vs. several years for general purpose CPUs
 - NVIDIA Titan XP... 3840 shaders (cores)
 - Graphic subsystems (GPUs)
 - Offloads graphics processing from CPU to chip designed for doing graphics operations fast
 - nVidia GeForce™, ATI Radeon™
 - GPUs used for special purpose computation, also being ganged together to make supercomputers
 - You can put multiple GPUs together in your computer using SLI.
 - GPUs has led to development of other dedicated subsystems
 - Physics: nVidia PhysX PPU (Physics Processing Unit), standard on many NVIDIA GPUs
 - Artificial Intelligence: Alseek Intia Processor (as of 2008)



nVidia GeForce™ chip

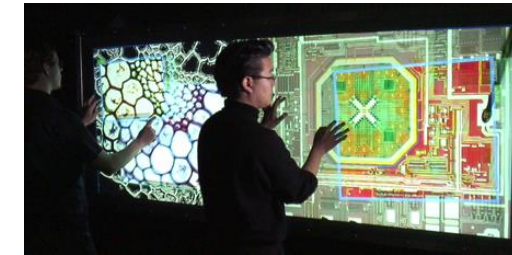
Enabling Modern CG

■ Many form factors

- Cell Phones/PDAs (smartphones), Laptop/Desktops,
- Jeff Han's [Perceptive Pixel](#), Microsoft Surface
- 3D immersive virtual reality systems

■ Software Improvements

- Parallelization
 - Most operations are embarrassingly parallel: changing value of one pixel is often independent of other pixels
- Distributed and Cloud computing
 - Send operations into 'cloud', get back results, don't care how
 - Rendering even available as internet service!
- Algorithms and data structures
 - Rendering of natural phenomena
 - Acceleration data structures for ray tracing



Perceptive
Pixel



Microsoft
Surface



Brown's
Cave™

Enabling Modern CG

■ Input Devices

- Mouse, tablet & stylus, multi-touch, force feedback, and other game controllers (e.g., Wii), scanner, digital camera (images, computer vision), etc.
- Whole body as interaction device:
 - <http://www.xbox.com/kinect>



Xbox Kinect



Leap Motion

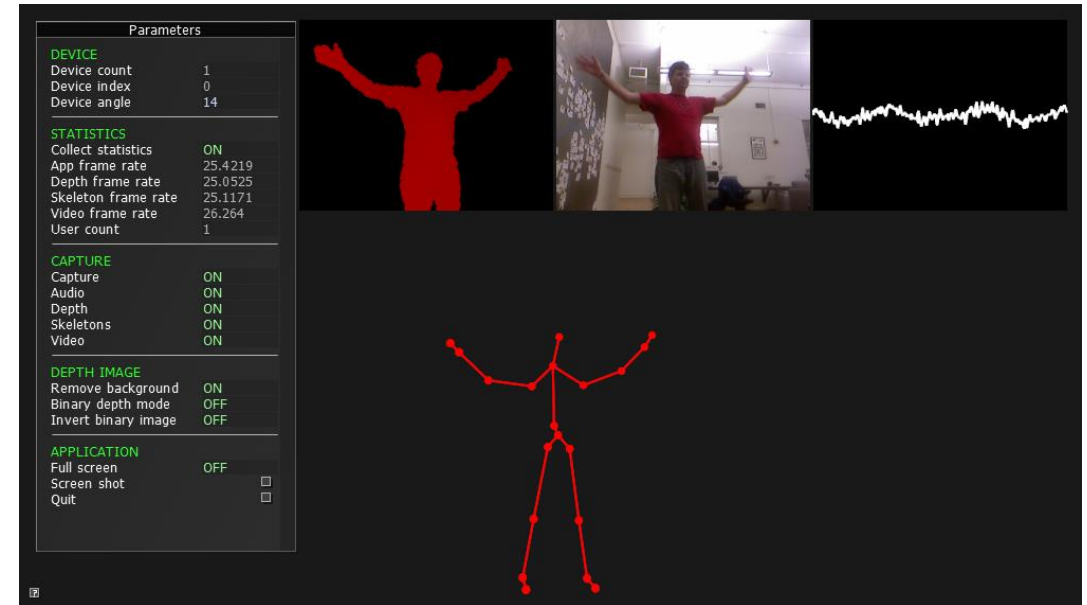
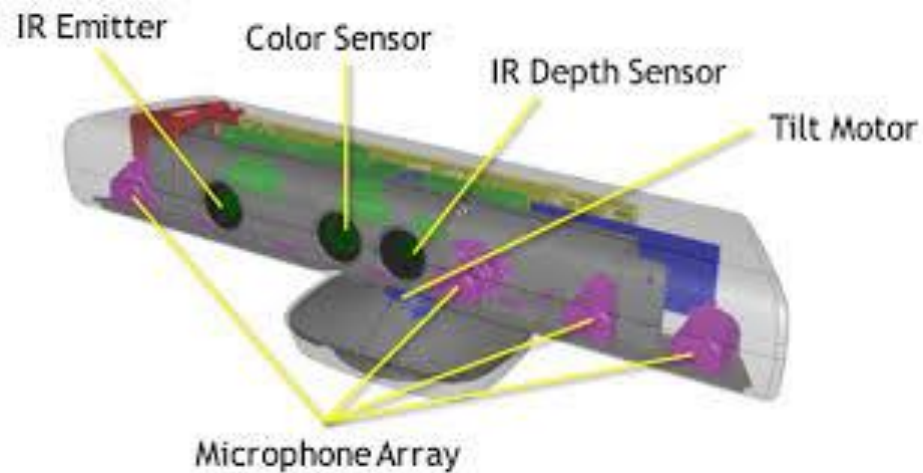


Nimble UX

Πως αλληλοεπιδρούμε με τις εικόνες γραφικών;



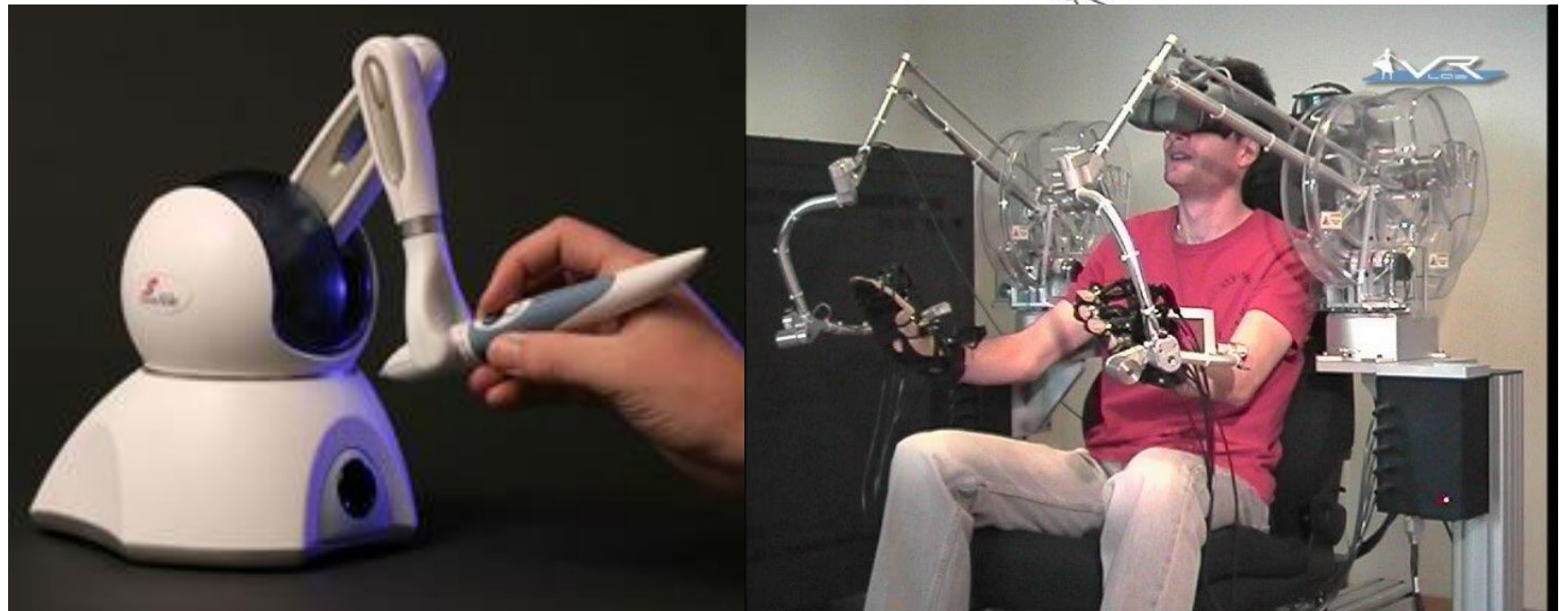
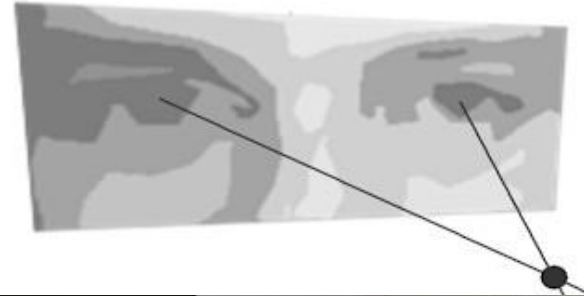
Πως αλληλοεπιδρούμε με τις εικόνες γραφικών;



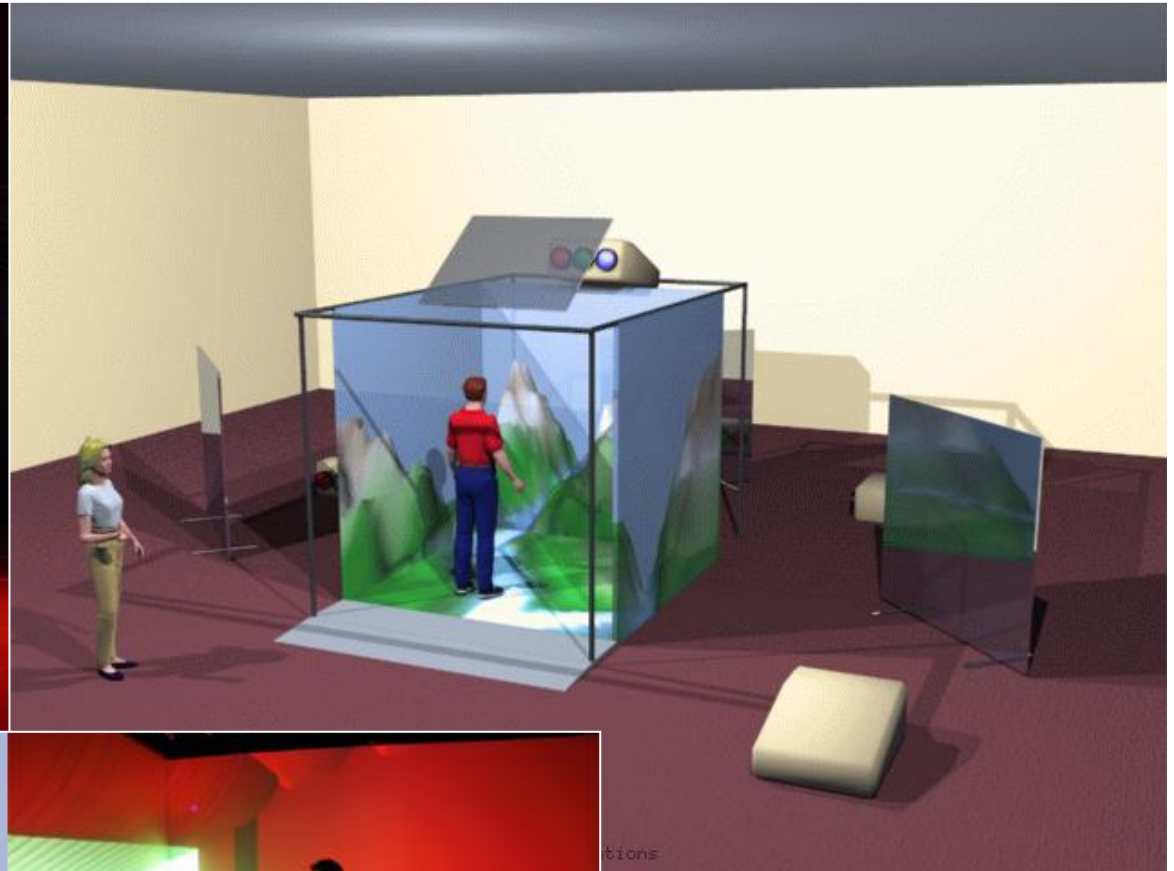
Immerse the user

- Stereo vision
- Tracking
- Haptics
- Surround sound
- Smell & taste (??)

Cooperative Stereo Vision



Πως αλληλοεπιδρούμε με τις εικόνες γραφικών;



Πως αλληλοεπιδρούμε με τις εικόνες γραφικών;



Stereo – Head Mounted Displays



Augmented Reality Goggles



Computer Graphics: *Introduction*

- **Computer Graphics**

- What's It All About?
- Application Areas
- Interactive Computer Graphics

- **How do graphics work**

- Modeling
- Animation
- Rendering

- **Course Outline**

- Lectures, Exams, Evaluation
- Books
- Miscellanea



Πώς φτιάχνουμε αυτή την εικόνα;



- Μοντελισμός
 - Γεωμετρία
 - Υλικά
 - Φωτισμός
- Κινησιολογία (Animation)
 - Πως κινούνται;
- Απόδοση
 - Απόδοση φωτισμού, σκιές
 - Κάμερα
 - Ειδικά εφέ
 - Μετά-επεξεργασία

Uncharted 4: <https://youtu.be/zL46dpNEPPA>

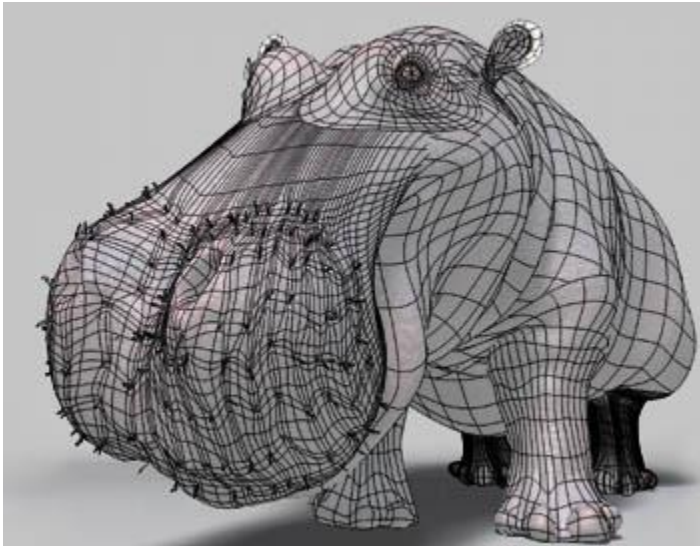
Making of Uncharted 4: <https://youtu.be/3uKia6kb1fk>

Πως δημιουργούνται οι εικόνες γραφικών

- **Απαραίτητα συστατικά:**

1. **Γεωμετρική μοντελοποίηση (Geometric Modeling):** δημιουργία μαθηματικών μοντέλων 2D και 3D αντικειμένων
2. **Κινησιογραφία (Animation):** ορισμός/αναπαράσταση χρονικής συμπεριφοράς των αντικειμένων
3. **Απόδοση (Rendering):** δημιουργία εικόνων

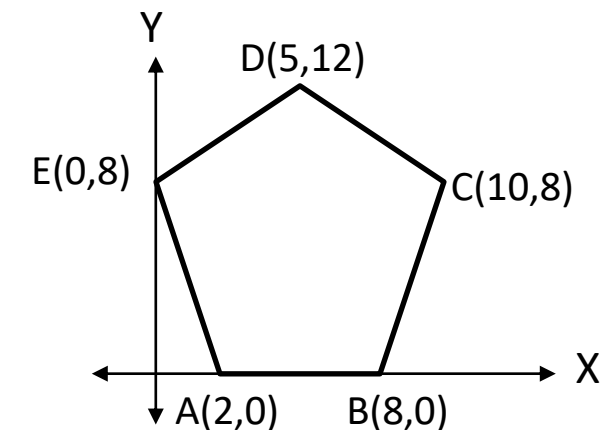
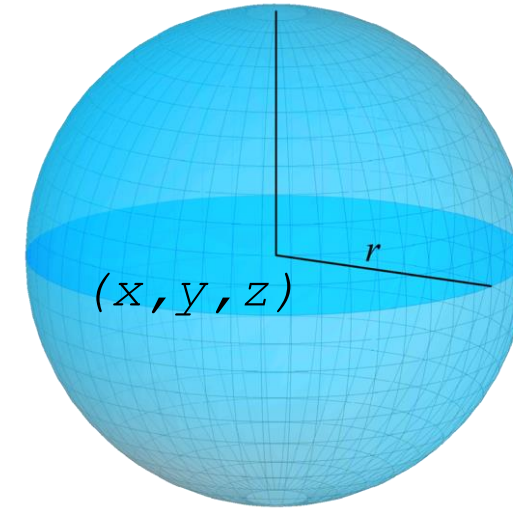
Γεωμετρική Μοντελοποίηση



<http://www.3drender.com/>

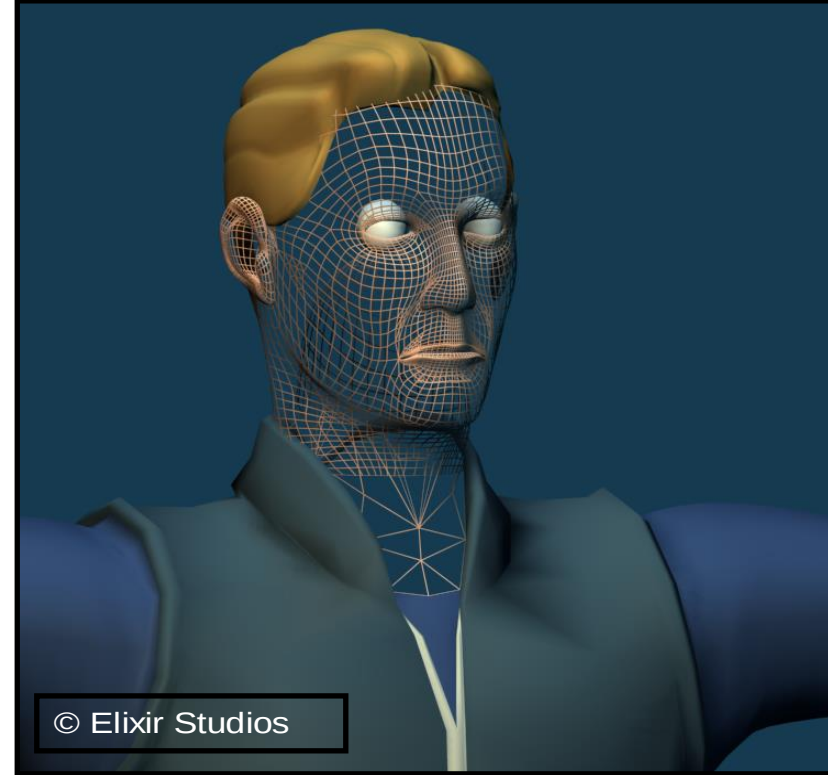
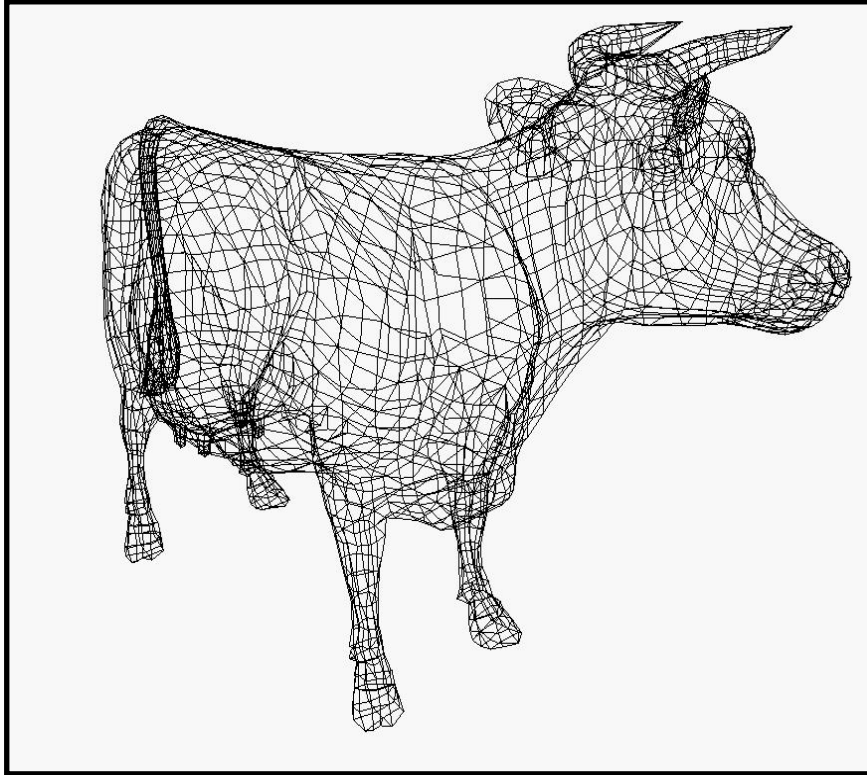
Γεωμετρική μοντελοποίηση

- Απλά αντικείμενα μπορούν να αναπαρασταθούν απευθείας:
 - Π.χ. μια σφαίρα χρειάζεται μόνο 4 τιμές (x, y, z, r)
 - Για ένα πολύγωνο χρειάζονται οι συντεταγμένες των κορυφών του



Γεωμετρική μοντελοποίηση

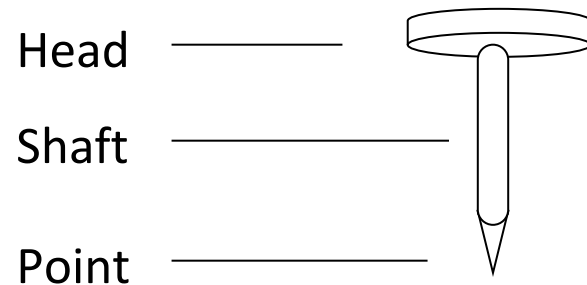
- Με συνδυασμό πολυγώνων μπορούμε να περιγράψουμε οποιοδήποτε σχήμα



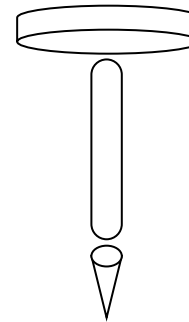
Βέβαια ο αριθμός των πολυγώνων μπορεί να είναι πολύ μεγάλος

Decomposition of a Geometric Model

- Divide and Conquer
- Hierarchy of geometrical components
- Reduction to primitives (e.g., spheres, cubes, etc.)
- Simple vs. not-so-simple elements (nail vs. screw)



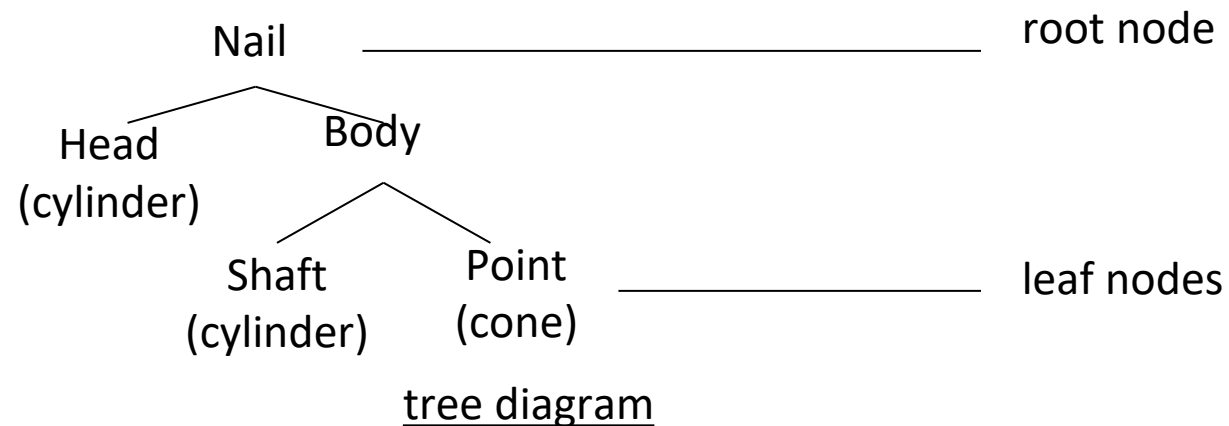
composition



decomposition

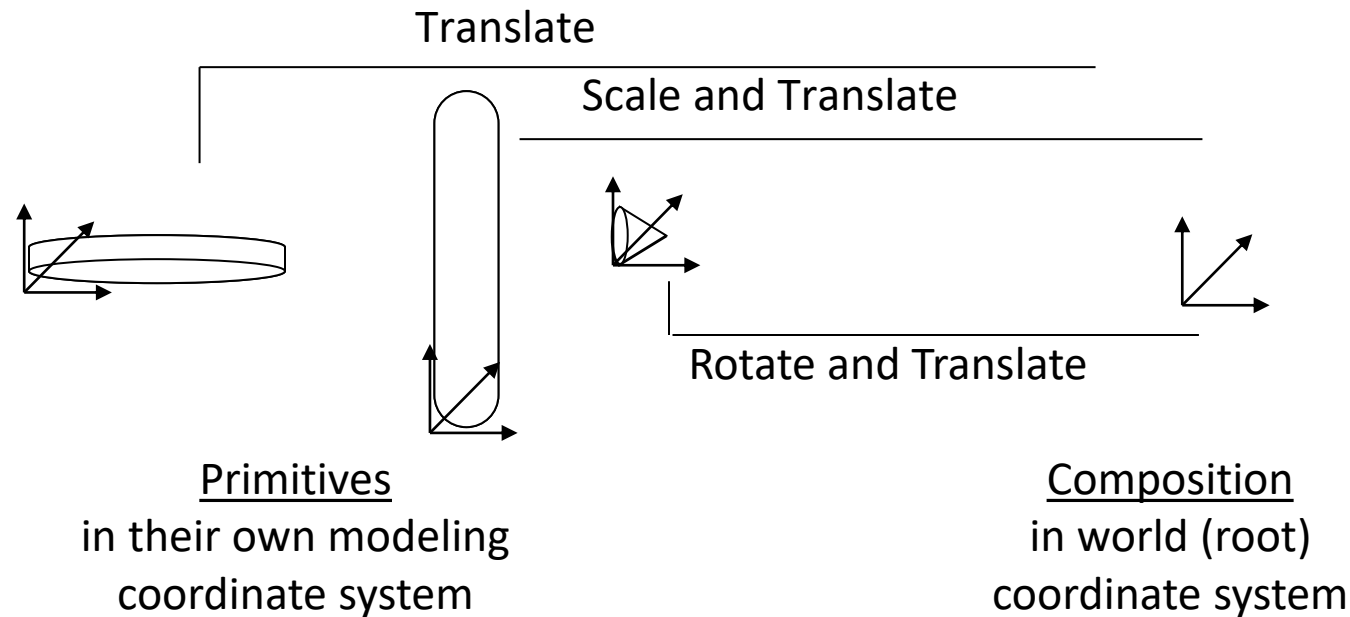
Hierarchical (Tree) Diagram of Nail

- Object to be modeled is (visually) analyzed, and then decomposed into collections of primitive shapes.
- Tree diagram provides visual method of expressing “composed of” relationships of model



- Such diagrams are part of 3D program interfaces (e.g., 3D Studio MAX, Maya)
- As a data structure to be rendered, it is called a **scenegraph**

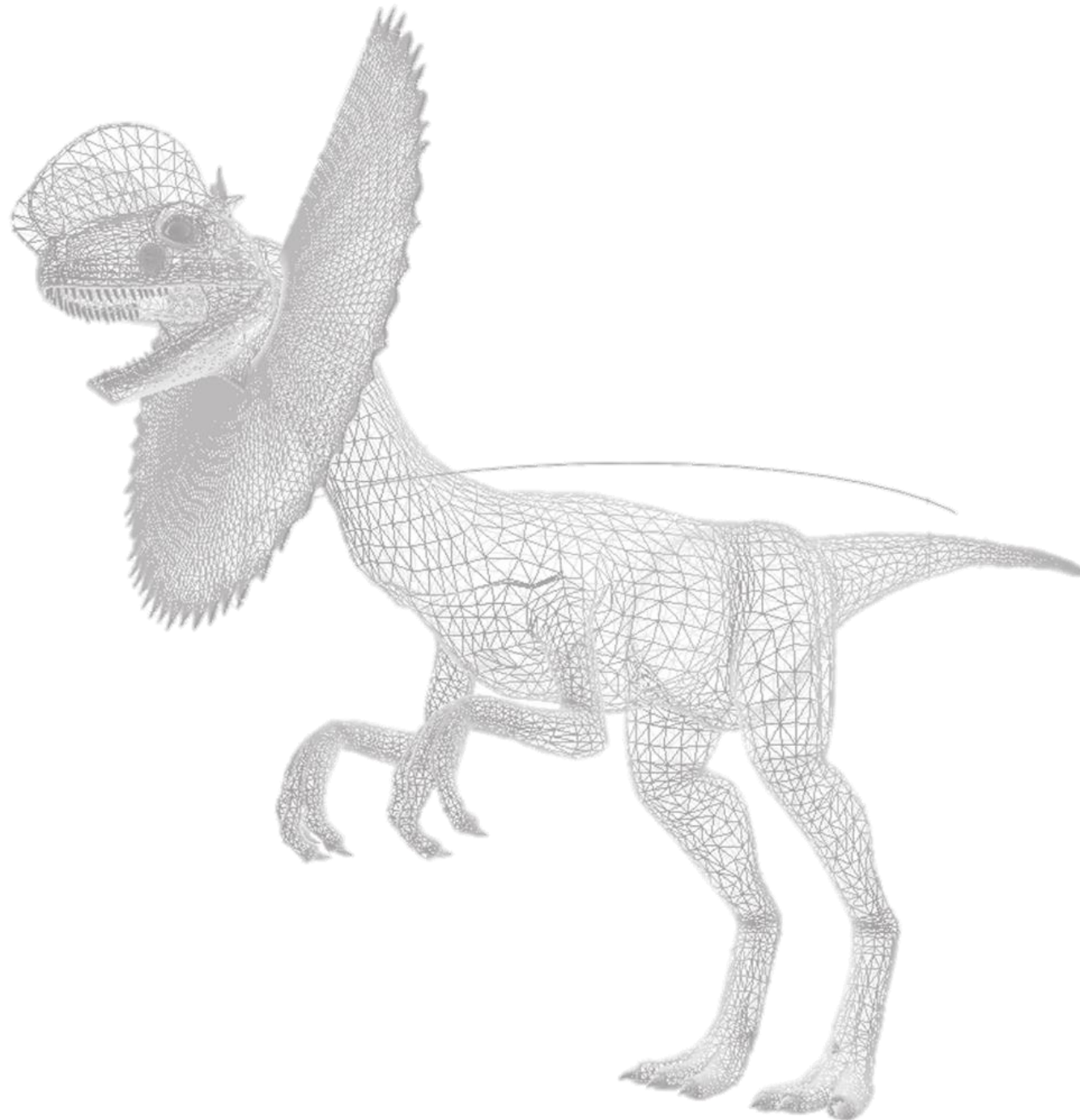
Composition of a Geometric Model



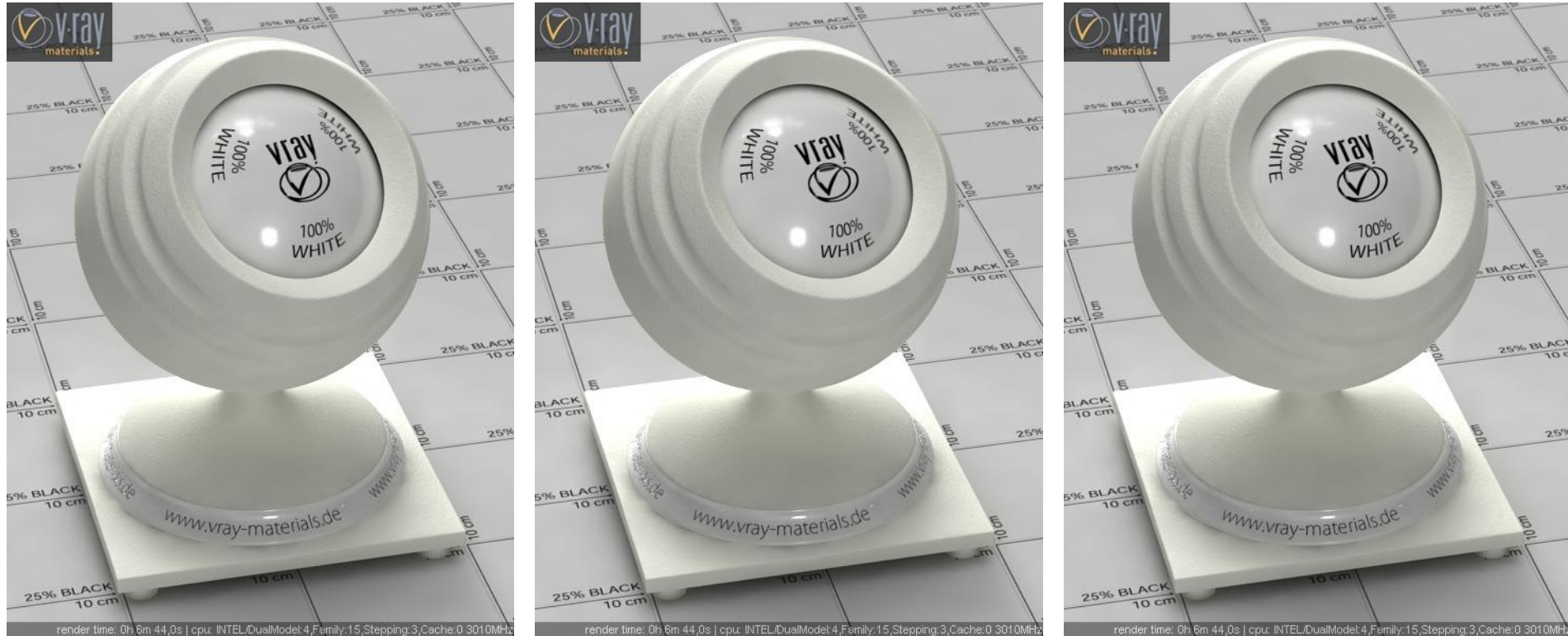
- Primitives created in decomposition process must be assembled to create final object. Done with **affine transformations**, T, R, S (as in above example). Order matters – these are not commutative!

Objects

- Objects consist of geometry + materials
- Geometry - typically a 3D Mesh
 - Approximates a continuous surface with a set of polygons (triangles + quads)
 - In offline rendering, we can also trace mathematical objects and volumes
- Material – describes how light interacts with the object

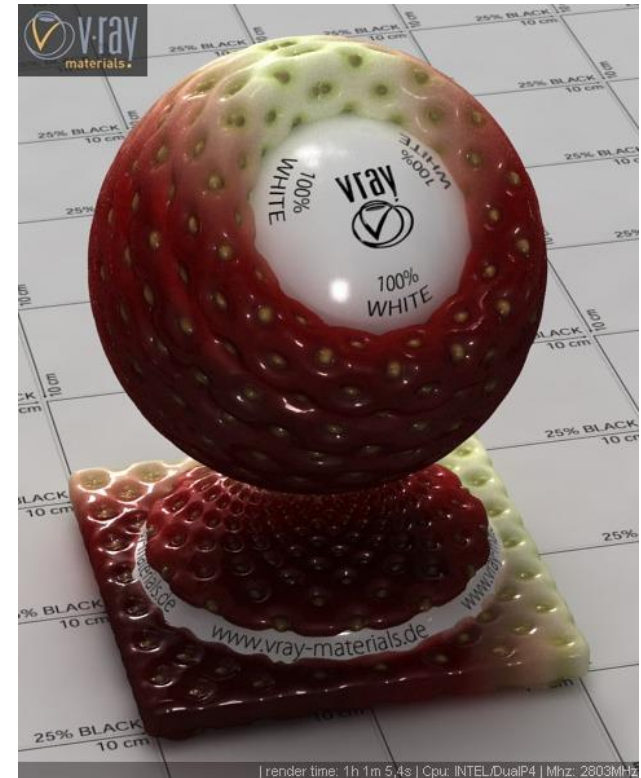


Μοντελοποίηση του υλικού



Identical Light Transport Algorithm, Geometry and Material descriptions

Μοντελοποίηση του υλικού



Identical Light Transport Algorithm and Geometry but different Material descriptions

Υλικά – ανακλαστικές ιδιότητες



specular material

diffuse material



Materials

Images from: <https://3dcoat.com/pbr/>

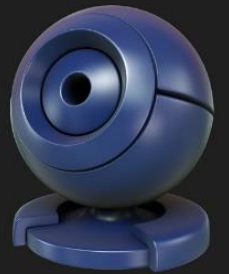
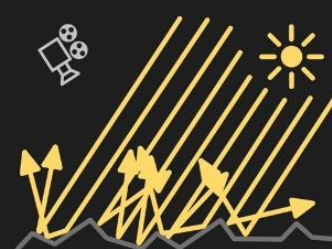
ALBEDO



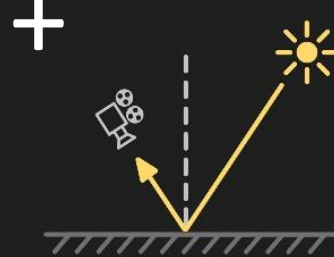
DIFFUSE



ROUGHNESS



SPECULAR



roughness intensity

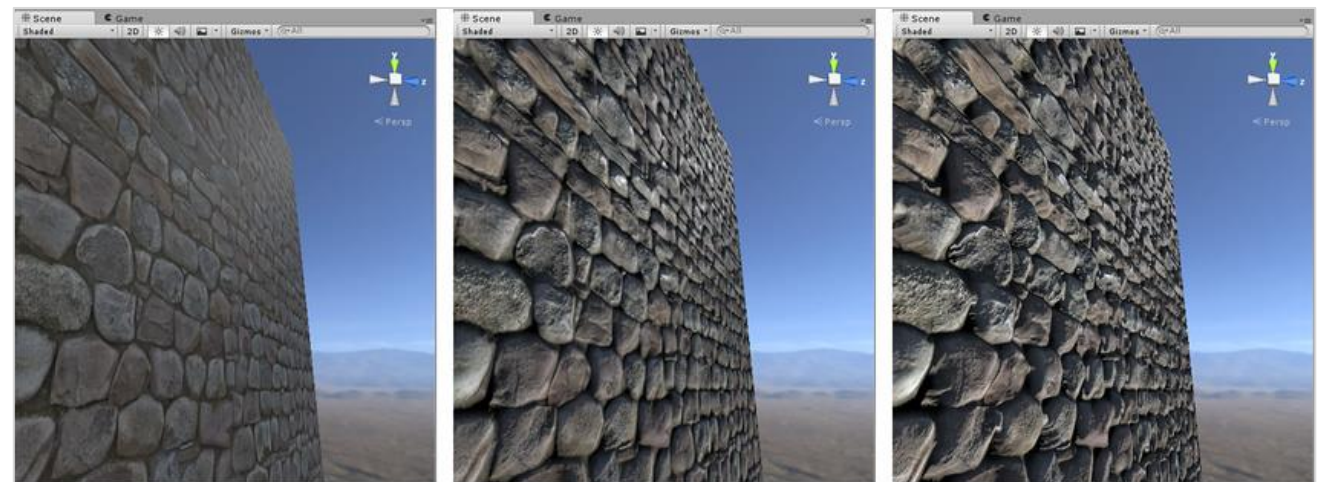
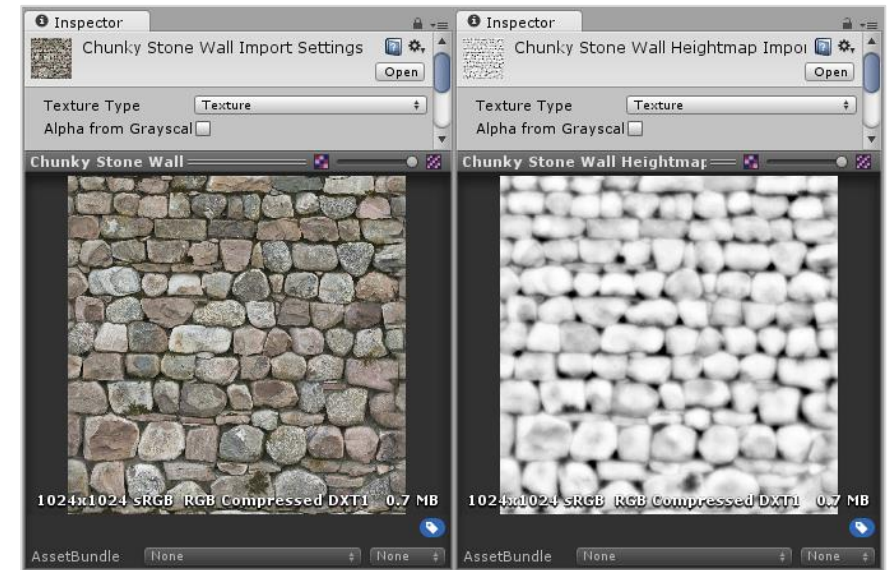
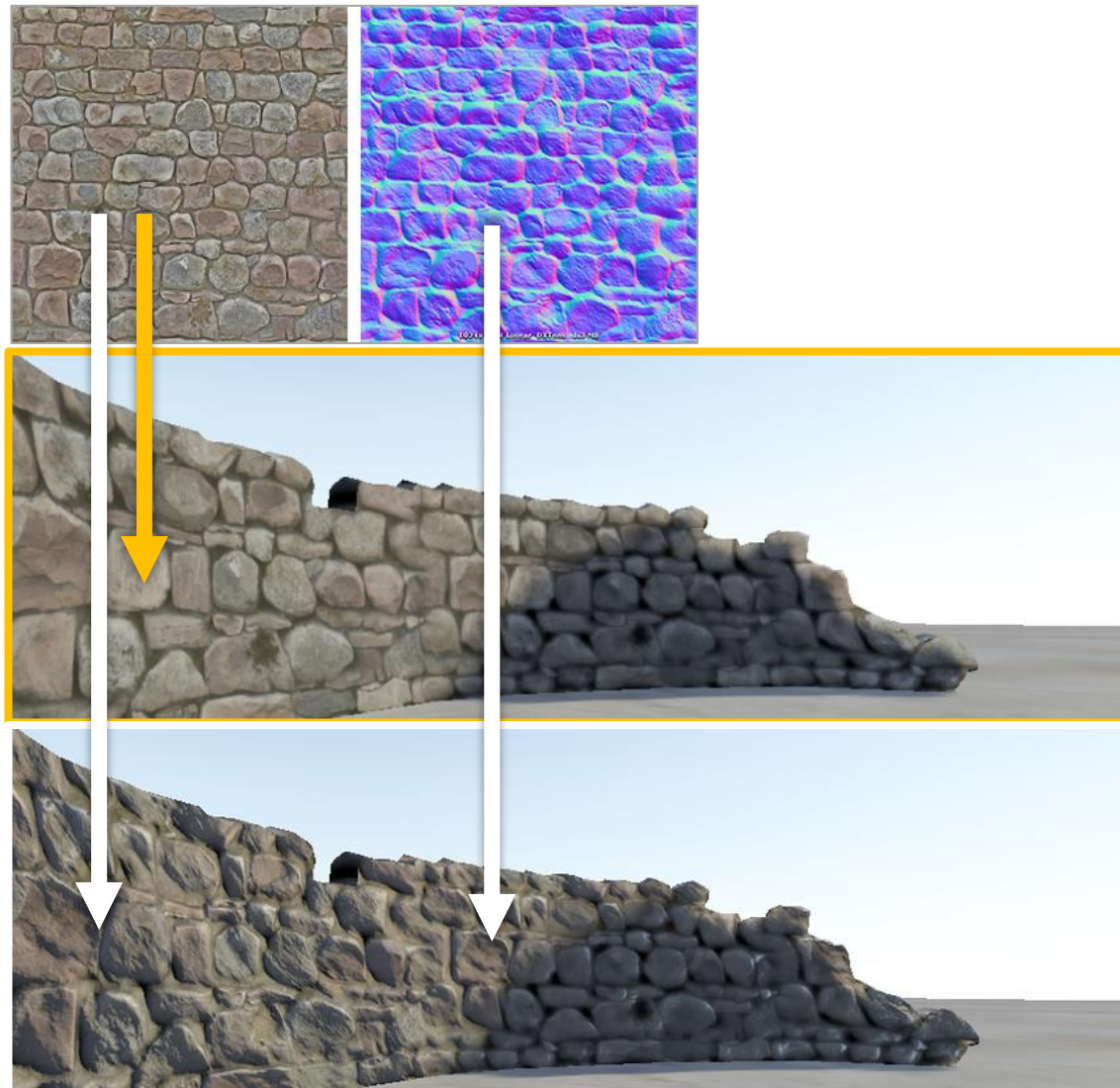
DIELECTRICS



METALS



Materials: Roughness without the geometry

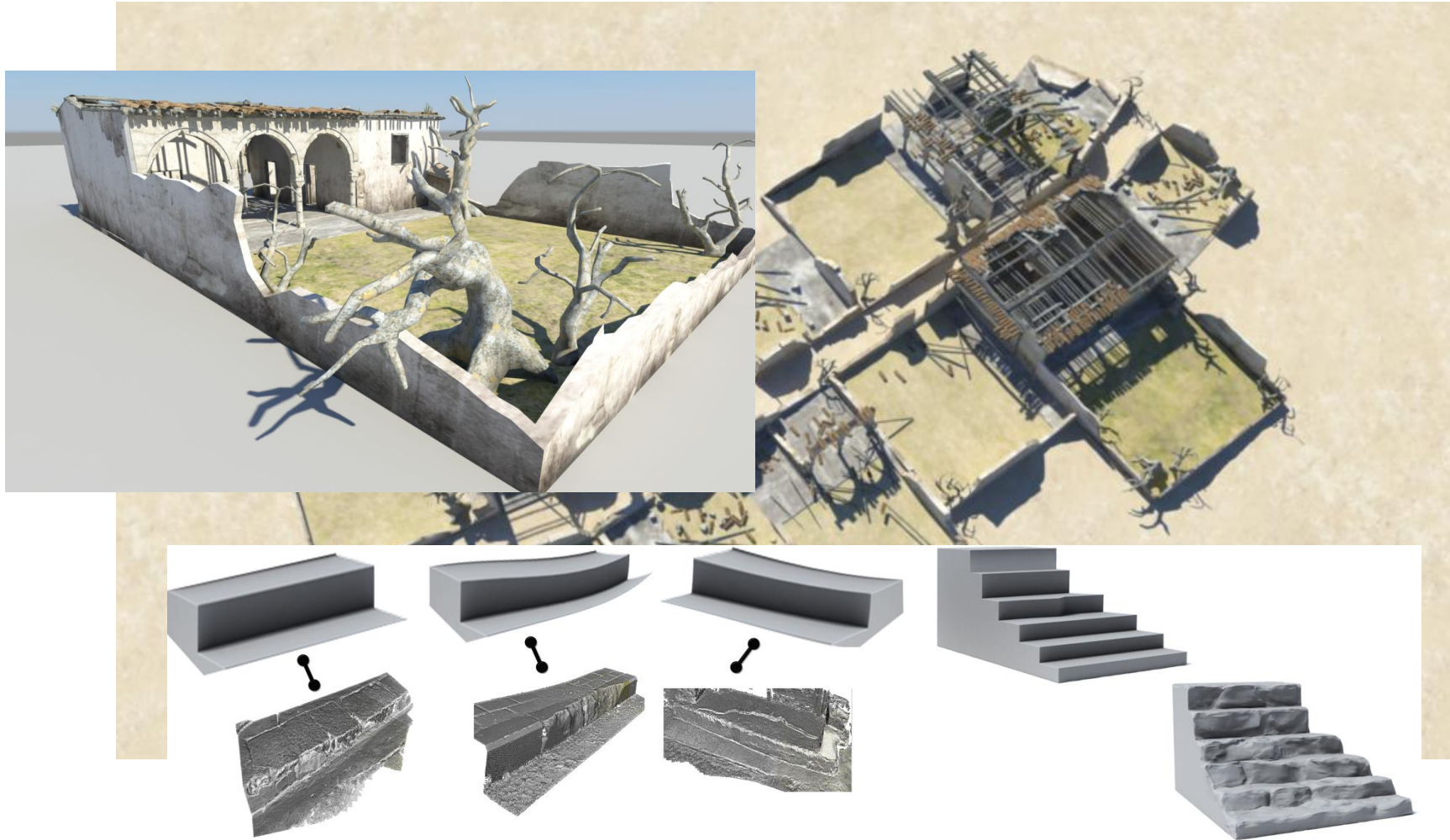


Materials

Your imagination is the limit



Materials: *Aging*



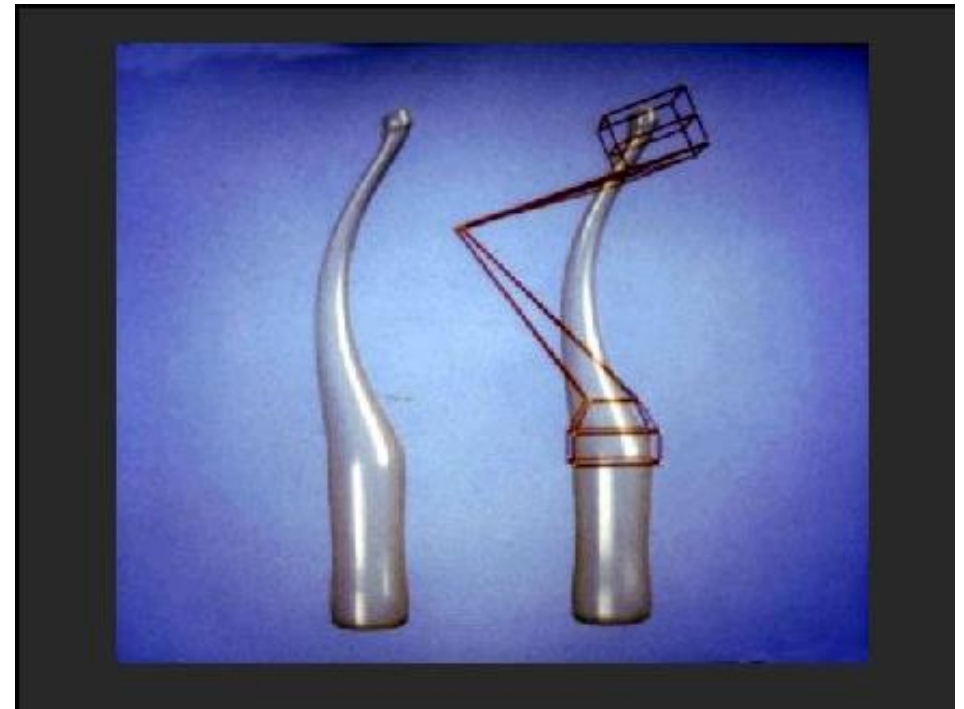
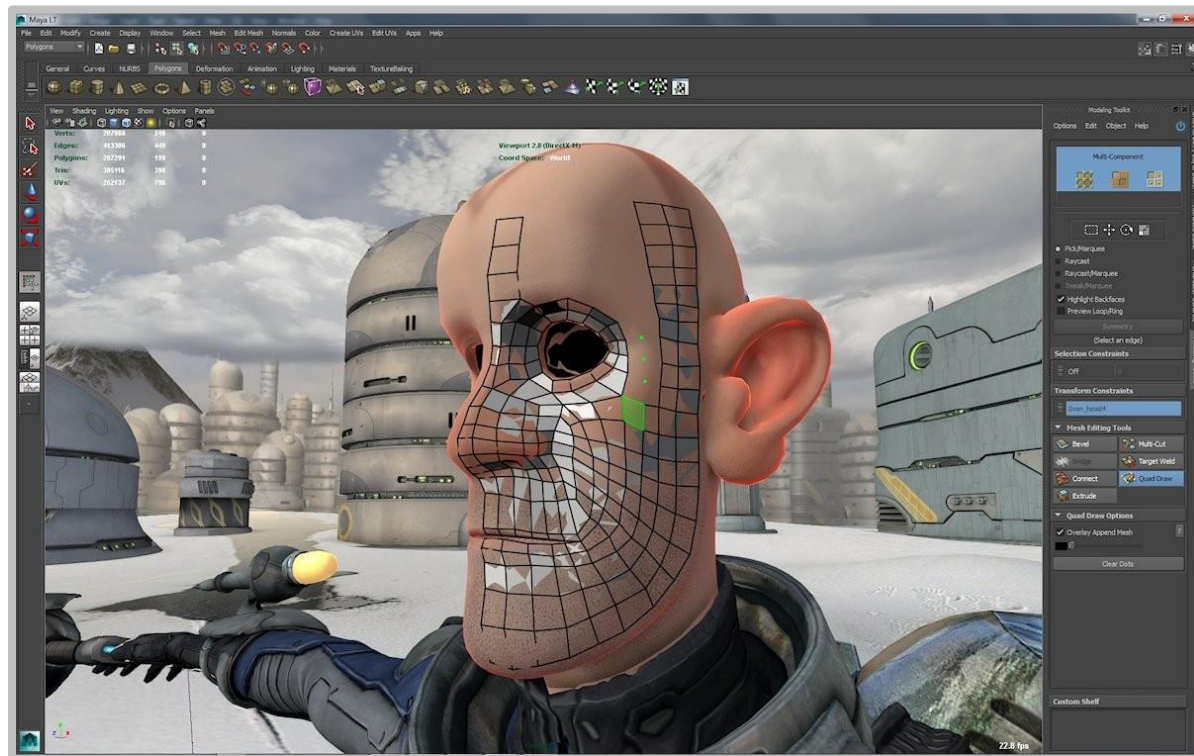
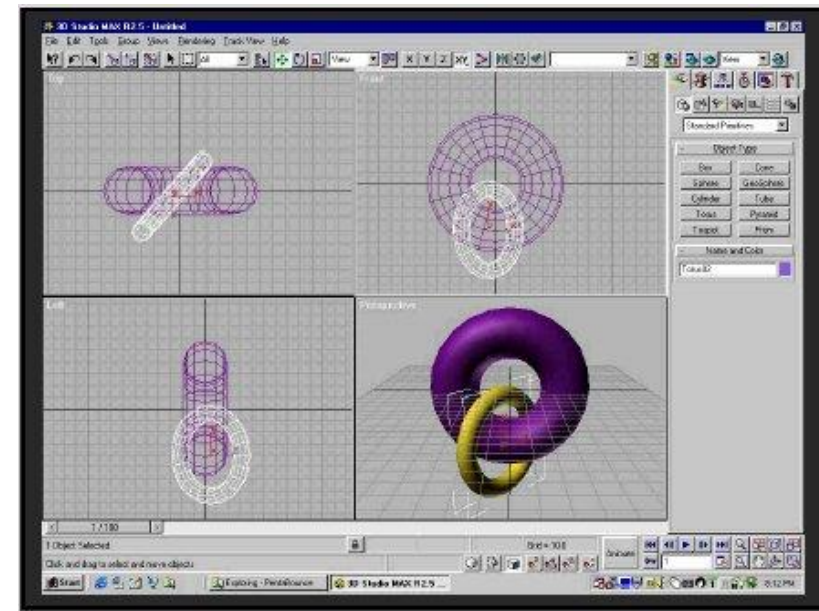
Μέθοδοι μοντελοποίησης

- Model library



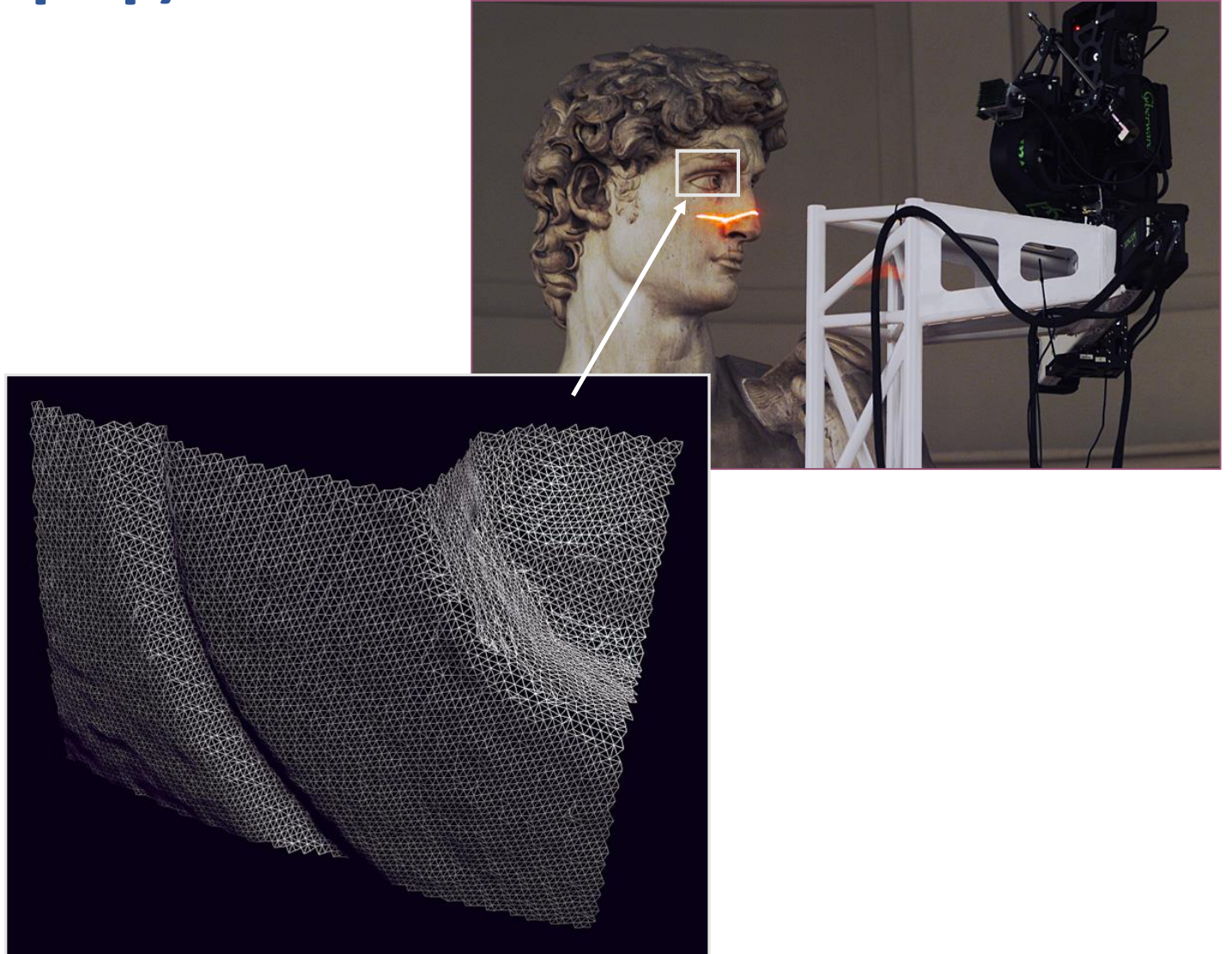
Μέθοδοι μοντελοποίησης

- Model library
- **Modeling software**



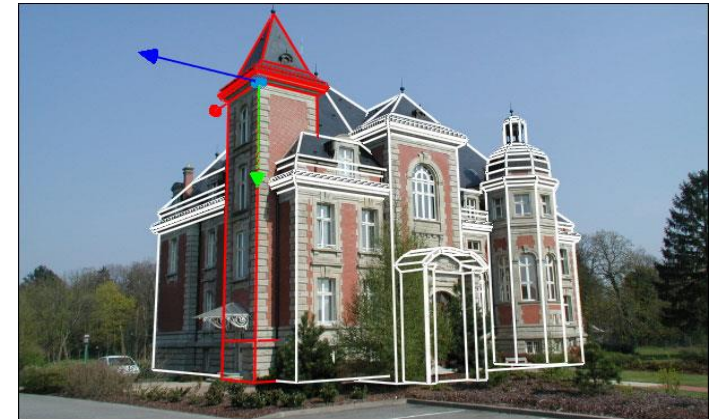
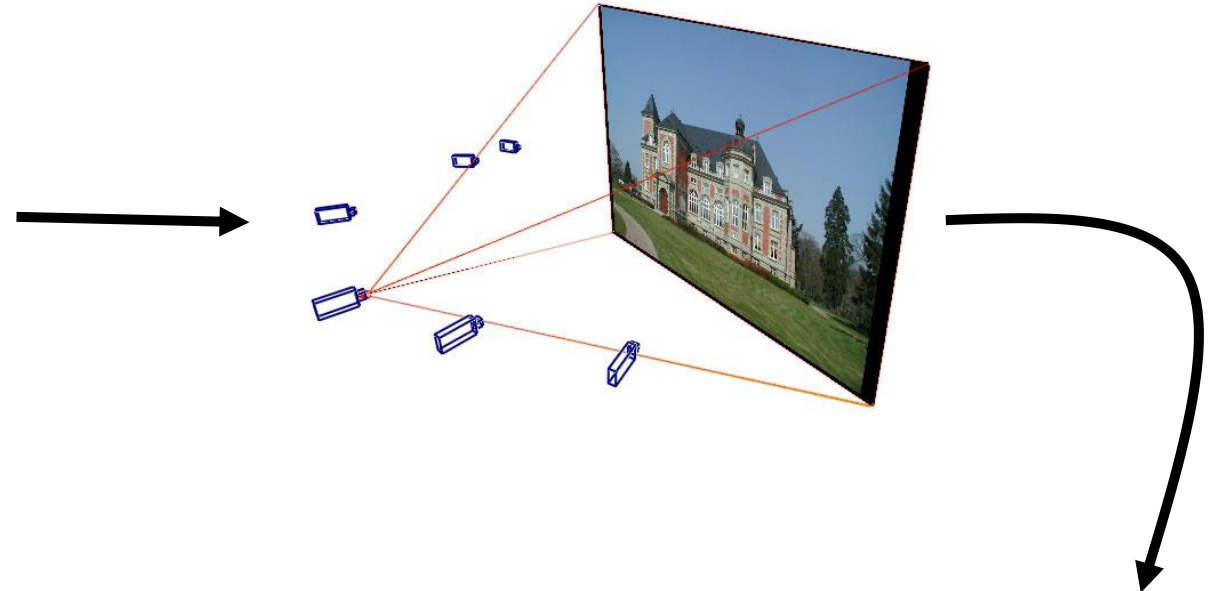
Μέθοδοι μοντελοποίησης

- Model library
- Modeling software
- **3D scanner**



Μέθοδοι μοντελοποίησης

- Model library
- Modeling software
- 3D scanner
- **Image based modeling**

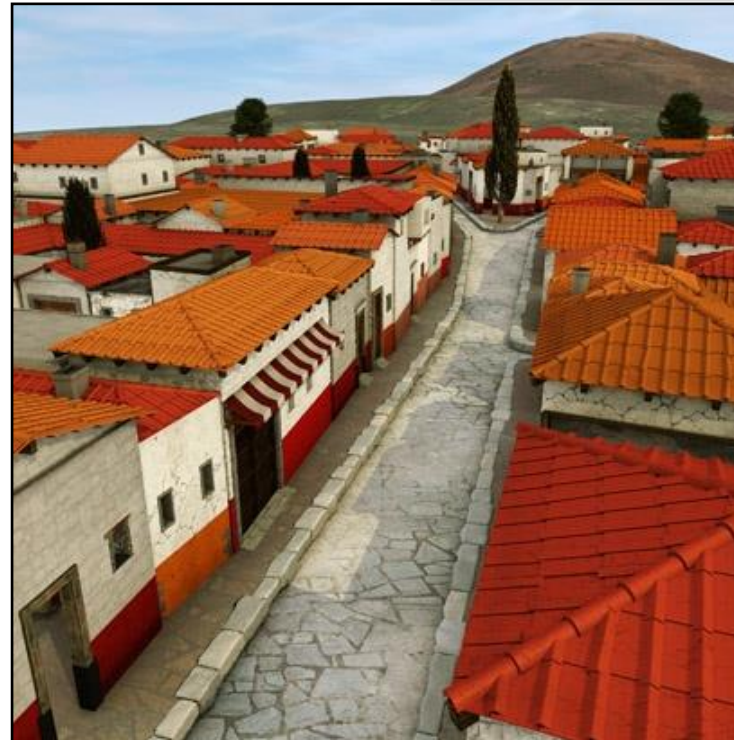
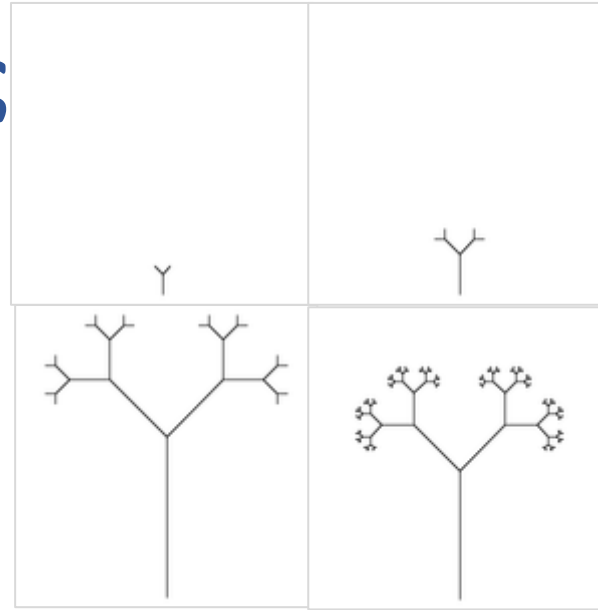


Paphos Gate



Μέθοδοι μοντελοποίησης

- Model library
- Modeling software
- 3D scanner
- Image based modeling
- **Procedural**



Virtual Pompeii

<https://youtu.be/dQs9h3YurOk>

Procedural modeling (using Esri's CityEngine)

- Use CGA shape grammar
- A set of rules that describe recursively the shape and details of the buildings

1: fac $\leadsto$ Subdiv("Y",3.5,0.3,3,3,3){ floor | ledge | floor | floor | floor }

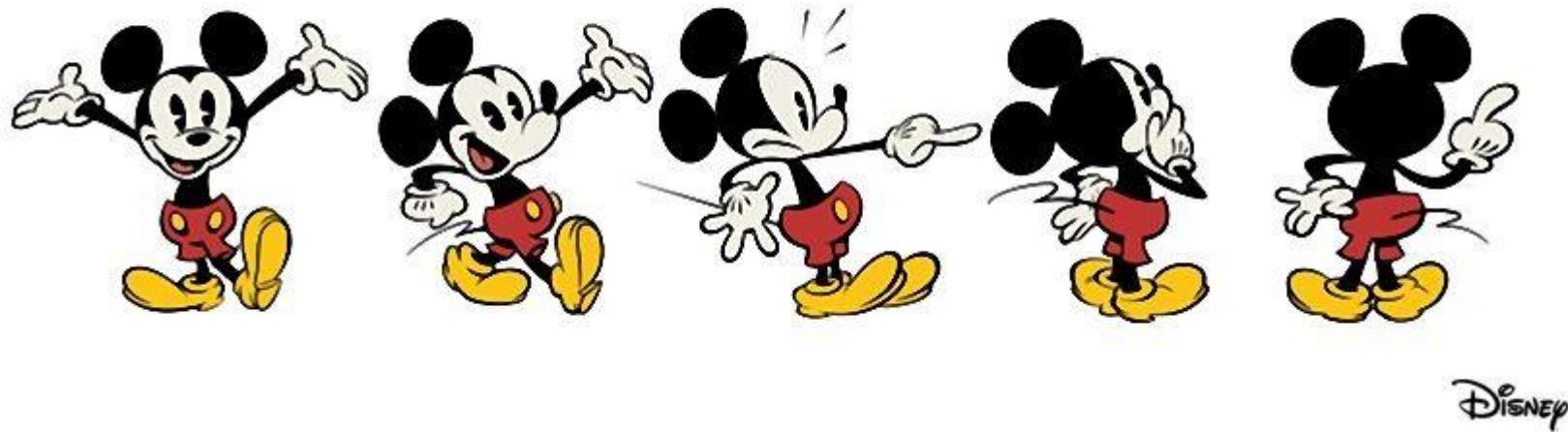


B	A	A	B	} floor	3.0m
B	A	A	B	} floor	3.0m
B	A	A	B	} floor	3.0m
				} ledge	30cm
B	A	A		} floor	3.5m

Procedural modeling

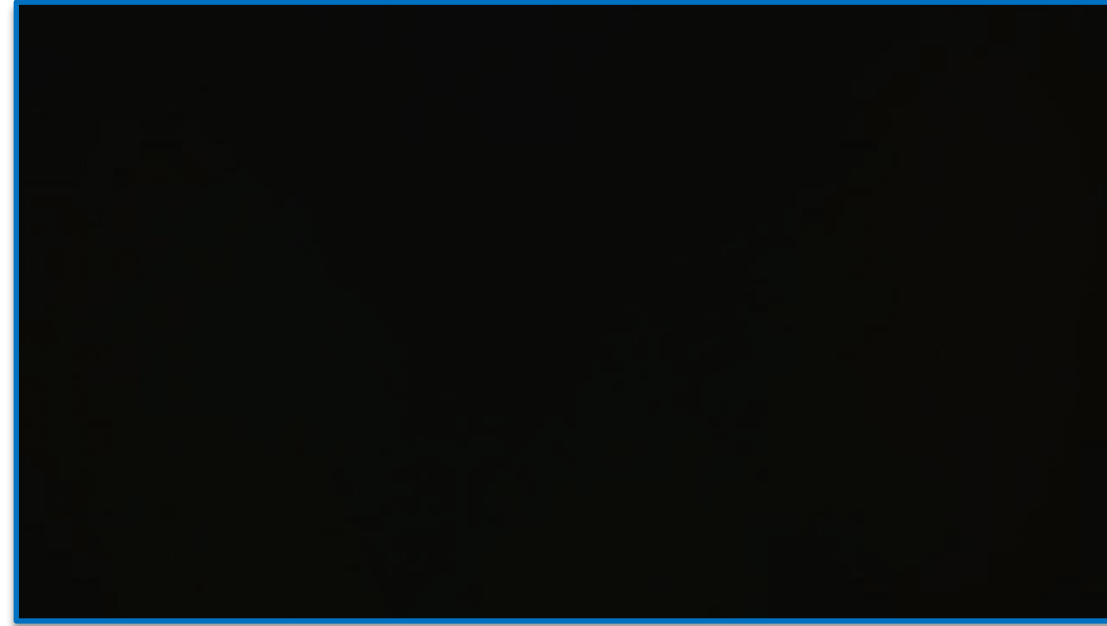


Κινησιογραφία/Animation

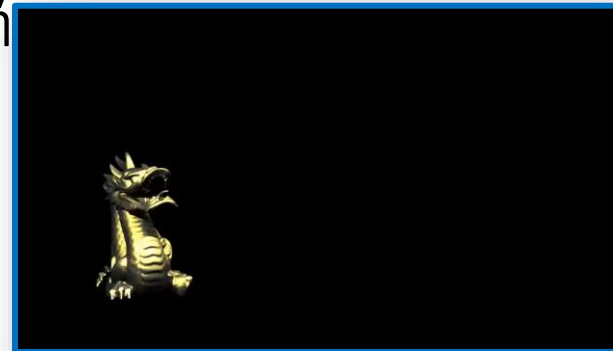


Animation

- Μπορούμε να δώσουμε ζωή σε εικονικούς χαρακτήρες
- Υπάρχουν πολλές εφαρμογές που απαιτούν κίνηση χαρακτήρων ή αντικειμένων
 - Ψυχαγωγία (e.g., ταινίες, παιχνίδια)
 - Εικονική και αυξημένη πραγματικότητα
 - Για συστήματα εκπαίδευσης, και προσομοίωσης
- Άλλες μορφές για animation;
 - Δέντρα, υγρά, φωτιά, ζώα, σύννεφα, κτλ.
- Άλλοι σημαντικοί παράγοντες για την παραγωγή animation
 - Φωτισμός, Εικονική απόδοση (rendering), etc.



© Pixar Animation



Character Animation

- Μπορεί να χωριστεί σε 3 κατηγορίες:
 - **Κίνηση του σκελετού** – κίνηση στα κύρια μέρη του κορμιού.



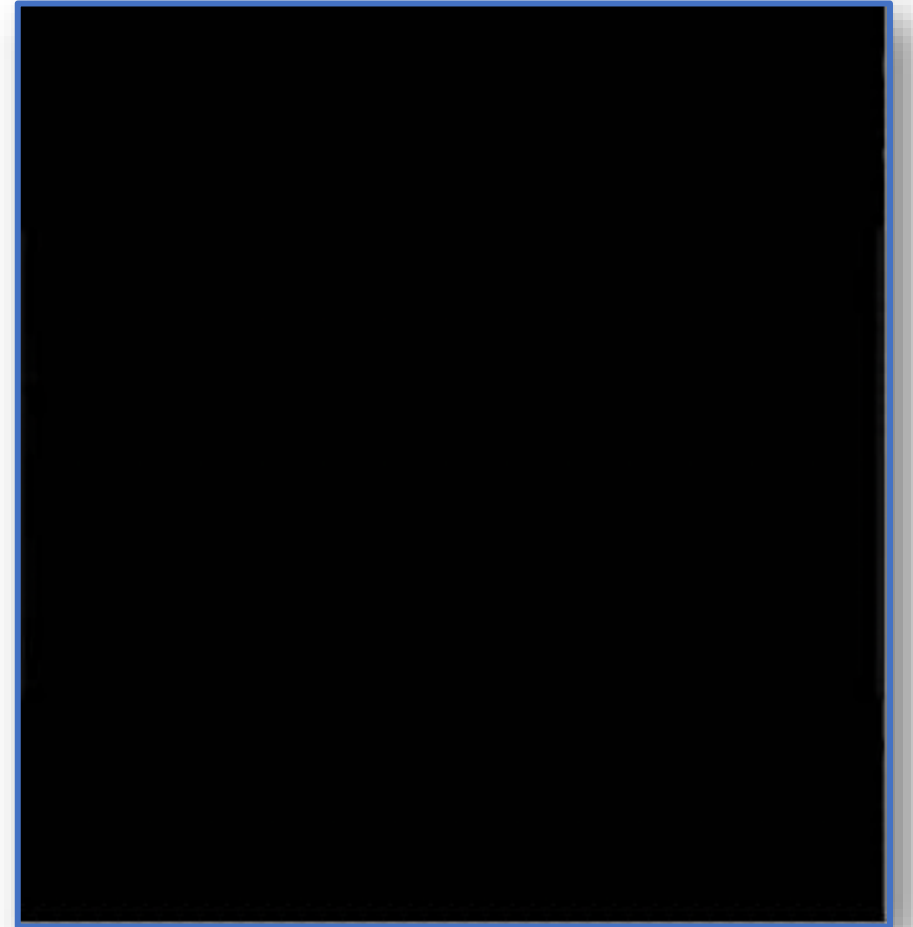
Character Animation

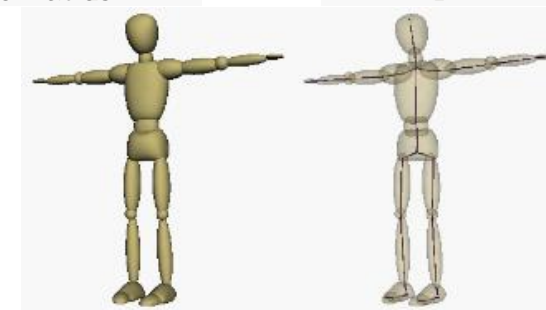
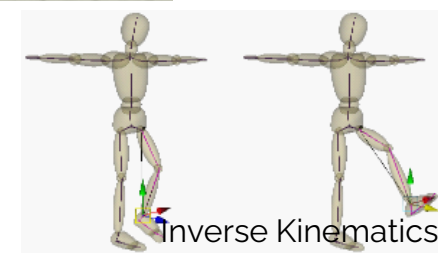
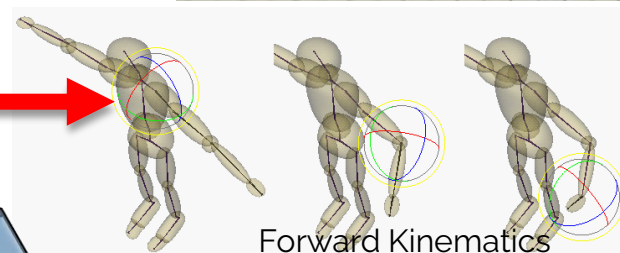
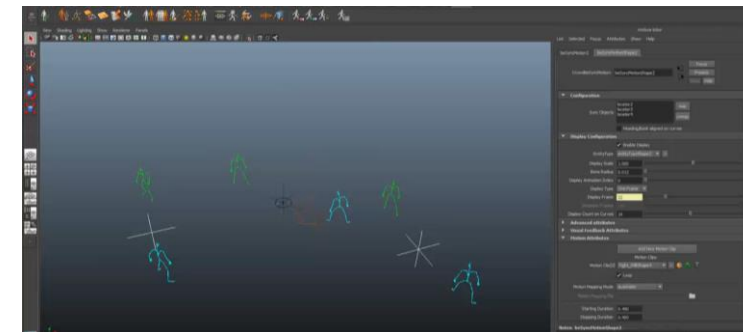
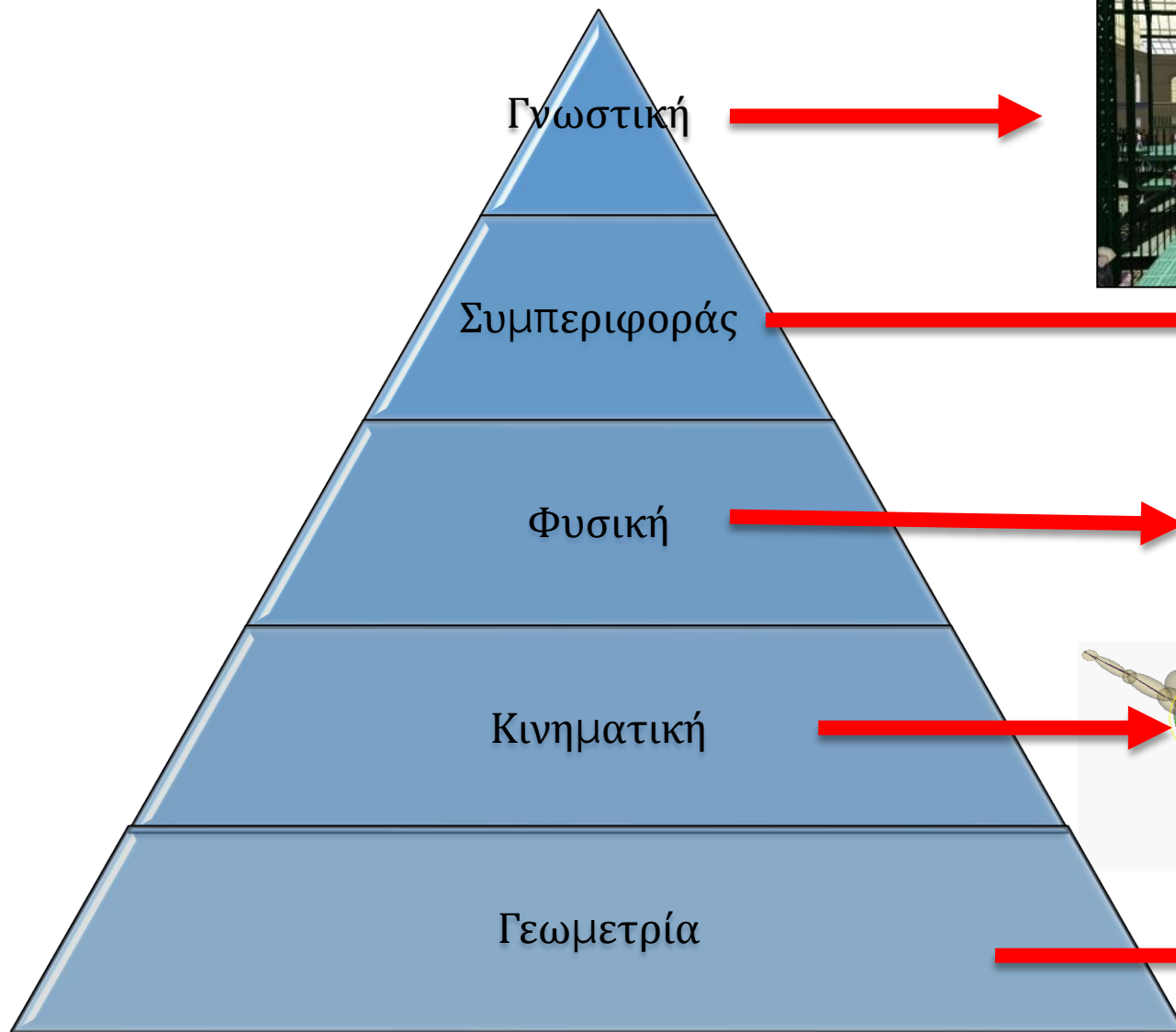
- Μπορεί να χωριστεί σε 3 κατηγορίες:
 - **Κίνηση του σκελετού** – κίνηση στα κύρια μέρη του κορμιού.
 - **Κίνηση προσώπου** – κίνηση στα κύρια χαρακτηριστικά του προσώπου.

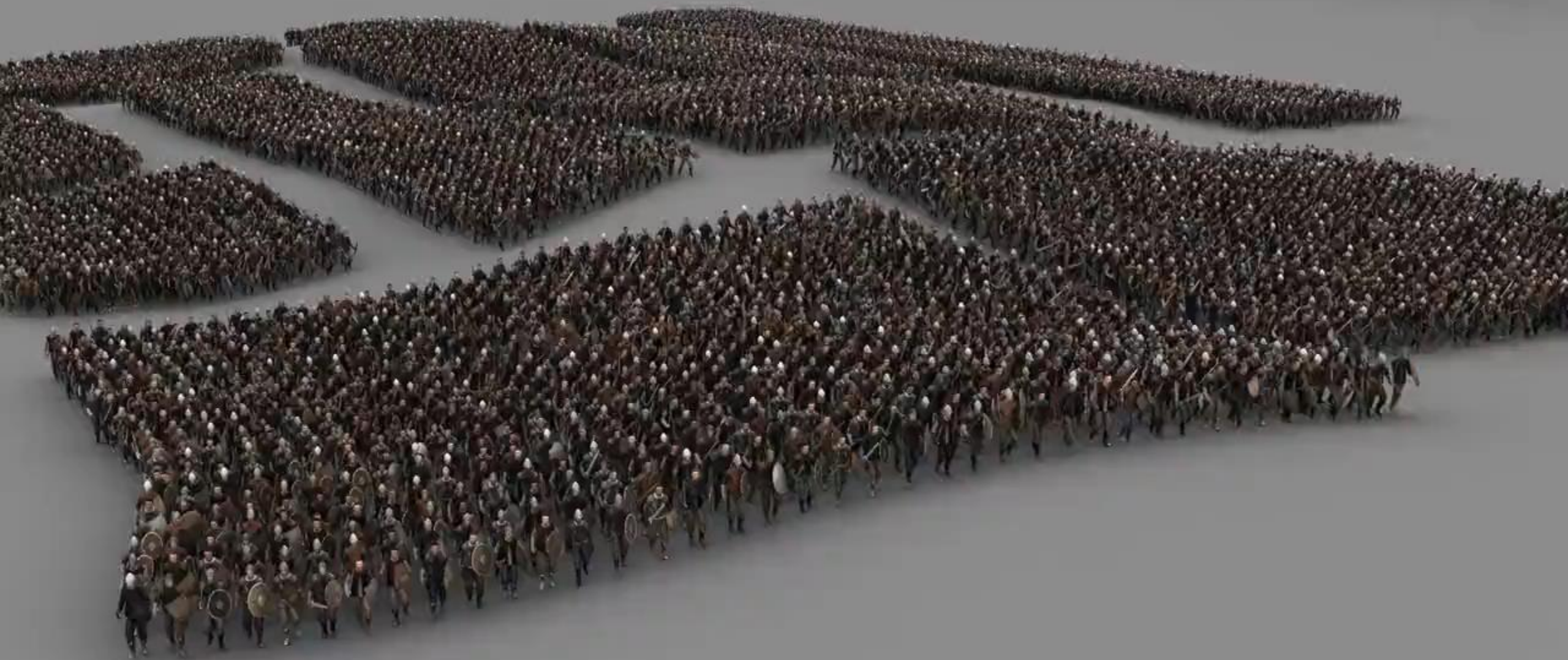


Character Animation

- Μπορεί να χωριστεί σε 3 κατηγορίες:
 - **Κίνηση του σκελετού** – κίνηση στα κύρια μέρη του κορμιού.
 - **Κίνηση προσώπου** – κίνηση στα κύρια χαρακτηριστικά του προσώπου.
 - **Κίνηση των μαλλιών, του δέρματος, και των ρούχων**







Συμπεριφορά σε πλήθος



FRAMESTORE



Animation: *Εισαγωγή*

- Ποιος είναι ο πιο κοινός τρόπος για να δημιουργήσουμε κινούμενους χαρακτήρες;

Animation: *Animated Manually: key-framing*



Flipbook Animation



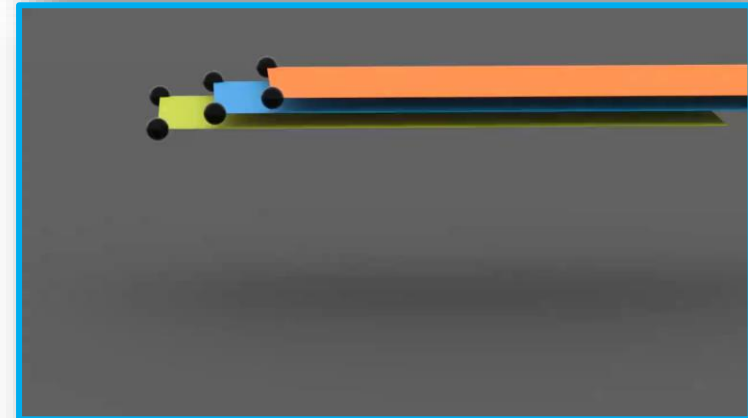
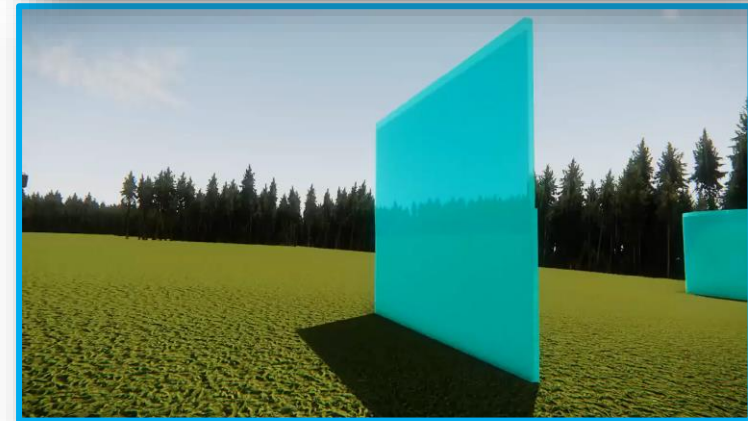
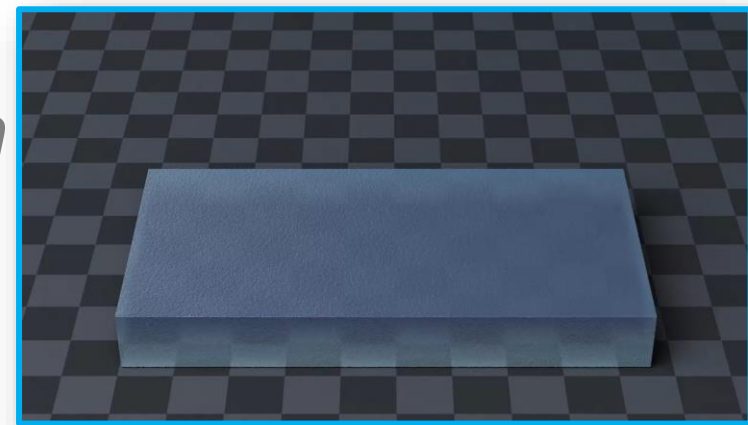
@ Disney Studios

Animation: *Animated Manually: key-framing*

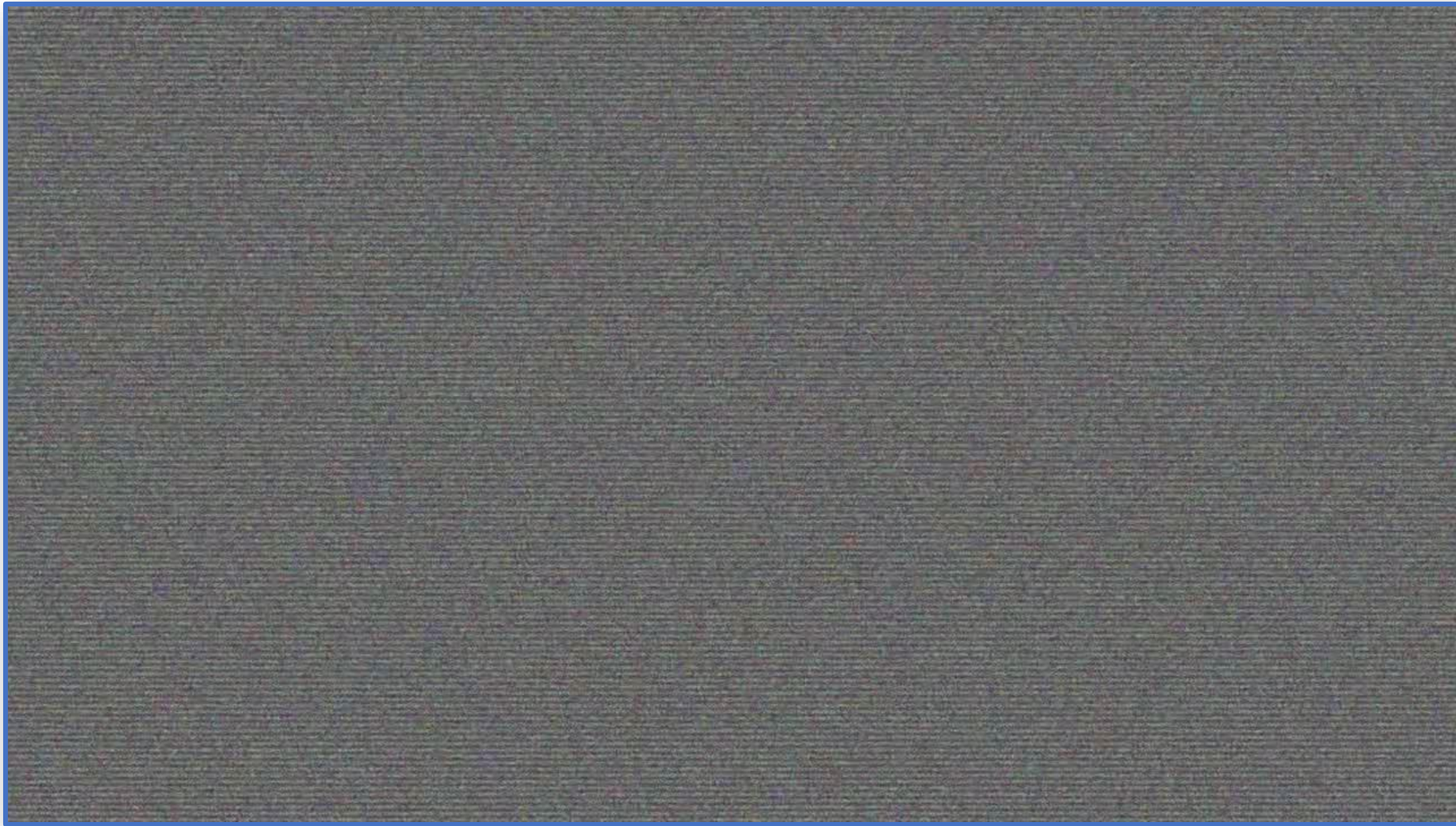


Character Animation: *Φυσική προσομοίωση*

We present a control system based on 3D muscle actuation



Character Animation: *Motion Capture*



Character Animation: *Motion Capture*



Image courtesy of Naughty Dog.



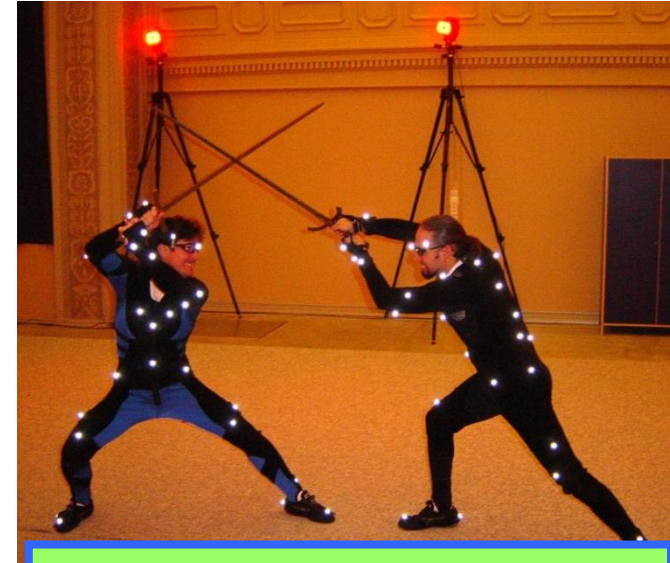


Animation

Το πιο δύσκολο είναι το animation χαρακτήρων



Animated Manually



Motion Captured



Synthesize in some Manner

3. Απόδοση / Rendering



Modelling Vs Rendering

■ Modeling

- Create models
- Apply materials to models
- Place models around scene
- Place lights in scene
- Place the camera

■ Rendering

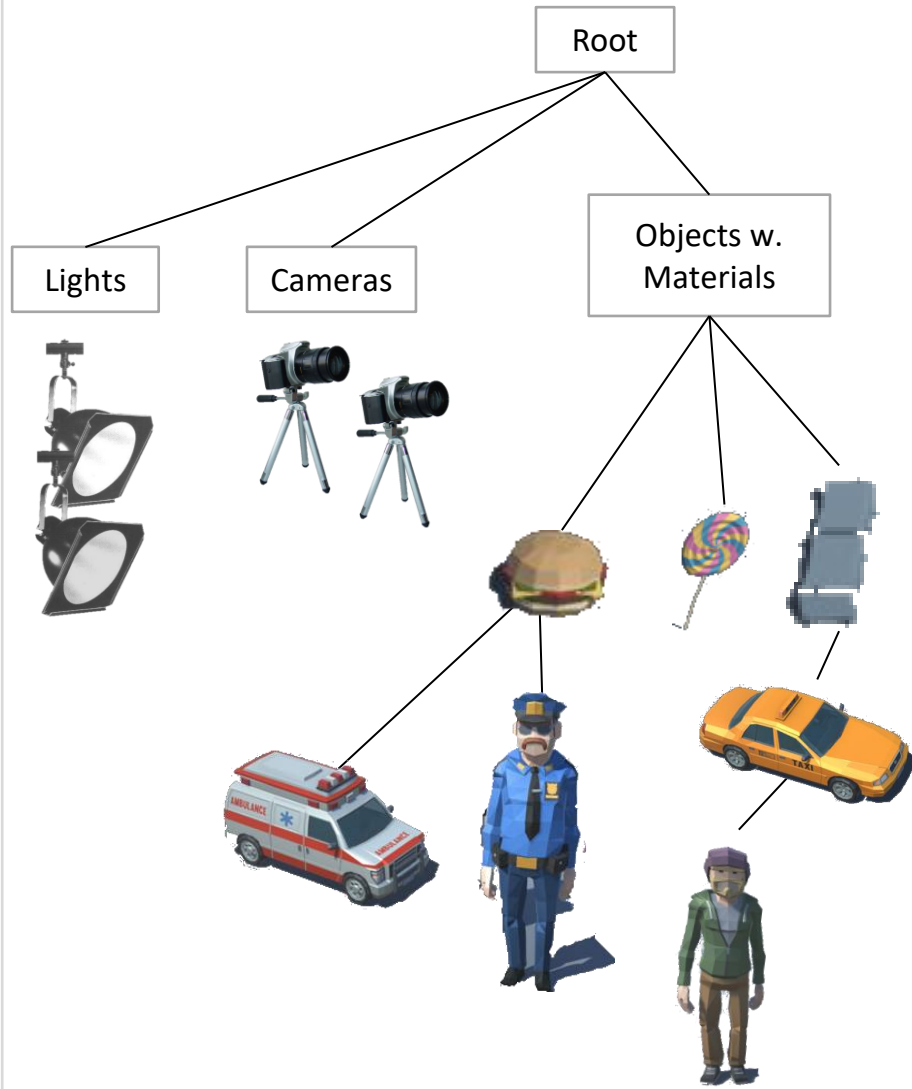
- Take “picture” with camera
- ▶ Both can be done with commercial software:
Autodesk Maya™, 3D Studio Max™, Blender™, etc.



CS128 lighting assignment by Patrick Doran, Spring 2009

Computer Graphics

Scene Description



Rendering
Algorithm

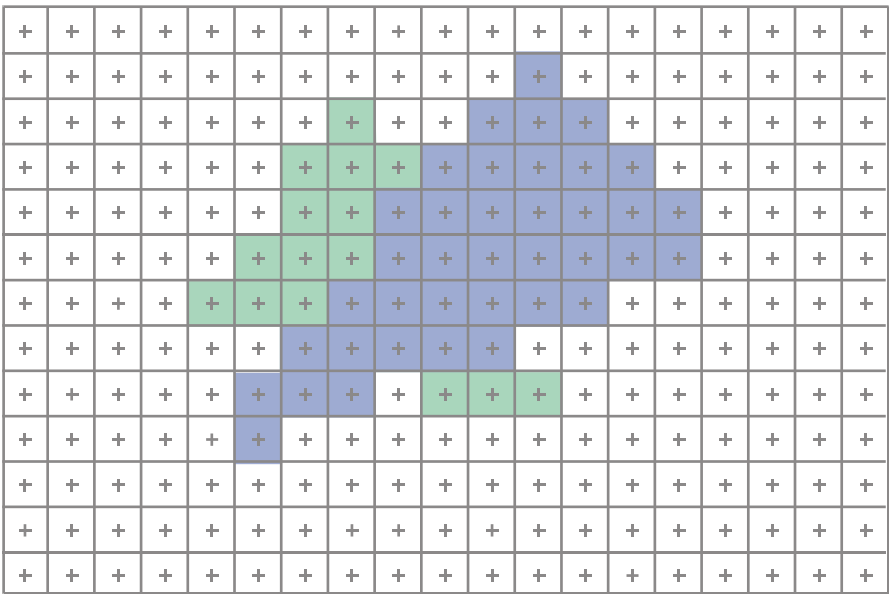
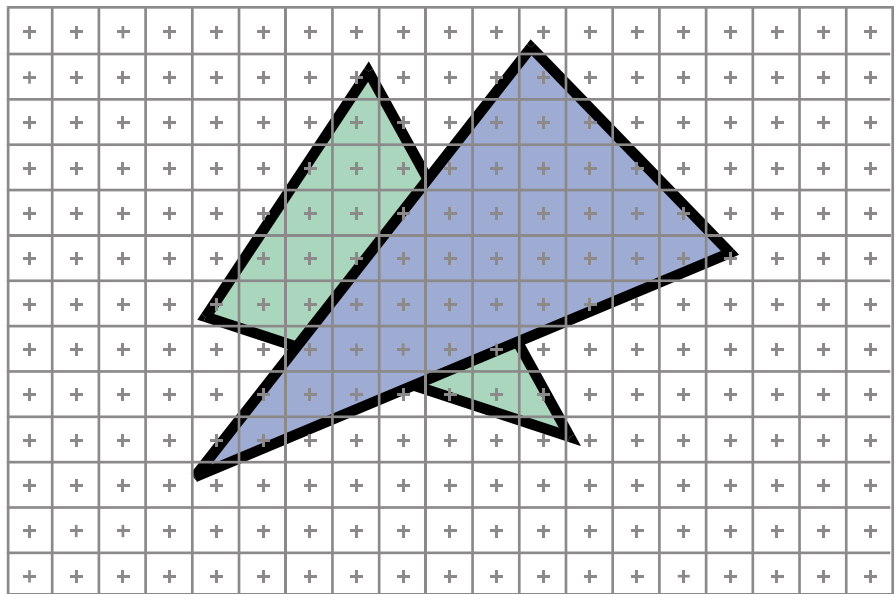
Image



Polygon City Pack for Unity

<https://www.assetstore.unity3d.com/en/#!/content/95214>

Τι είναι μια ψηφιακή εικόνα;

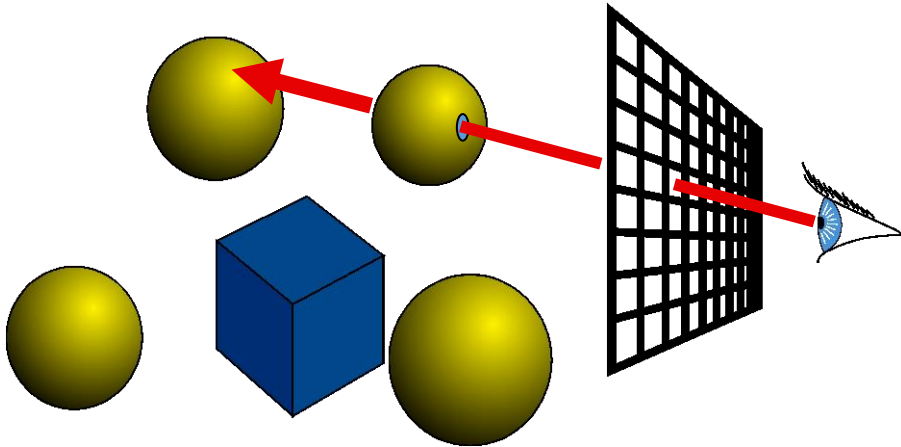


Δύο γενικές προσεγγίσεις για δημιουργία εικόνων

A. Ray Casting

- For each pixel
 - For each object

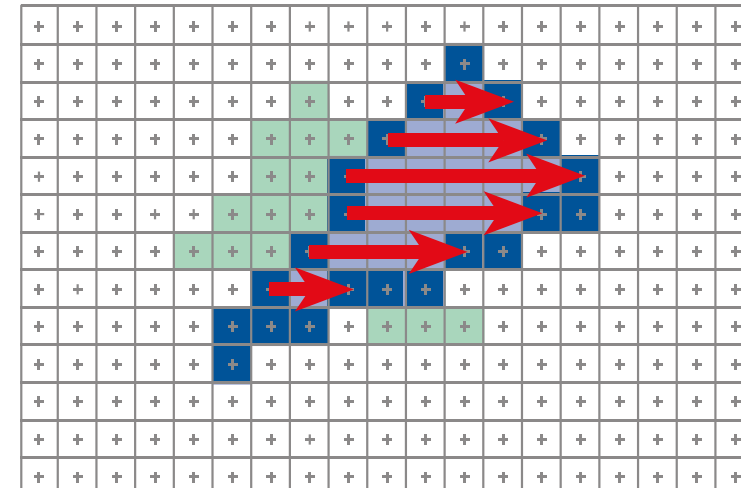
Send pixels to the scene



B. Rendering Pipeline

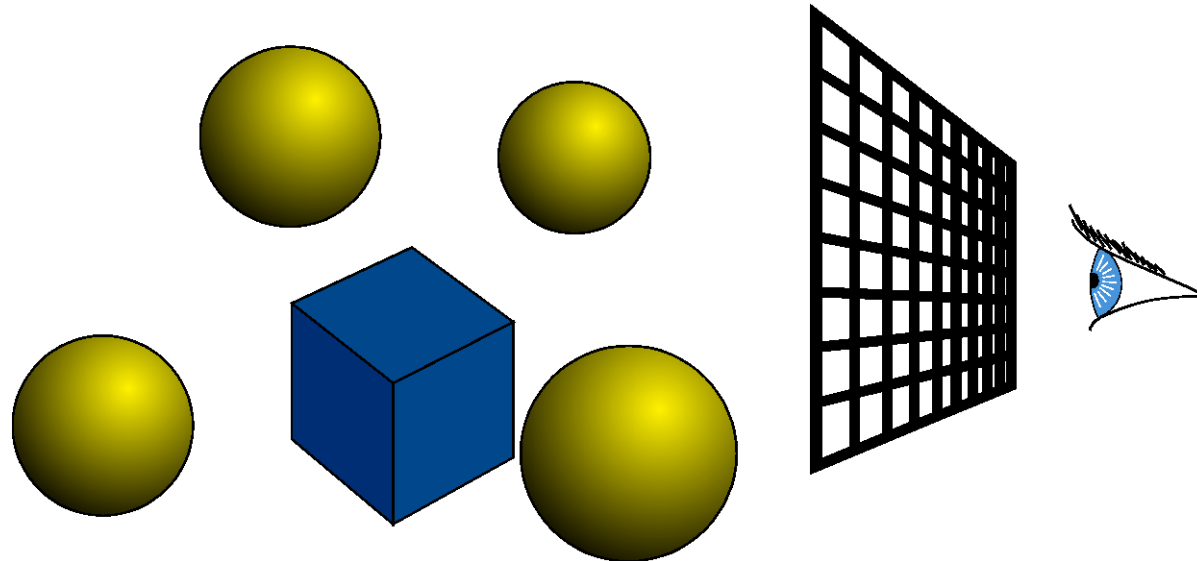
- For each triangle
 - For each projected pixel

Project scene to the pixels



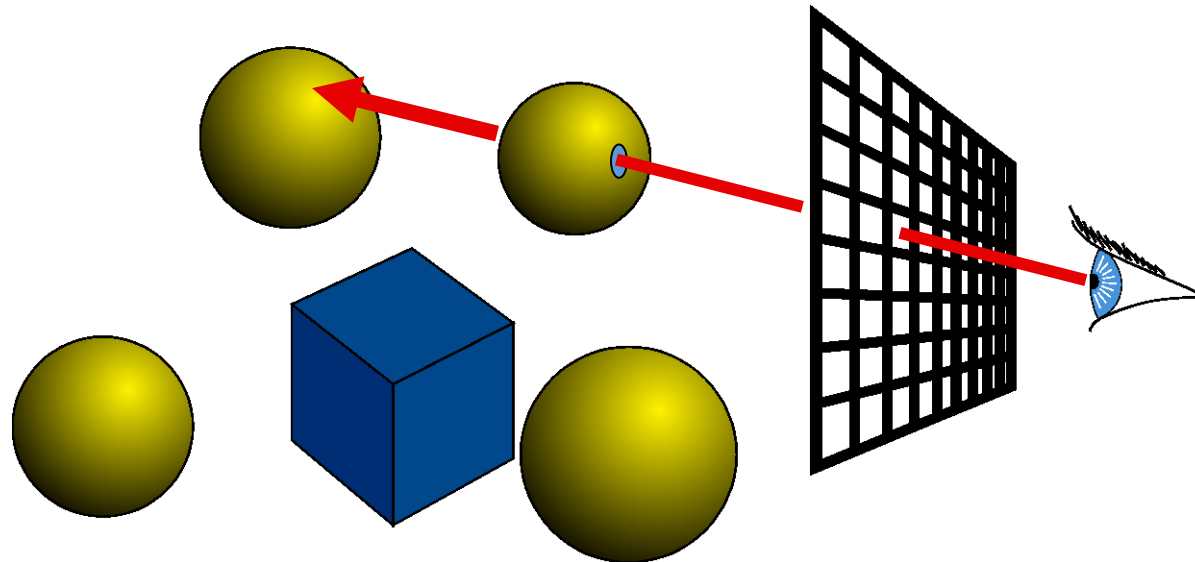
Βολή ακτίνας (Ray Casting)

- For every pixel
construct a ray from the eye
 - For every object in the scene
 - Find intersection with the ray
 - Keep if closest



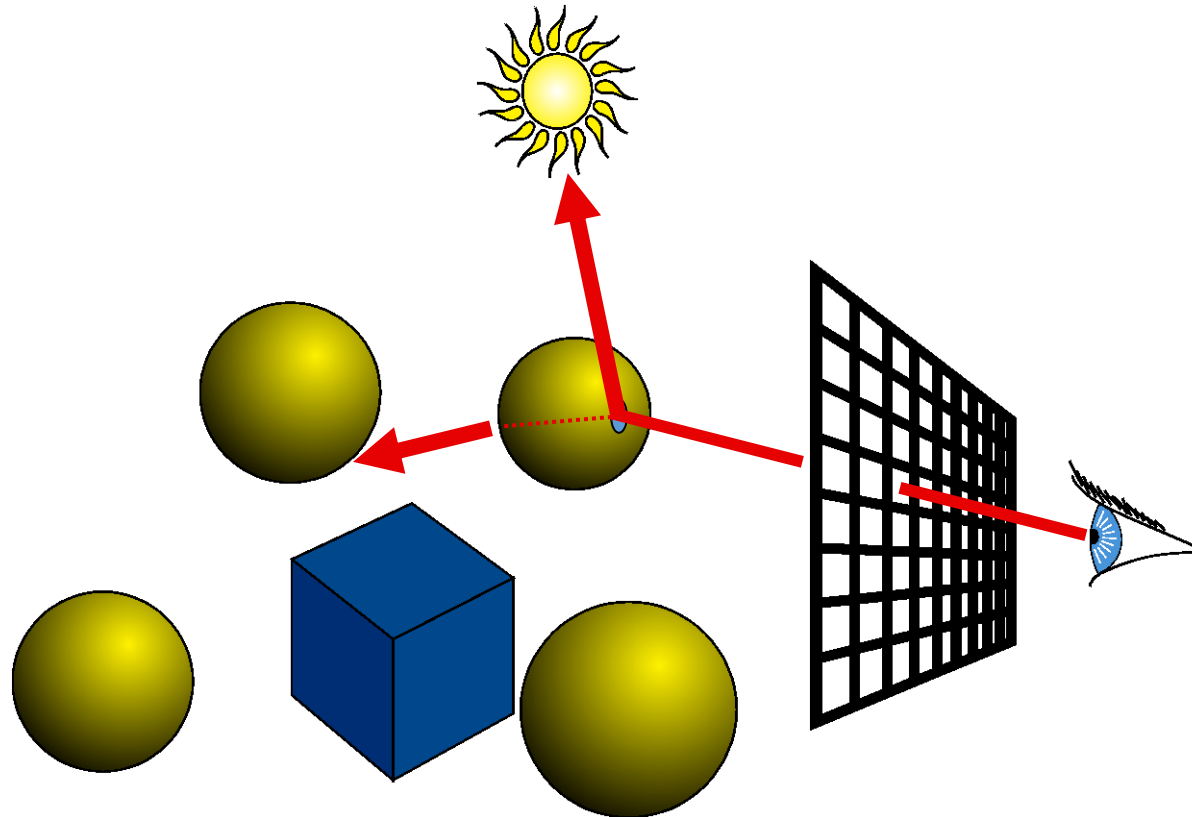
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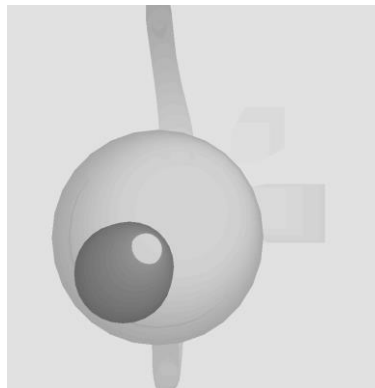
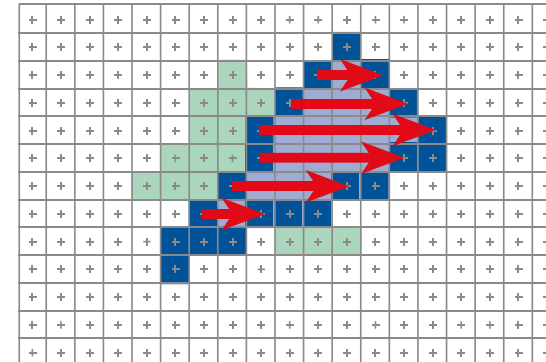
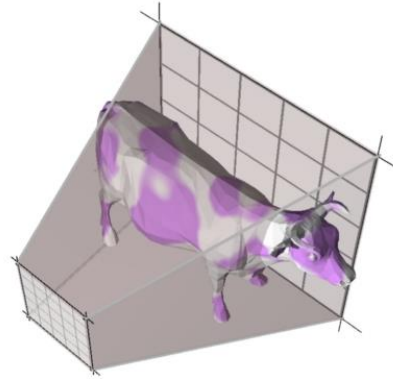
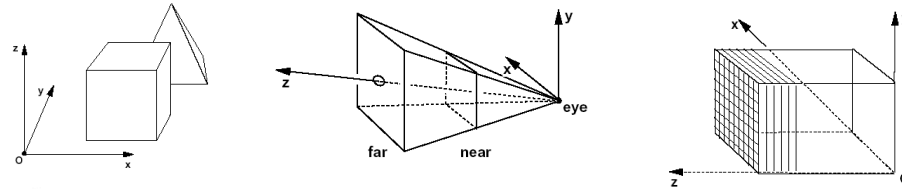
Βολή ακτίνας – παρακολούθηση ακτίνας

- Shade (interaction of light and material)
- Secondary rays (shadows, reflection, refraction)



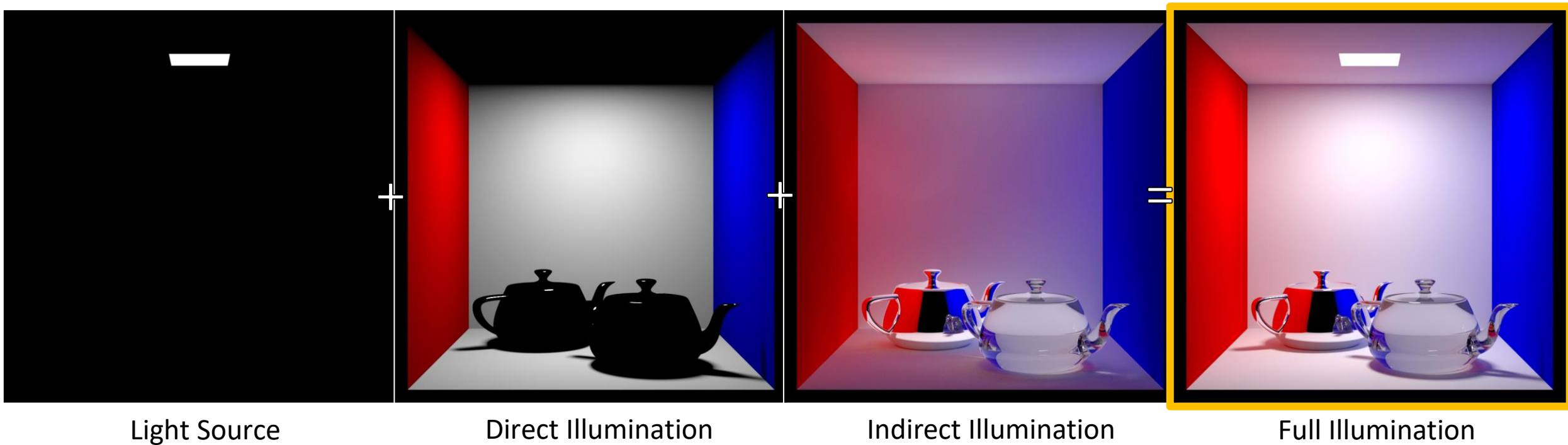
Γραφική σωλήνωση (Rendering Pipeline)

- Μετασχηματισμοί
- Αποκοπή
- Σάρωση
- Ορατότητα

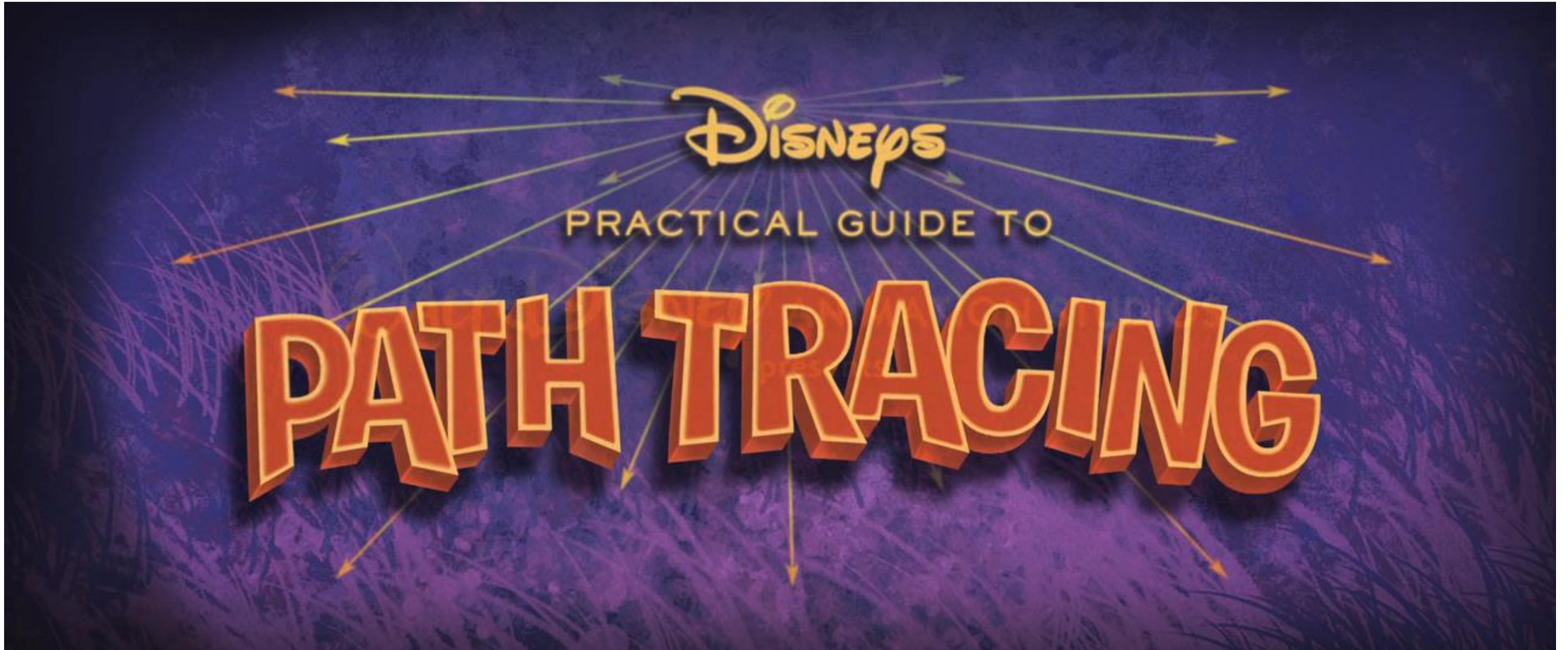


Φωτισμός – ίσως το πιο σημαντικό μέρος της διαδικασίας

Rendering algorithms split illumination in several parts

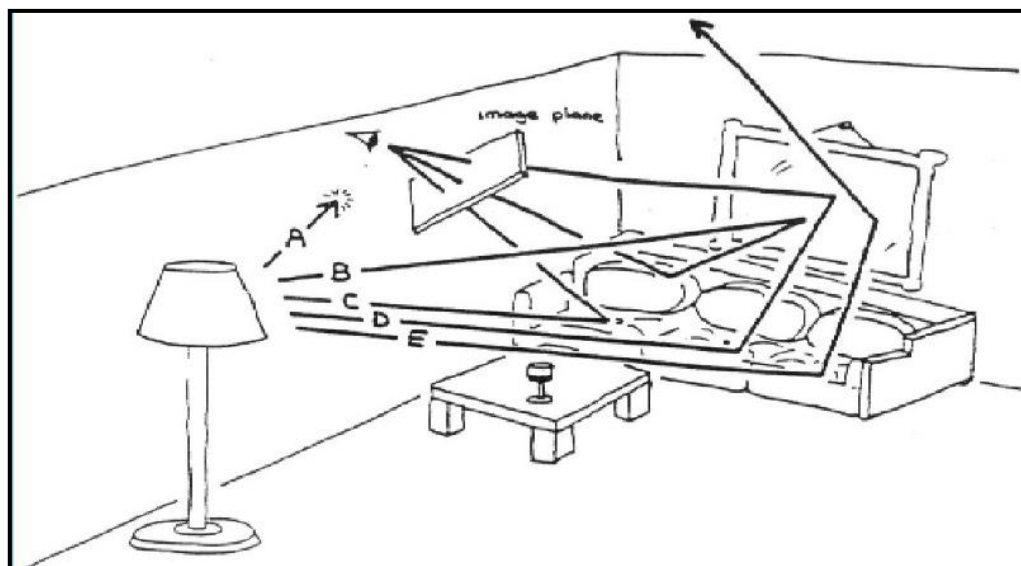


How Light works



https://youtu.be/frLwRLS_ZR0

Photorealism



The rendering equation

$$\begin{aligned}
 L(\mathbf{r}, \vec{\omega}, \lambda, \mathbf{e}, t) = & \mu(\mathbf{r}, \mathbf{s}) \left[L^e(\mathbf{s}, \vec{\omega}, t, \lambda) \right. \\
 & + m_p(\vec{\omega}) \int_{-\infty}^t d(t - \tau) P_p(\mathbf{s}, \lambda) \int_{\Theta_i^t} L(\mathbf{s}, \vec{\omega}', \lambda, \mathbf{e}, \tau) \cos \theta' d\vec{\omega}' d\tau \\
 & \left. + \int_{\Theta_i^t} f(\mathbf{s}, \lambda, \vec{\omega}' \rightarrow \vec{\omega}) \int_{\mathcal{R}_v} P_f(\mathbf{s}, \lambda' \rightarrow \lambda) L(\mathbf{s}, \vec{\omega}', \lambda', \mathbf{e}, t) d\lambda' \cos \theta' d\vec{\omega}' \right] \\
 & + \int_0^{h(\mathbf{r}, \vec{\omega})} \mu(\mathbf{r}, \mathbf{a}) \left[L^e(\mathbf{a}, \vec{\omega}, t, \lambda) \right. \\
 & + m_p(\vec{\omega}) \int_{-\infty}^t d(t - \tau) P_p(\mathbf{a}, \lambda) \int_{\Theta_i^t} L(\mathbf{s}, \vec{\omega}', \lambda, \mathbf{e}, \tau) \cos \theta' d\vec{\omega}' d\tau \\
 & \left. + \int_{\Theta_i^t} f(\mathbf{a}, \lambda, \vec{\omega}' \rightarrow \vec{\omega}) \int_{\mathcal{R}_v} P_f(\mathbf{a}, \lambda' \rightarrow \lambda) L(\mathbf{a}, \vec{\omega}', \lambda', \mathbf{e}, t) d\lambda' \cos \theta' d\vec{\omega}' \right] d\alpha
 \end{aligned}$$

Γενικός φωτισμός



Measured

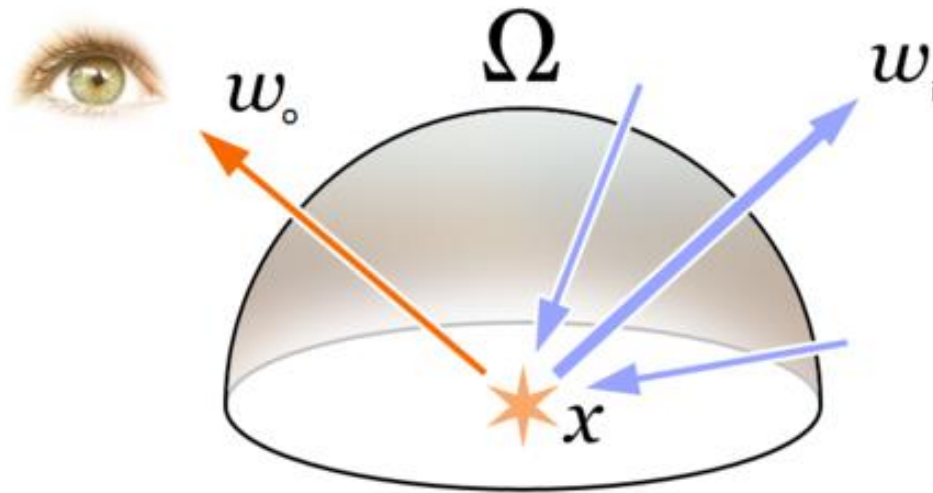


Simulated

The Rendering Equation

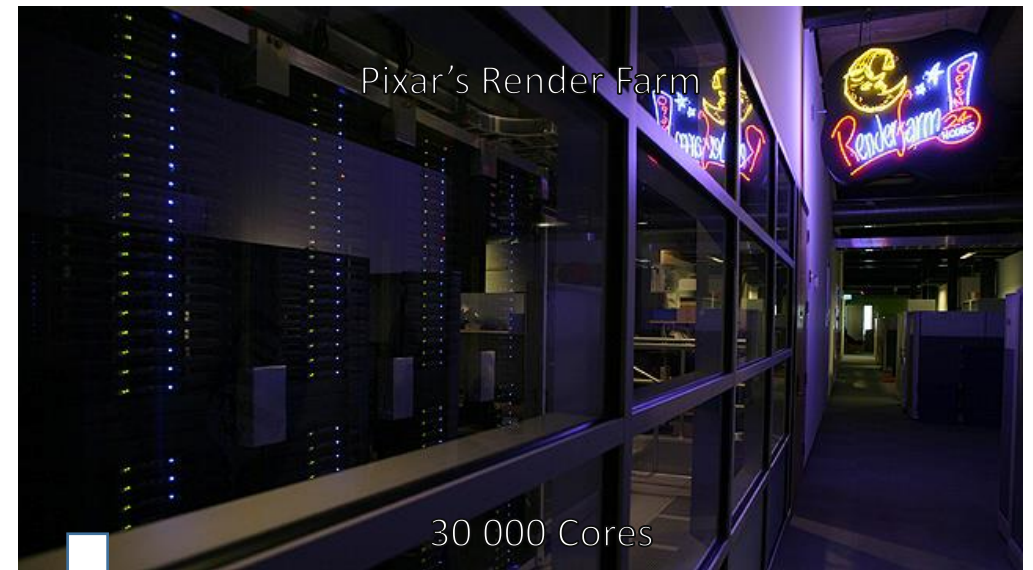
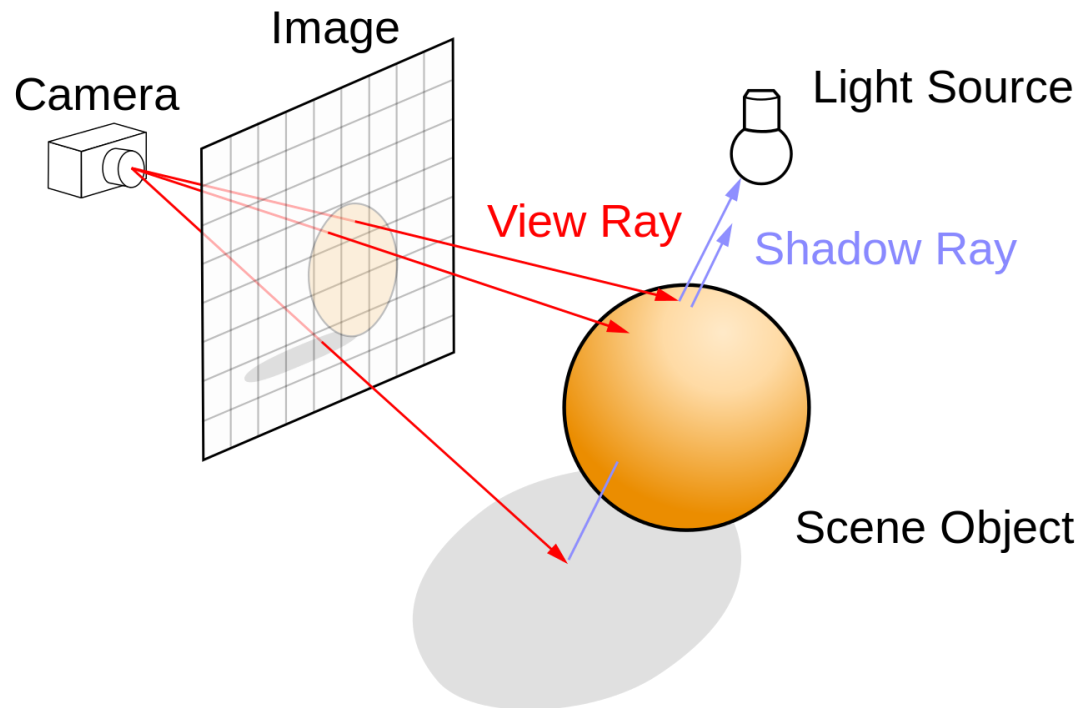
- Rendering methods approximate the following equation:

$$\textit{Outgoing Light} = \textit{Emitted Light} + \textit{Reflectance Function} * \textit{Incoming Light}$$



Offline Computer Graphics

- Aka, Batch Computer Graphics, for final production-quality video and film (special effects – FX).
- Realistic but computationally expensive
- Typically based on **tracing rays** of light to the eye/camera



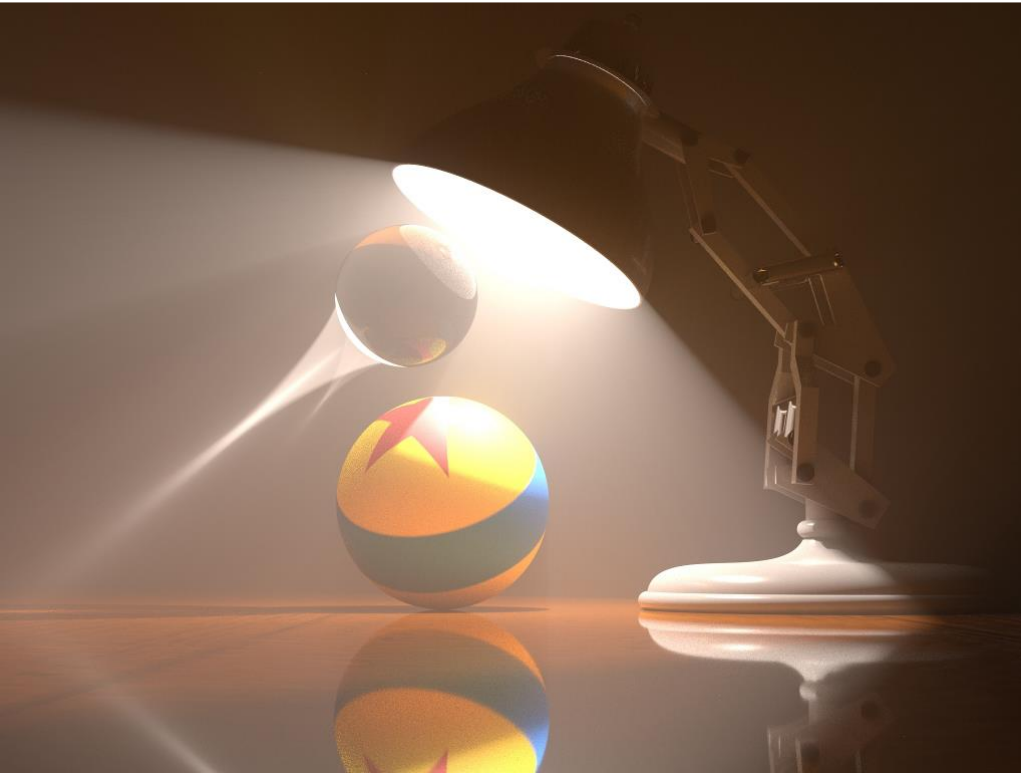
Rendering a single frame of The Good Dinosaur (a 24 fps movie) averaged 48 hours on a 30,000-core render farm!

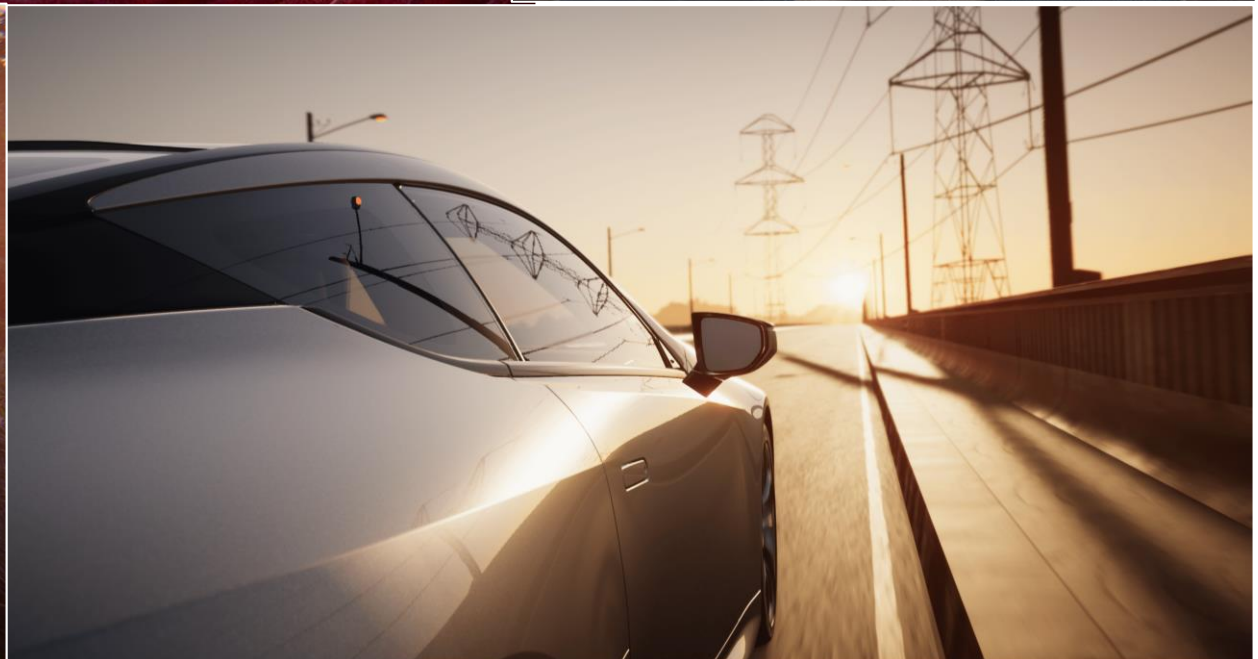
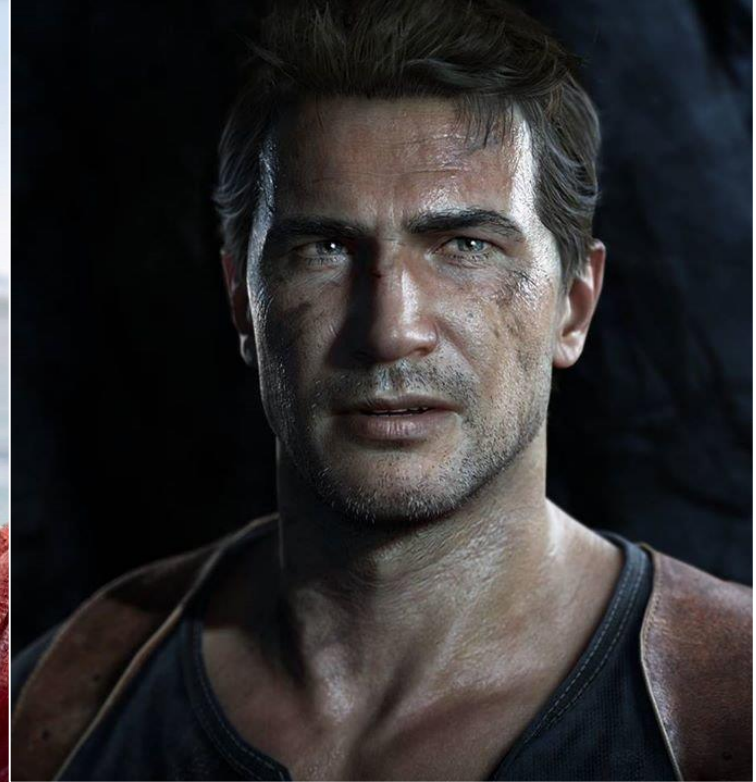
Graphics Library

- Examples: OpenGL™, DirectX™, Windows Presentation Foundation™ (WPF), RenderMan™, HTML5 + WebGL™
- Primitives (characters, lines, polygons, meshes,...)
- Attributes
 - Color, line style, material properties for 3D
- Lights
- Transformations
- Immediate mode vs. retained mode
 - **immediate mode**: no stored representation, package holds only attribute state, and application must completely draw each frame
 - **retained mode**: library compiles and displays from **scenegraph** that it maintains, a complex DAG. It is a display-centered extract of the Application Model

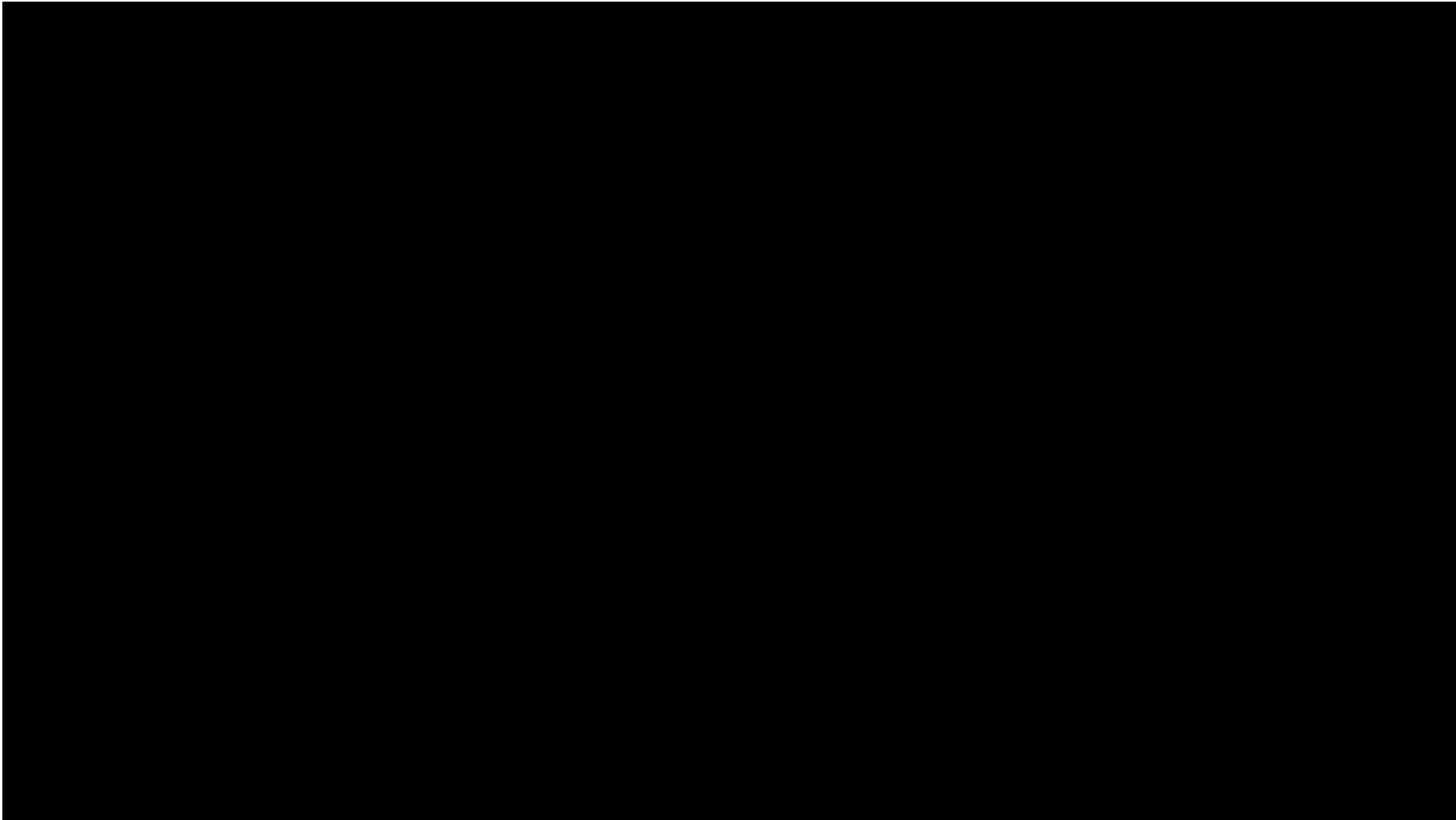


Some eye candy





Photorealistic Rendering







Computer Graphics: *Introduction*

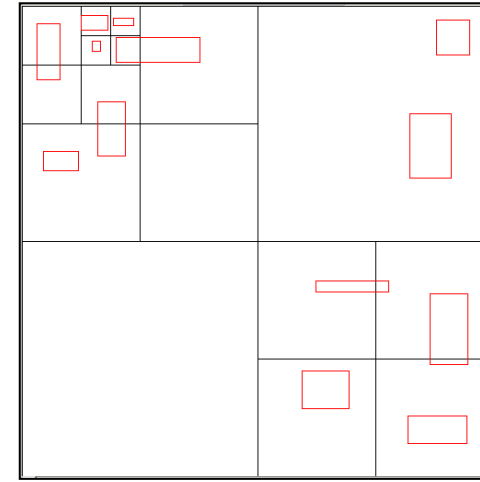
- **Computer Graphics**
 - What's It All About?
 - Application Areas
 - Interactive Computer Graphics
- **How do graphics work**
 - Modeling
 - Animation
 - Rendering
- **Course Outline**
 - Lectures, Exams, Evaluation
 - Books
 - Miscellanea

Τι θα μάθουμε στο ΕΠΛ426

- Τις βασικές αρχές και αλγόριθμους των γραφικών υπολογιστών
- Αρκετές πρακτικές γνώσεις ώστε να μπορούμε να υλοποιήσουμε τα περισσότερα από τα πιο πάνω
 - Γεωμετρική Μοντελοποίηση – Βασικά Πράγματα
 - Κινησιογραφία (Animation) – Σύνομη Εισαγωγή
 - Απόδοση – Σε Αρκετό Βάθος

Τι θα μάθουμε στο ΕΠΛ426

- Ορισμός κάμερας
- Μοντελοποίηση
 - πολύγωνα, πολύεδρα
 - γράφημα σκηνής
- Γραφική σωλήνωση
 - αποκοπή, απόκρυψη, σάρωση, σκιές
- Γενικός φωτισμός με Radiosity
- Μεθόδους επιτάχυνσης
 - ιεραρχικές δομές
- Παρακολούθηση ακτίνας
- Προγραμματισμός σε κάρτες γραφικών
- OpenGL & WebGL & Unity3D game engine
- Εισαγωγή στην Κινησιογραφία



hierarchical data structures



Τι ΔΕΝ θα μάθουμε στο ΕΠΛ426

- 2Δ πακέτα επεξεργασίας εικόνων
 - Photoshop and other painting tools
- Artistic skills
- Game design

Ποια τα προαπαιτούμενα

- Καλός Προγραμματισμός
 - Θα χρειαστούμε C/C++ για τις ασκήσεις των εργαστηρίων (Javascript για WebGL)
 - ΕΠΛ 132, ΕΠΛ 232
- Γραμμική Άλγεβρα
 - Θα χρειαστεί να ξέρουμε για διανύσματα, πίνακες, συστήματα γραμμικών εξισώσεων και απλή γεωμετρία
 - Θα γίνει μια μικρή επανάληψη για κάποια από αυτά τις πρώτες δύο εβδομάδες του εξαμήνου

Αξιολόγηση

- Συμβόλαιο στην ιστοσελίδα του μαθήματος:

<http://www.cs.ucy.ac.cy/courses/EPL426/>

- Η ιστοσελίδα του μαθήματος θα ανανεώνεται τακτικά
 - Σημειώσεις θα είναι διαθέσιμες την προηγούμενη μέρα του μαθήματος

- Αξιολόγηση:

Αξιολόγηση	Βάρος
Ασκήσεις	40%
Ενδιάμεση Εξέταση	20%
Τελική Εξέταση	40%
Logipaision	Up to 10%

Η φιλοσοφία μας

- **Θέλουμε ενεργούς φοιτητές στην τάξη:** ελάτε στα μαθήματα, συμμετέχετε
 - Οι κάμερες θα είναι ανοικτές, και θα παίρνω παρουσία
 - Τα μαθήματα ΔΕΝ θα βιντεογραφούνται
- **Απαιτητικές ασκήσεις** (επόμενη διαφάνεια)
- **Απαιτητικές εξετάσεις**
- Εύλογη και επιεικής αξιολόγηση (τουλάχιστον αυτό πιστεύει ο εξεταστής)

Πρακτική

- Ένα μεγάλο μέρος του τελικού βαθμού θα δοθεί από τις πρακτικές εργασίες:
 - Διάφορες μικρές **ασκήσεις** για υλοποίηση των εννοιών που θα μάθουμε στην θεωρία
 - **Εργαστηριακή άσκηση** σε OpenGL/webGL (15%)
 - **Τελικό project** σε ομάδες των 2 ατόμων για την υλοποίηση μιας «εντυπωσιακής» εφαρμογής (25%)

GDC

GAME DEVELOPMENT CHALLENGE

17 DECEMBER 2021 - 14 MAY 2022

TEAM REGISTRATION

OPEN UNTIL DECEMBER 17 2021

ENROLL NOW!

GAME SUBMISSIONS

BY MARCH 31 2022

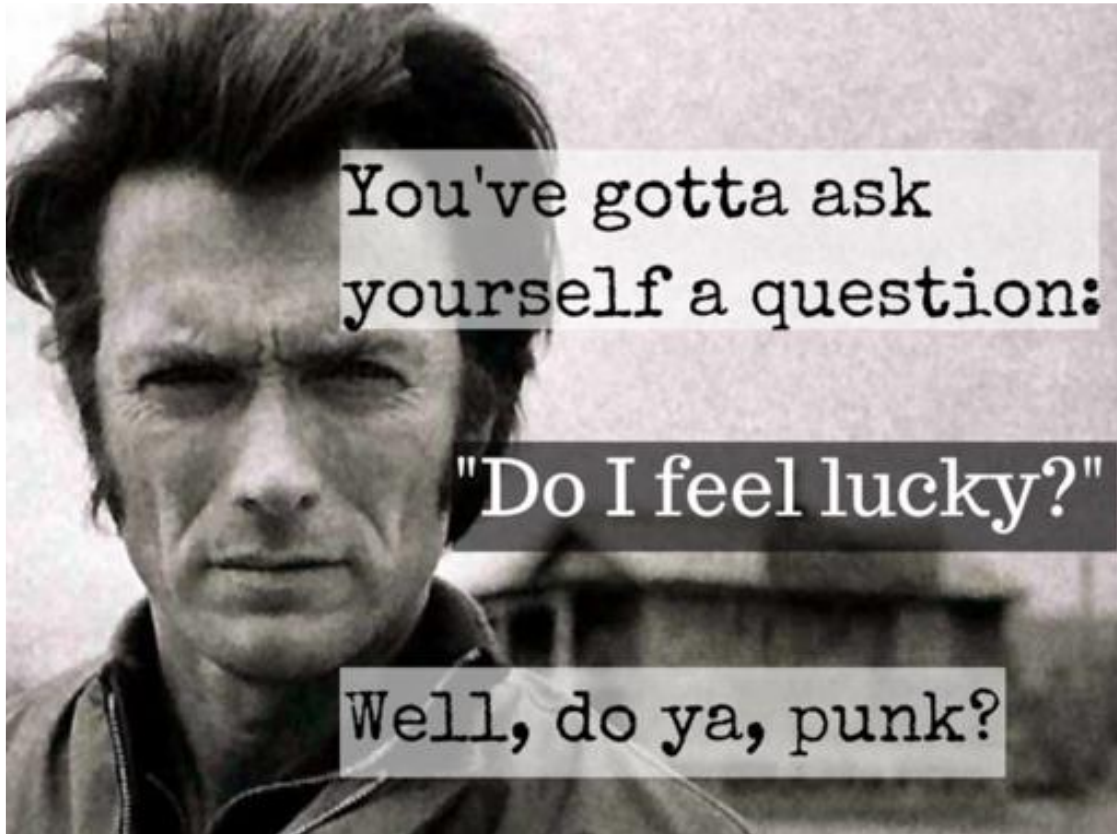
SUBMIT YOUR GAME



Late hand-in policy

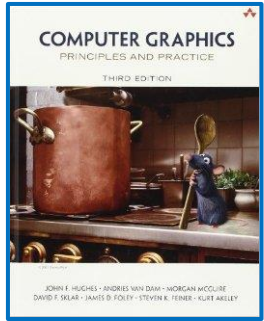
- Programming assignments
 - No late assignments will be accepted!
 - No extensions will be given!

Cheating Policy



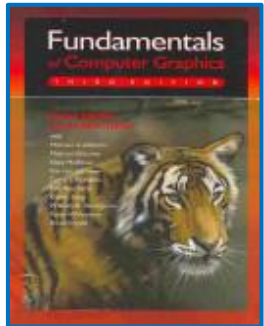
- Let's keep it simple: if you are caught cheating, you will get a **zero** for the entire course (not just the assignment).

Books

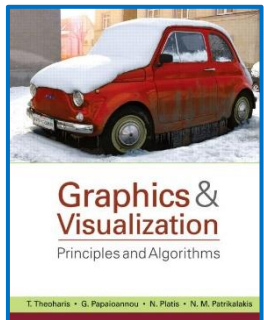


- “Computer Graphics: Principles and Practice”, J. F. Hughes, A. van Dam, M. McGuire, D. F. Sklar, J. D. Foley, S. K. Feiner, K. Akeley, Addison-Wesley, 2013

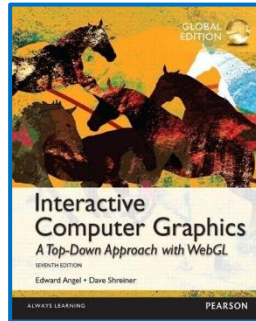
Great for really in-depth theory



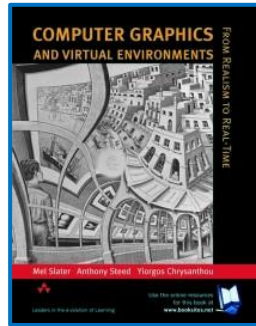
- “Fundamentals of Computer Graphics”, P. Shirley, M.I. Ashikhmin, M. Gleicher, W. B. Thompson, P. Willemsen, E. Reinhard, S. R. Marschner, K. Sung, Taylor & Francis, 2009



- “Graphics and Visualization: Principles & Algorithm”, T. Theoharis, G. Papaioannou, N. Platis, N. M. Patrikalakis, A K Peters, 2007.



- “Interactive Computer Graphics with WebGL, E. Angel and D. Shreiner, Pearson; 7th edition, ISBN-13: 978-1292019345. 2014.



- Computer Graphics and Virtual Environments: From Realism to Real-Time, M. Slater, A. Steed and Y. Chrysanthou, Addison Wesley publishers, ISBN 0-201-62420-6, 2001.

We have no textbook for this class —the lecture slides are the primary course reference

Next Lecture

- Next time, we'll do a math review & preview
 - Linear algebra, vector calculus
 - Help make the rest of the course easier!

Ευχαριστώ!

