3D Models and Toolkits

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3D vs. 2D

2D

- Drawn in X and Y direction
- No depth or thickness -> No Volume
- Cannot be rotated or viewed from any other angle

3D

- Drawn in X, Y and Z direction
- Depth and thickness
- Can be rotated and viewed from any angle
- More complicated to create and produce

3D Computer Graphics

- Graphics that use 3D model for the purposes of performing calculations and rendering 2D images
- Process of creating 3D computer graphics
  1. 3D Modeling
  2. 3D Animation
  3. 3D Rendering

3D model

- A three-dimensional mathematical representation (in X, Y, Z) of any three-dimensional object (volume > 0) using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc
- Can be displayed visually as a 2D image through a process called 3D rendering
- Is not technically a graphic until it is rendered and visually displayed
- Can be used in non-graphical computer simulations and calculations for scientific purposes

3D Model Usage

- Wide Variety of Fields
  - Game, Movie, Animation: characters, objects, backgrounds, animations, special effects, etc
  - Science: highly detailed models for calculations, chemical compounds
  - Architecture: demonstration of proposed buildings and landscapes though Software Architectural Models
  - Engineering: designs of new devices, dynamics estimation tests for vehicles
  - Medical: detailed models of organs
  - Geology: 3D geological models such as Google Earth

3D model

- Two most common sources of 3D models
  - 3D Scanner: Scanned directly into a computer from real-world objects using 3D scanners
  - 3D Modeling: Designed by an artist or engineer using 3D modeling tools

3D Scanner vs. 3D Modeling

+ More time efficient
+ More accurate
+ More detailed
- Expensive
- Need an object

+ Can create anything
+ Can simply
+ Full control
+ Less expensive
- Time consuming
- Less accurate

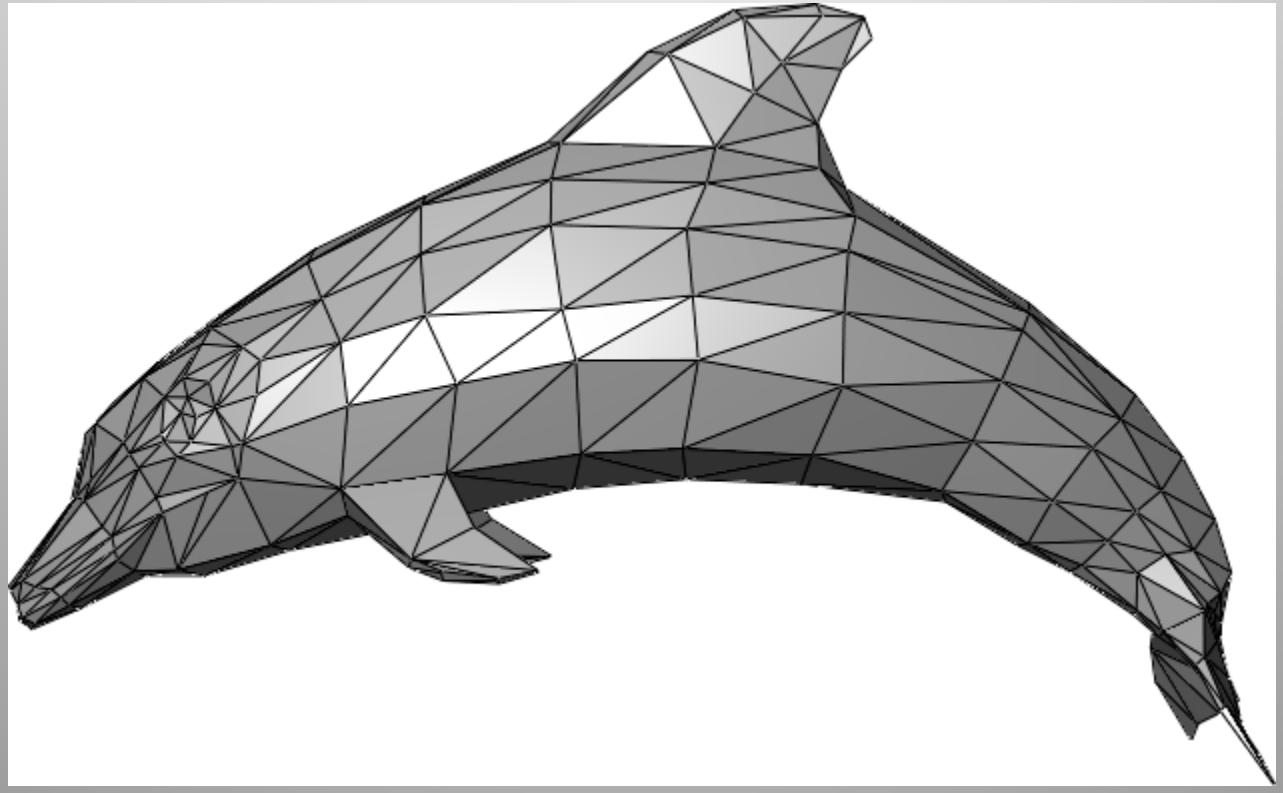
3D Scanner

- A device that analyzes a real world object or environment to collect data on its shape and its appearance (i.e. color) to construct a 3D model
- Create a point cloud of geometric samples on the surfaces of the object

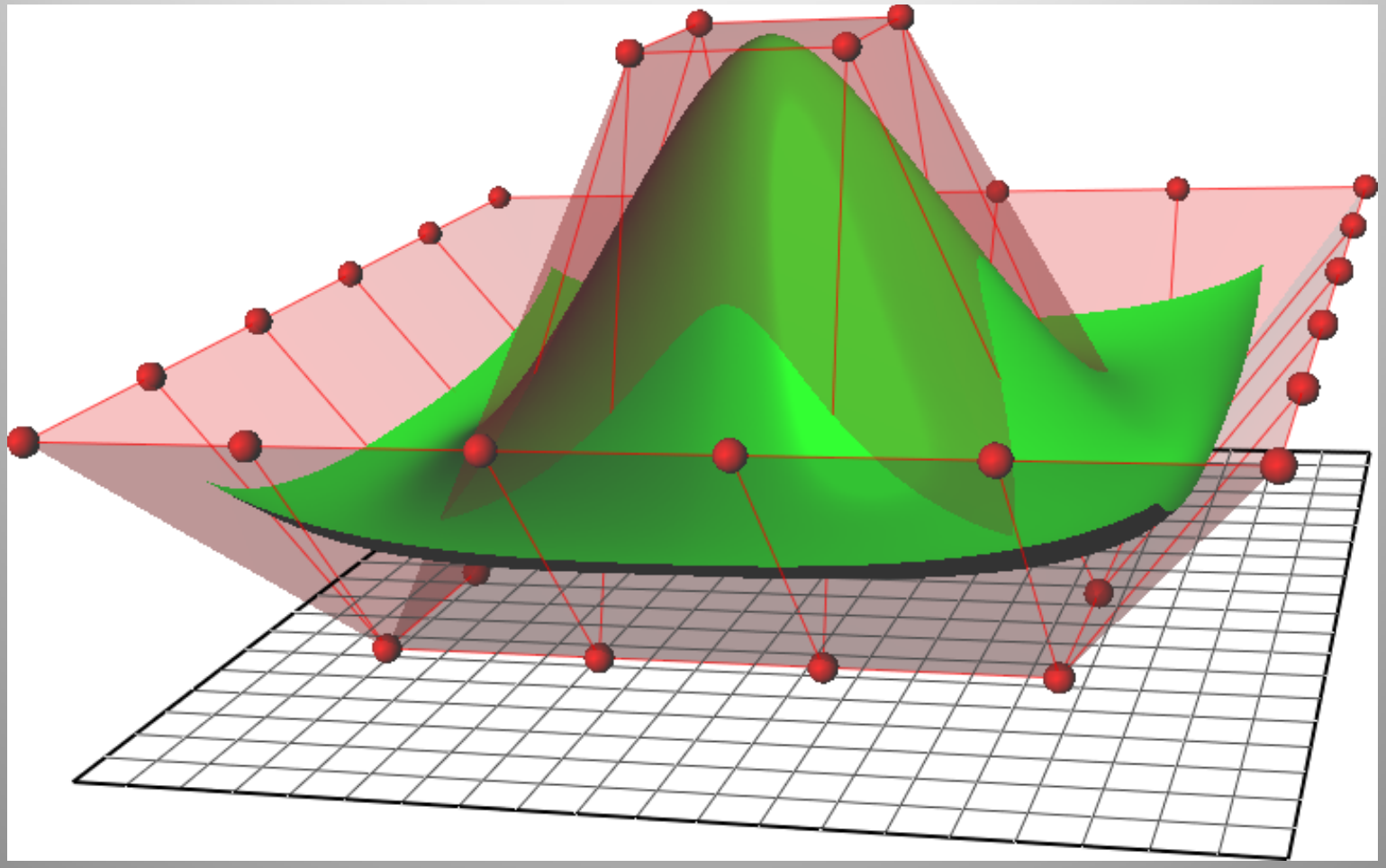
Point Cloud

- A set of vertices in a three-dimensional coordinate system defined by X, Y and Z coordinates
- Not directly usable in most 3D applications
- Usually converted to triangle mesh models, NURBS surface models, or CAD models to be usable

3D Triangle Mesh Model



NURBS (Non-Uniform Rational B-Spline) Model



3D Scanner Usage

- Entertainment industry in the production of movies and video games
- Industrial design
- Orthotics and prosthetics
- Reverse engineering
- Prototyping
- Quality control / Inspection
- Documentation of cultural artifacts

3D Scanner Technologies

- Different technologies used altogether
- Each technology has its own limitations
- Limitations in the kind of objects that can be digitized are still present
  - i.e. optical technologies encounter difficulties with shiny, mirroring or transparent objects -> getting false three dimensional information

3D Scanner Example: Rexcan III

- High-end 3D scanner of Solutionix Corp
- Uses two high-resolution CCD cameras and provides 3D measurement data with high-resolution and high-accuracy
- By adopting recent advances in dense polygon handling technologies, Rexcan III enables the seamless 3D scanning process
- Video: Rexcan3.mp4 (1:55)

3D Modeling

- The process of developing a 3D model via specialized software such as Autodesk Maya, 3ds Max, Softimage
- Almost all 3D models can be divided into two categories
  - Solid
  - Shell/boundary

Solid 3D Model

- Define the volume of the object they represent
- Realistic, but more difficult to build
- Mostly used for non-visual simulations such as medical and engineering simulations, and for specialized visual applications such as ray tracing and constructive solid geometry

Shell/Boundary 3D Model

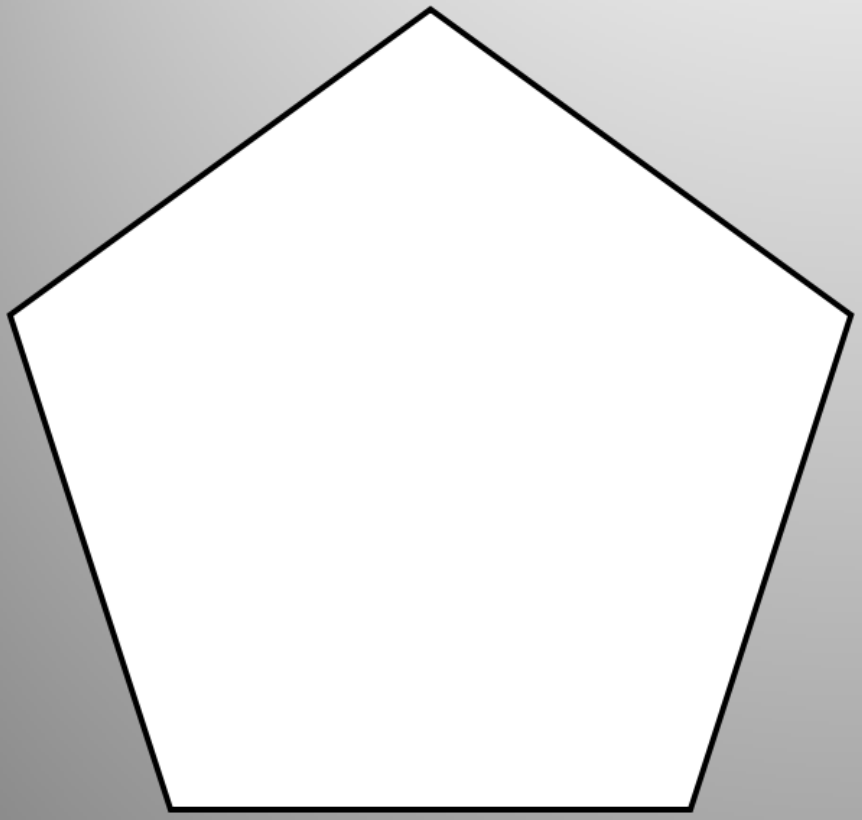
- Represent the surface, e.g. the boundary of the object, not its volume (like an infinitesimally thin eggshells)
- Easier to work with than solid models
- Almost all visual models used in games and film are shell models

Polygon Mesh

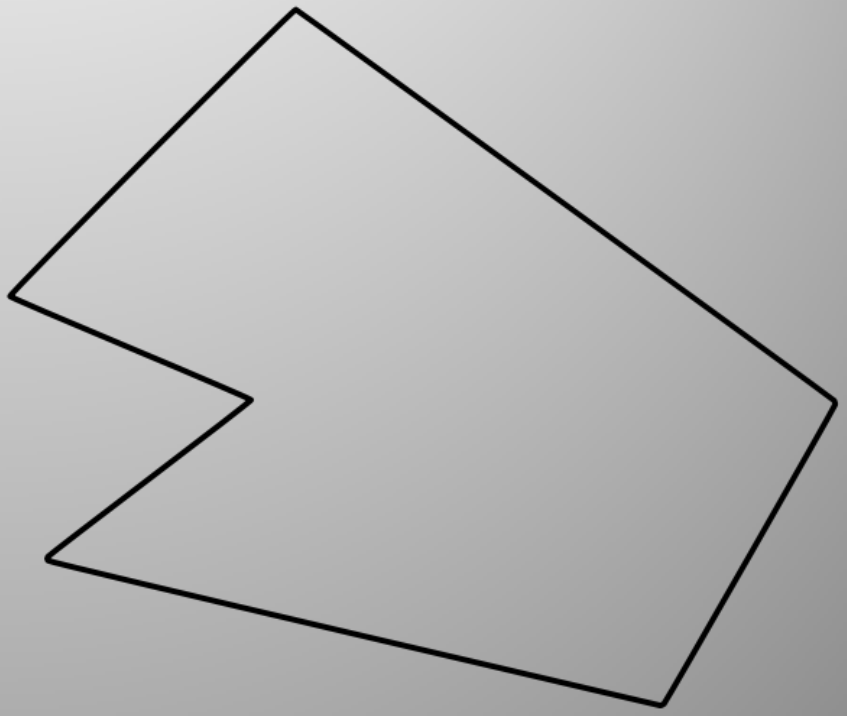
- A collection of vertices, edges and faces that defines the shape of a polyhedral object
- The faces usually consist of triangle, quadrilaterals or other simple convex polygons
- Only represent the surface (the volume is implicit)
- Algorithms exist for ray tracing, collision detection, and rigid-body dynamics of polygon meshes

Convex polygon vs. Concave polygon

Convex polygon



Concave polygon



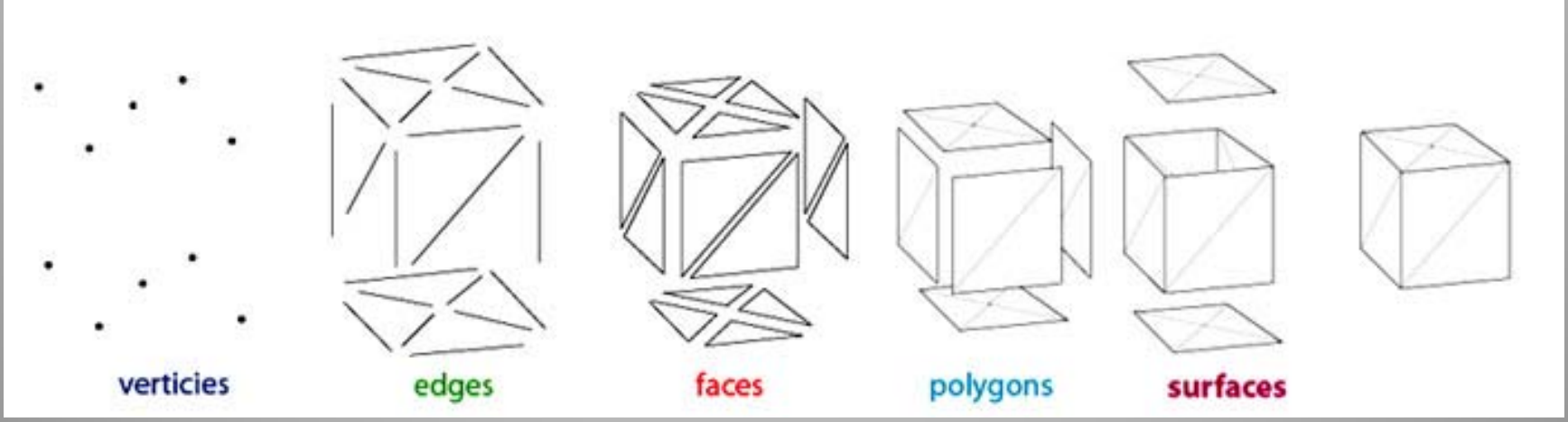
Polygon Mesh

- Objects created with polygon meshes must store different types of elements: Vertices, edges, faces, polygons, and surfaces
- In many applications, only vertices, edges and faces are stored
- A complete solution for polygonal modeling requires polygons and surfaces as well

Polygon Mesh

- Vertex: a position along with other information such as color, normal vector and texture coordinates.
- Edge: a connection between two vertices
- Face: a closed set of edges, in which a triangle face has three edges, and a quad face has four edges
- Polygon: a set of faces. In a system that support multi-sided faces, polygons and faces are equivalent. However, most rendering hardware supports only 3 or 4 sided faces, so polygons are represented as multiple faces
- Surfaces: needed to group smooth parts of a mesh just as polygons group 3-sided faces

Polygon Mesh Overview



3D Rendering

- Process of generating a 2D image from a 3D model that contains geometry, color, texture, viewpoint, lighting, and shading information using computer programs
- Final process of creating the actual 2D image or animation from the prepared scene
- Compared to taking a photo after the setup (model positioning, lighting, camera angle, etc) is complete

Real-time 3D Rendering

- Calculated and displayed in real time, at rates of approximately 20 to 120 frames per second
- For interactive media, such as games and simulations
- Goal is primarily speed and not photo-realism
- Rapid increase in computer processing power has allowed a progressively higher degree of realism even for real-time rendering

Non Real-time 3D Rendering

- For non-interactive media, such as films and video
- Rendered much more slowly for higher image quality
- Based on the complexity level of scenes and rendering methods, it may take from a few seconds to several days for one image/frame

3D Rendering Techniques

- Rasterization
- Polygon-based rendering
- Scanline rendering
- Radiosity
- Ray tracing

Rasterization

- Loops through each of the primitives (triangle or polygons), determines which pixels in the image it affects, and modifies those pixels accordingly
- Usually faster than pixel-by-pixel rendering because large areas of the image may be empty of primitives; rasterization will ignore these areas
- Improves cache coherency and reduce redundant work by taking advantage of the fact that the pixels occupied by a single primitive tend to be contiguous in the image

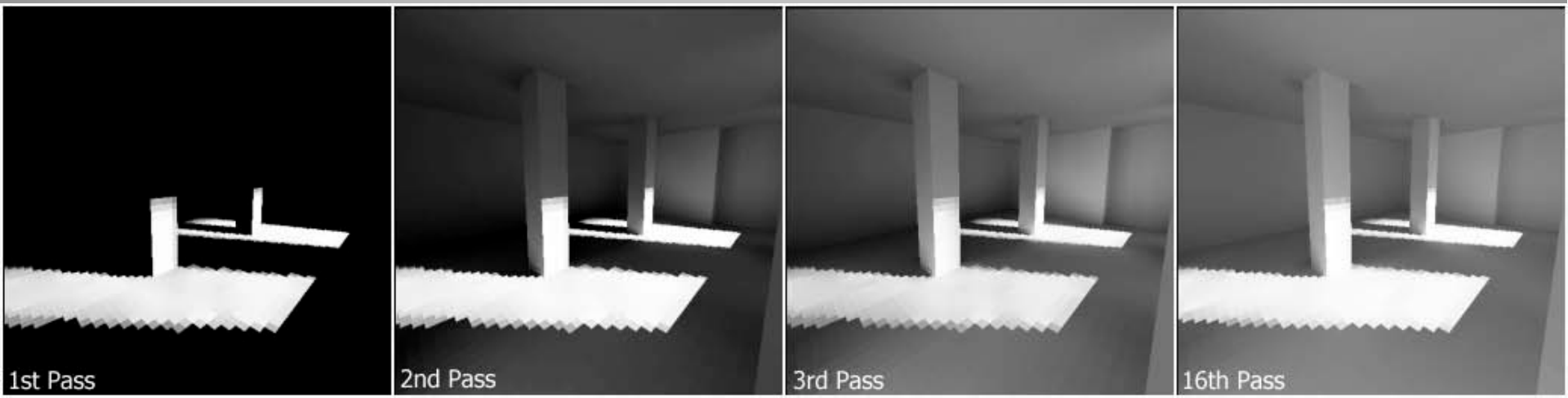
Scanline Rendering

- A row-by-row basis rather than a polygon-by-polygon or pixel-by-pixel basis
- All of the polygons to be rendered are first sorted by the top y coordinates at which they first appear
- Each row of the image is computed using the intersection of a scanline with the polygons

Radiosity

- Global illumination algorithm
- Only account for paths which leave a light source and are reflected diffusely some number of times before hitting the eye

Radiosity Examples



Ray Tracing

- A technique for generating an image by tracing the path of light through pixels in an image plane
- Capable of producing a very high degree of photorealism, but at a great computational cost
- Best suited for applications where the image can be rendered slowly ahead of time
- Reflection, refraction, scattering, and chromatic aberration

Ray Tracing

- Trace a path from an imaginary eye through each pixel in a virtual screen and calculating the color of the object visible through it
- Each ray must be tested for intersection with some subset of all objects in the scene
- At each intersection with an object, it will calculate the incoming light at the point of the intersection, examine the material properties of the object, and combine this information to calculate the final color of the pixel

Ray Tracing Example

- Image: Glasses_800_edit.png
- This image was created by Gilles Tran with POV-Ray 3.6 using Radiosity. The glasses, ashtray and pitcher were modeled with Rhino and the dice with Cinema 4D
- Video: quakewars.mp4 (1:25)
- Video of a ray traced version of Enemy Territory: QUAKE Wars. The ray traced port has been done by the Intel ray tracing research group

Production-Quality 3D Renderer

- Mental ray by mental images (Berlin, Germany), bought in December 2007 by NVIDIA
  - http://www.mentalimages.com/products/mental-ray.html
- PhotoRealistic RenderMan (PRMan) by Pixar Animation Studios
  - Also available for Maya
  - https://renderman.pixar.com/

Free / Open Source 3D Softwares

- 3D Modeler
  - Blender: http://www.blender.org/
  - Wings 3D: http://www.wings3d.com/
- 3D Renderer
  - POV-Ray: http://www.povray.org/
  - YafaRay: http://www.yafaray.org/
  - LuxRender: http://www.luxrender.net/
  - SunFlow: http://sunflow.sourceforge.net/index.php
  - Kerkythea: http://www.kerkythea.net/joomla/

Autodesk Maya

- High-end 3D modeling, animation, visual effects, and rendering solution
- Open architecture: all work can be scripted or programmed using a comprehensive API or one of two embedded scripting languages, the Maya Embedded Language (MEL) or Python
- Can strip the software completely of its standard appearance and, using only the kernel, transform it into a highly customized version of the software
- Appealing to large studios, which tend to write custom code for their productions using the provided software development kit

Maya Complete 2009

- Intuitive User Interface
- Data and Scene Management Tools
- Polygon Modeling
- NURBS Modeling
- Subdivision Surface Modeling and
- Polygon Proxy Modeling
- General Animation
- Character Animation
- Muscle and Skin System
- Deformers
- Rigid and Soft Body Dynamics
- Particles and Fields
- Maya Paint Effects
- Toon Shader
- Maya Artisan
- 3D Paint
- Multiple Rendering Options
- Rendering Controls and Effects
- Integrated Scripting
- OpenMaya API/SDK
- Japanese Localization
- Connectivity and Integration
- CAD Data Transfer
- Plug-ins

Maya Unlimited 2009

- Maya Fluid Effects
- Maya Fur
- Maya nCloth
- Maya nParticles
- Maya Live
- Maya Hair

Tutorials / Examples

- Modeling a human head in 3D (9:51): Modeling_a_human_head_in_3D_with_great_edge_flow.mp4
- 3D model of Don King (0:34): 3D_model_of_Don_King.mp4
- Introduction to dynamics Autodesk Maya Tutorial (6:45): Introduction_into_dynamics_Autodesk_Maya_Tutorial.mp4
- RealFlow4 Demo Reel: 2008/2009 (3:13): rf_reel_web.flv

Readings / Reference

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- Luis Valente and Aura Conci, "Guff: A Game Development Tool", IV Workshop de Teses e Disserta��es em Computa��o Gr�fica e Processamento de Imagens, SIBGRAPI, 2005.
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- Realflow. http://www.realflow.com/.
- Wikipedia. http://en.wikipedia.org/wiki/Wiki .
- Youtube. http://www.youtube.com/.