MSc Computer Games and Entertainment

Maths & Graphics Unit 2011/12

Lecturer: Gareth Edwards

Introduction to Pre & Real-Time Rendering

Introduction to the principle topics
to be covered in Term 2

What does Pre-Rendering have to do with Real-Time Rendering?

<u>**Everything!**</u>

- The aesthetics of Pre-Rendering DRIVES Real-Time Techniques and Technologies
- The algorithms developed in Pre-Rendering are the jumping off point for the development of the Real-Time algorithms
- Commercial techniques, methodologies and working practices developed to exploit commercially driven advances in Pre-Rendering are "inherited" by Real-Time Rendering

In this lecture I will:

- Give a brief history of Image Synthesis and Effects
- Explain what Image Synthesis / Rendering is, and
- The differences between Pre and Real-Time Rendering

I will then:

- Explore key Pre-Rendering techniques and discuss, and where appropriate describe, how they have been realised in Real-Time Rendering and Shading.

History

- You are the inheritors of a long and noble history!
  - **History of VFX, CGI, CG Animation - Spreadsheet**

Avatar

- [Movie Trailer]
- [Game Play Trailer]

Rendering is the process of generating an image from a model or set of models, by means of computer programs.

A model is a description of three-dimensional data that might include:

- Geometry
- Viewpoint
- Texture
- Lighting
- Shading

The result of the rendering process is typically:

- A file containing encoded data that represents a digital image
- A raster graphics image

A Renderer is a program incorporating a wide variety of disciplines, including:

- Light physics
- Visual perception
- Mathematics
- Advanced software techniques

There are essentially two types of rendering, these are:

- Pre-Rendering - done slowly and is typically a computationally intensive process
- Real-Time – done quickly and typically (though not always) uses graphics cards with 3D hardware accelerators.

Rendering Types

There are many distinct types of rendering.

These include:

- Artistic :
  - In artistic rendering visual information is interpreted by the graphic artist and displayed accordingly to that individuals aesthetics.
  - Typically the intention is not to create photorealistic imaging

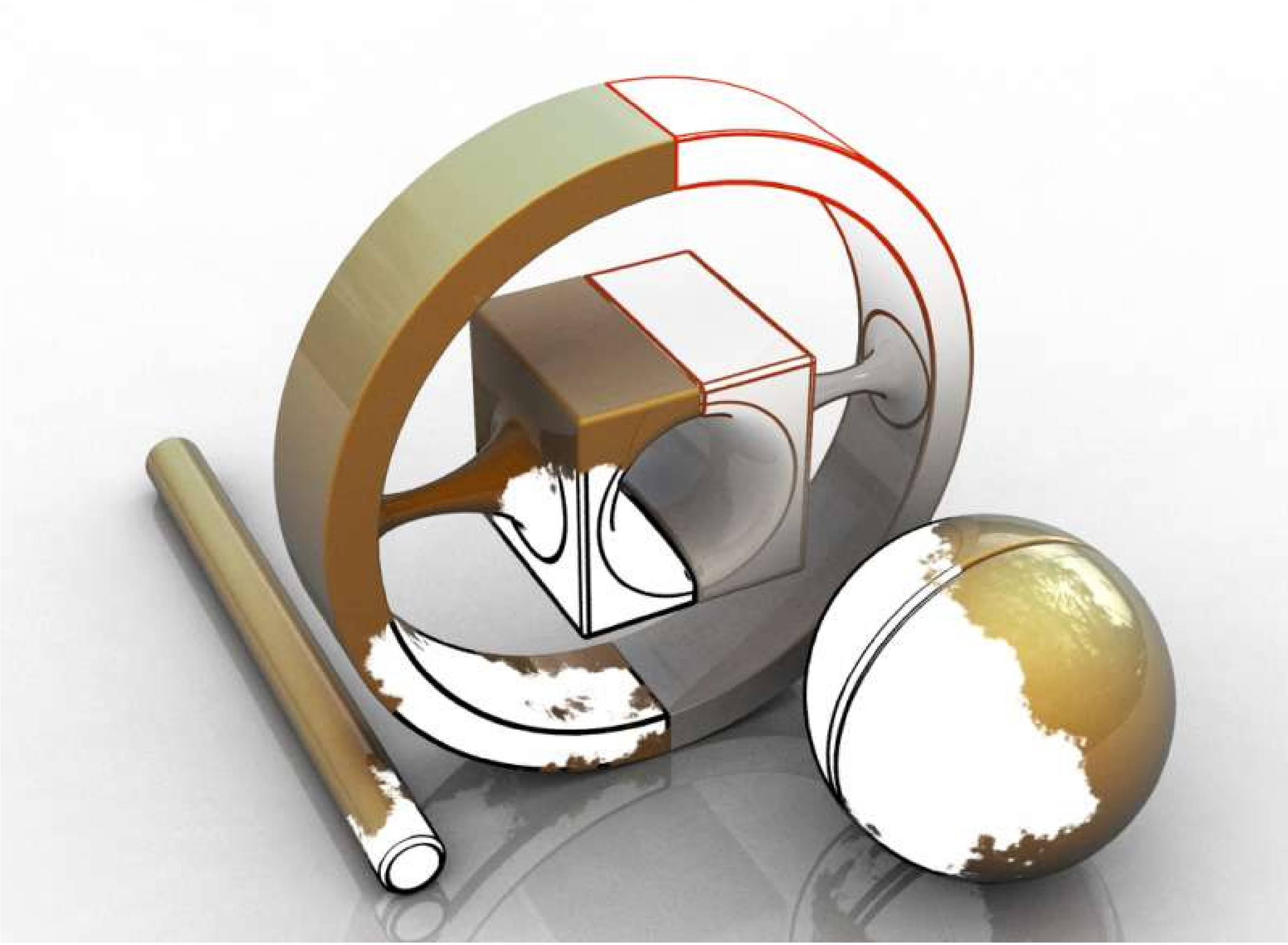
Artistic Rendering

Rendering Types

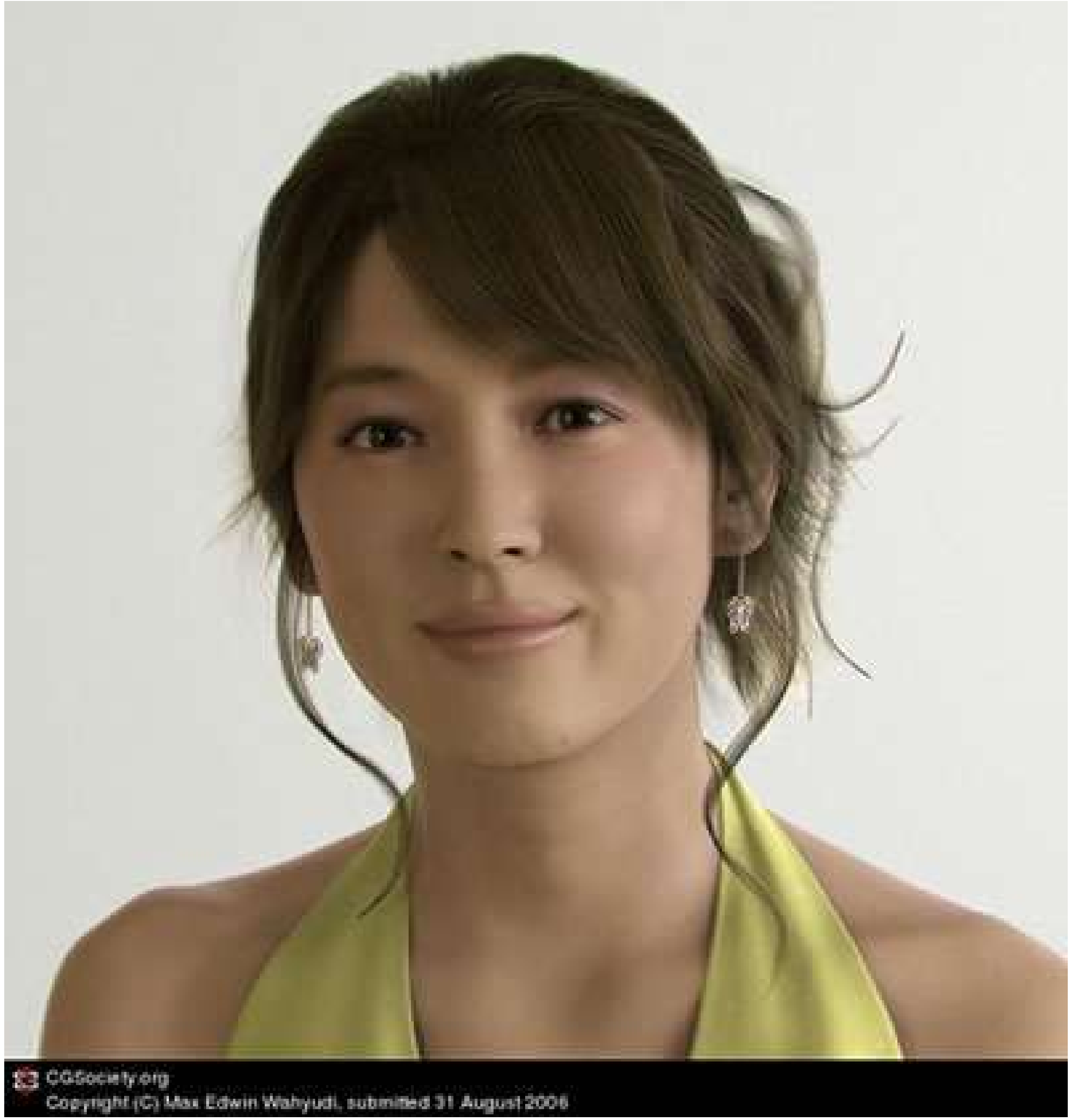
- Non-photorealistic - focuses on enabling a wide variety of expressive styles for digital art, these include:
    - Painting
    - Drawing
    - Technical illustration
    - Animated cartoons

- Photo-realistic
- Naturalistic
- Technical
- Etc.

Non-photorealistic Rendering



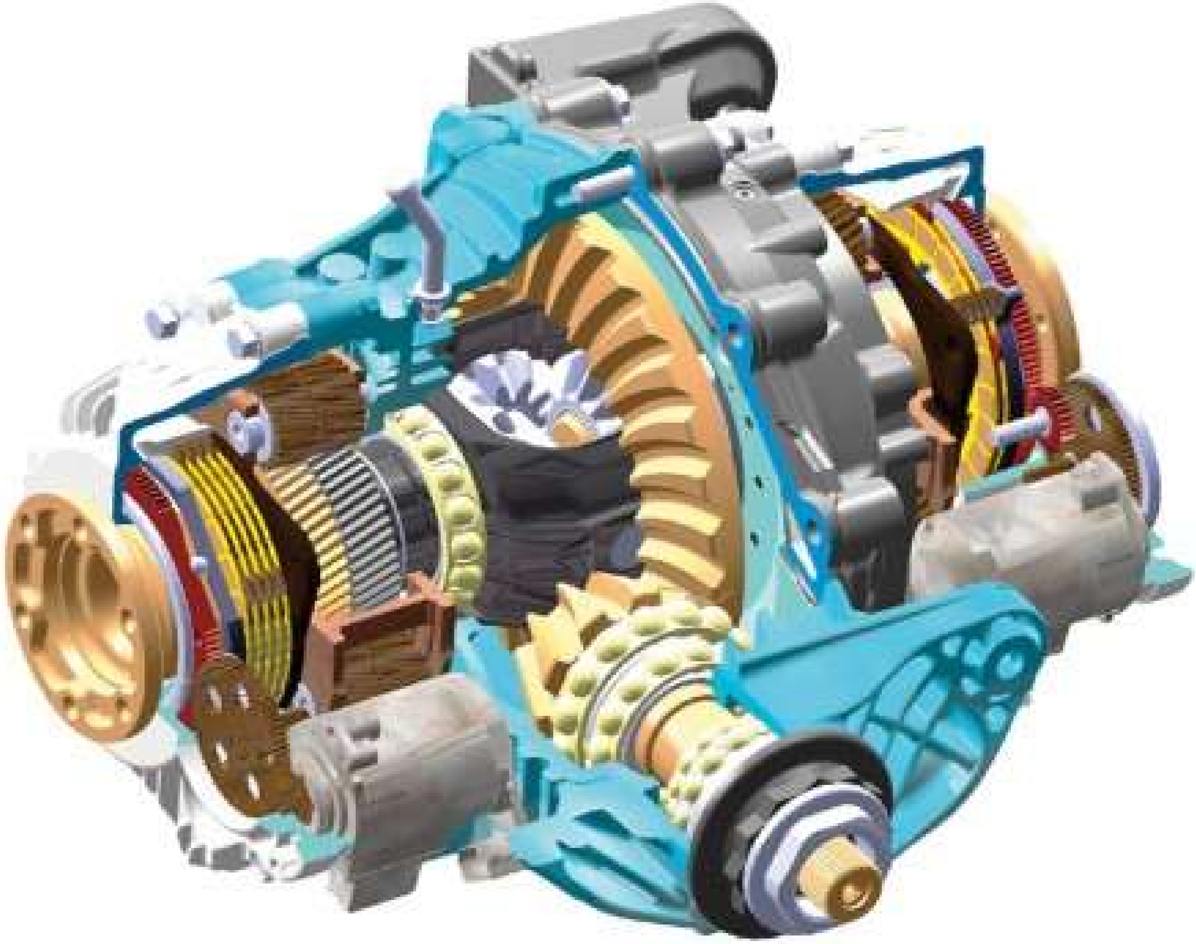
Photorealistic Rendering



Photorealistic Rendering

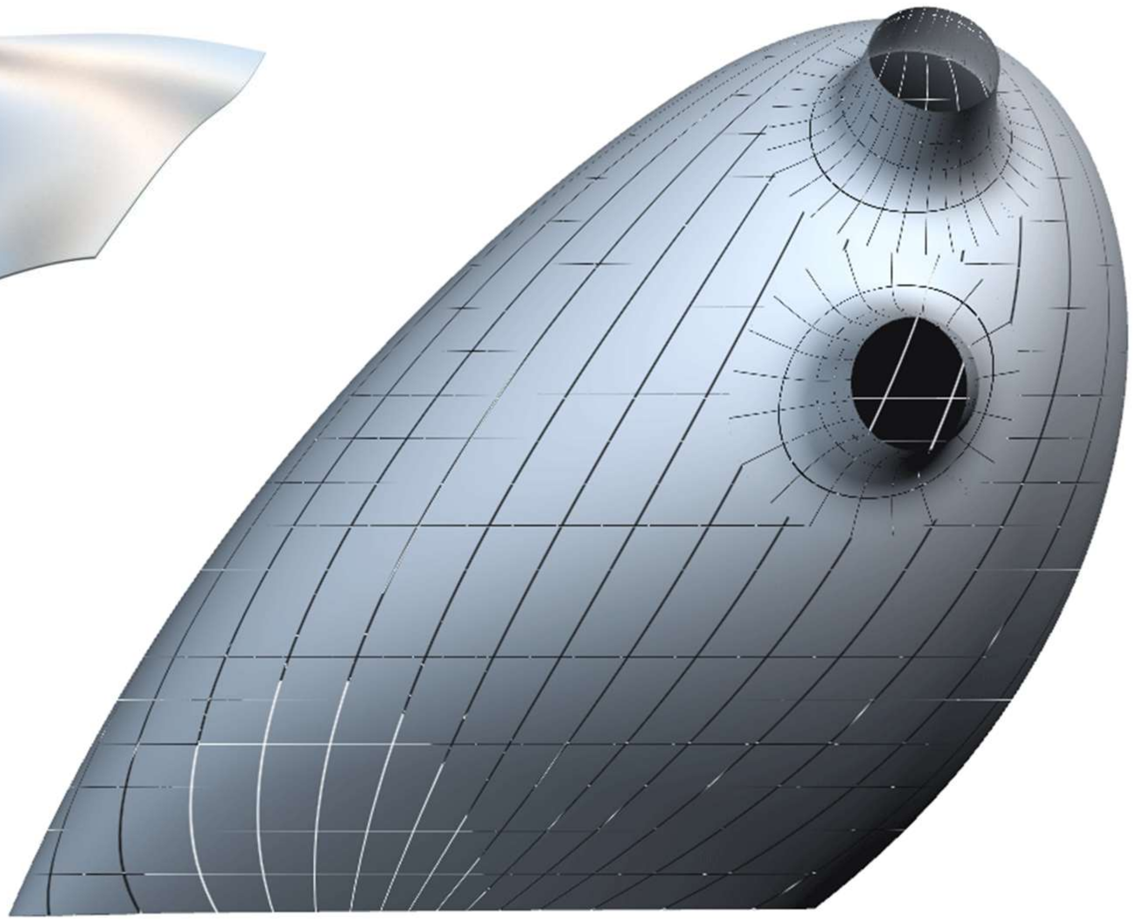
Naturalistic Rendering

Technical Rendering



Architectural Rendering

Architectural Rendering



Rendering Techniques

There are many rendering techniques, these include:

- **Painters** – algorithm for visible surface determination
- **Scanline** – algorithm for visible surface determination
- **Z/A/R/X/etc. Buffer** – algorithms for visible surface determination
- **Ray Tracing** –
- **Shading** – refers to depicting depth perception in 3D models or illustrations by varying levels of darkness
- **Anti-aliasing** – is the technique of minimizing the distortion artifacts known as aliasing when representing a high-resolution signal at a lower resolution
- **Texturing** – is a method for adding detail, surface texture (a bitmap or raster image), or colour to a computer-generated graphic or 3D model
- **Volume** – used to display a 2D projection of a 3D discretely sampled data set
- **Video** – real-time streaming
- **High dynamic range** – using calculations done in a larger dynamic range and allows for the preservation of details that may be lost due to limiting contrast ratios
- Etc.....,

Painter's algorithm

This is one of the simplest solutions to surface visibility.

The name "painter's algorithm" refers to the technique employed by many painters of painting distant parts of a scene before parts which are nearer thereby covering some areas of distant parts.

The painter's algorithm sorts all the polygons in a scene by their depth and then paints them in this order, farthest to closest.

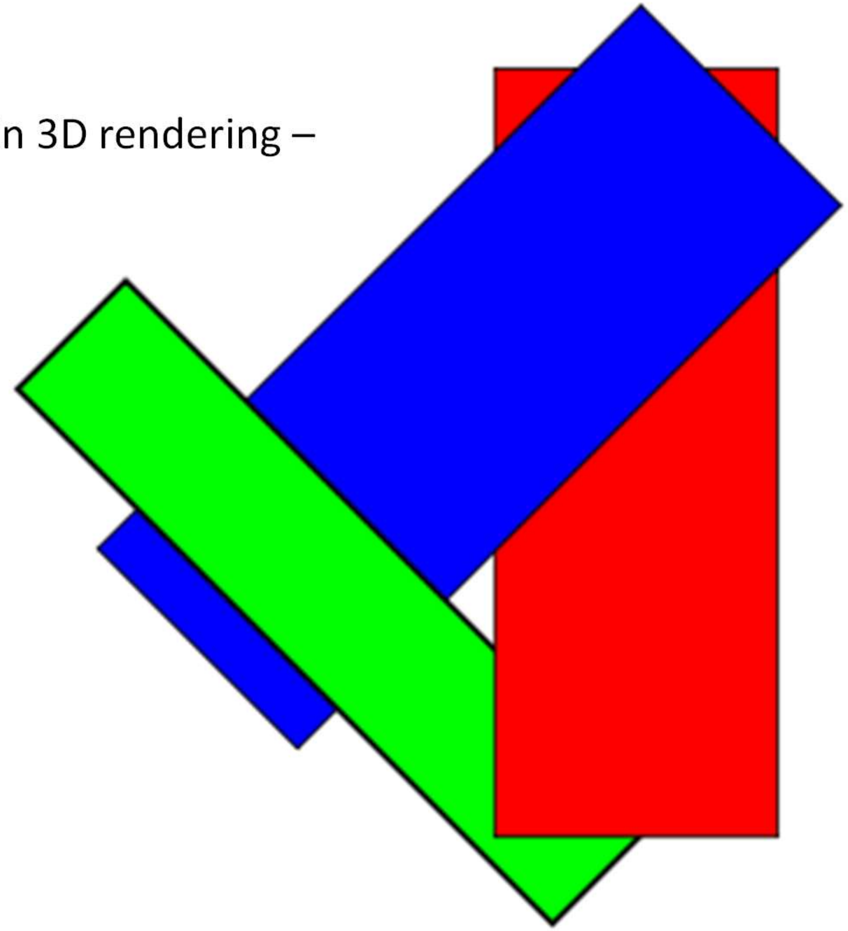
It will paint over the parts that are normally not seen.

It is a very inefficient solution to surface visibility.

Painter's algorithm

It fails – usually quite often if used in 3D rendering – for many reasons, including:

- Cyclic overlap
- Piercing polygons
- Differing size of polygons



Paper

Compositing Digital Images

Source International Conference on Computer Graphics and Interactive Techniques
Proceedings of the 11th annual conference on Computer graphics and interactive techniques
Pages: 253 – 259

Year of Publication: 1984

ISBN:0-89791-138-5

Authors: Thomas Porter, Tom Duff (Lucasfilm Ltd)

Compositing Digital Images

MOVIE

PAPER

Approximate And Probabilistic Algorithms For Shading And Rendering Structured Particle Systems

Source International Conference on Computer Graphics and Interactive Techniques
Proceedings of the 12th annual conference on Computer graphics and interactive techniques
Pages: 313 – 322

Year of Publication: 1985

ISBN:0-89791-166-0

Authors: William T. Reeves, Ricki Blau (Lucasfilm Ltd).

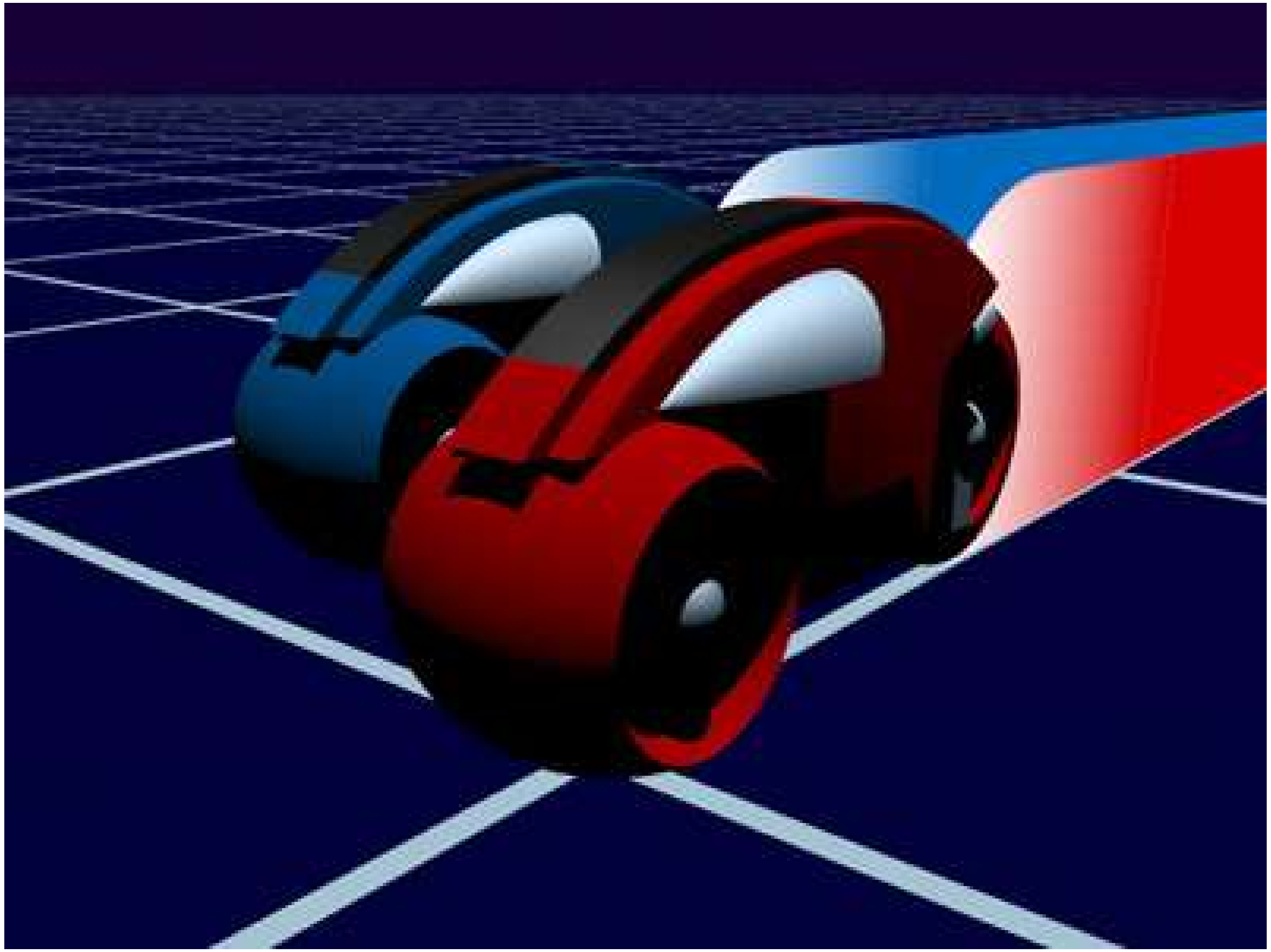
Scanline Rendering

Scanline rendering is an algorithm for visible surface determination, in 3D computer graphics, that works on 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 coordinate at which they first appear, then each row or scan line of the image is computed using the intersection of a scan line with the polygons on the front of the sorted list, while the sorted list is updated to discard no-longer-visible polygons as the active scan line is advanced down the picture.

The asset of this method is that it is not necessary to translate the coordinates of all vertices from the main memory into the working memory—only vertices defining edges that intersect the current scan line need to be in active memory, and each vertex is read in only once. The main memory is often very slow compared to the link between the central processing unit and cache memory, and thus avoiding re-accessing vertices in main memory can provide a substantial speedup.

Scanline Rendering



NOW – Ray traced is the norm!

PAPER

Computer Rendering Of Stochastic Models

Source Communications of the ACM
Volume 25 , Issue 6 (June 1982)
Pages: 371 – 384

Year of Publication: 1982

ISSN:0001-0782

Authors Alain Fournier, Don Fussell, Loren Carpenter

PAPER

Stochastic Sampling In Computer Graphics

Source ACM Transactions on Graphics (TOG)
Volume 5 , Issue 1 (January 1986)
Pages: 51 – 72

Year of Publication: 1986

ISSN:0730-0301

Author: Robert L. Cook

Z-buffer

Z-Buffer is regarded as a variant of the Painters Algorithm.
In computer graphics, z-buffering is the management of image depth coordinates in three-dimensional (3-D) graphics, usually done in hardware, sometimes in software.

When an object is rendered by a 3D graphics card, the depth of a generated pixel (z coordinate) is stored in a buffer (the z-buffer or depth buffer). This buffer is usually arranged as a two-dimensional array (x-y) with one element for each screen pixel.

If another object of the scene must be rendered in the same pixel, the graphics card compares the two depths and chooses the one closer to the observer. The chosen depth is then saved to the z-buffer, replacing the old one. In the end, the z-buffer will allow the graphics card to correctly reproduce the usual depth perception: a close object hides a farther one. This is called z-culling.

PAPER

A Hidden-Surface Algorithm With Anti-Aliasing

Source International Conference on Computer Graphics and Interactive Techniques
Proceedings of the 5th annual conference on Computer graphics and interactive techniques

Year of Publication: 1978

Author Edwin Catmull

PAPER

Rendering Antialiased Shadows with Depth Maps

Source Computer Graphics, Volume 21, Number 4, July 1987 III

Year of Publication: 1987

Authors:
William T. Reeves
David 1-1. Salesin
Robert L. Cook
Pixar
San Rafael, CA

A-buffer

A-Buffer is regarded as a variant of the Z-Buffer Algorithm.

The A-buffer (anti-aliased, area-averaged, accumulation buffer) is a general hidden surface mechanism suited to medium scale virtual memory computers. It resolves visibility among an arbitrary collection of opaque, transparent, and intersecting objects.

Using an easy to compute Fourier window (box filter), it increases the effective image resolution many times over the Z-buffer, with a moderate increase in cost.

The A-buffer is incorporated into the REYES 3-D rendering system at Lucasfilm and was used successfully in the “Genesis Demo” sequence in Star Trek II.

PAPER

The A -buffer, An Antialiased Hidden Surface Method

Source ACM SIGGRAPH Computer Graphics
Volume 18 , Issue 3 (July 1984)
Pages: 103 – 108

Year of Publication: 1984

ISSN:0097-8930

Author Loren Carpenter

PAPER

R-buffer: A Pointerless A-buffer Hardware Architecture

Source SIGGRAPH/EUROGRAPHICS Conference On Graphics Hardware
Proceedings of the ACM SIGGRAPH/EUROGRAPHICS workshop on Graphics hardware
Los Angeles, California, United States
Pages: 73 – 80

Year of Publication: 2001

ISBN:1-58113-407-X

Author: Craig M. Wittenbrink

PAPER

The Reyes Image Rendering Architecture

Source ACM SIGGRAPH Computer Graphics
Volume 21 , Issue 4 (July 1987)
Pages: 95 - 102

Year of Publication: 1987

ISSN:0097-8930

Authors Robert L. Cook, Loren Carpenter, Edwin Catmull (Pixar)

So – Digital Compositing + Scanline + Z-Buffer + A-Buffer + Depth Maps = Luxo Jnr.

MOVIE

Ray Tracing

Ray tracing is a technique for generating an image by tracing the path of light through pixels in an image plane and simulating the effects of its encounters with virtual objects.

The technique is capable of producing a very high degree of visual realism, but at a greater computational cost.

This makes ray tracing best suited for applications where the image can be rendered slowly ahead of time, and more poorly suited for real-time applications like computer games where speed is critical.

Ray tracing is capable of simulating a wide variety of optical effects, including:

- Reflection
- Refraction
- Scattering
- Shadowing
- Chromatic aberration

Ray Tracing

Radiosity

Real-Time Ray Tracing (NVIDIA)

MOVIE

Real-Time Radiosity (DALI)

MOVIE

Volume

A typical Volume rendering 3D data set is a group of 2D slice images acquired by a CT, MRI, or Micro-CT scanner.

These are acquired in a regular slices, such as one every millimetre.
Each volume element, or voxel, is represented by a single value that is obtained by sampling the immediate 3d space.

Volume rendering is a computationally intensive task that may be performed in several ways.

Typically a volume rendering may be viewed by extracting surfaces of equal values from the volume and rendering them as polygonal meshes or by rendering the volume directly as a block of data.

The Marching Cubes algorithm is a common technique for extracting a surface from volume data.

PAPER

Illustrative Context-Preserving Volume Rendering

Authors: Stefan Bruckner, Sören Grimm, Armin Kanitsar, Meister Eduard Gröller

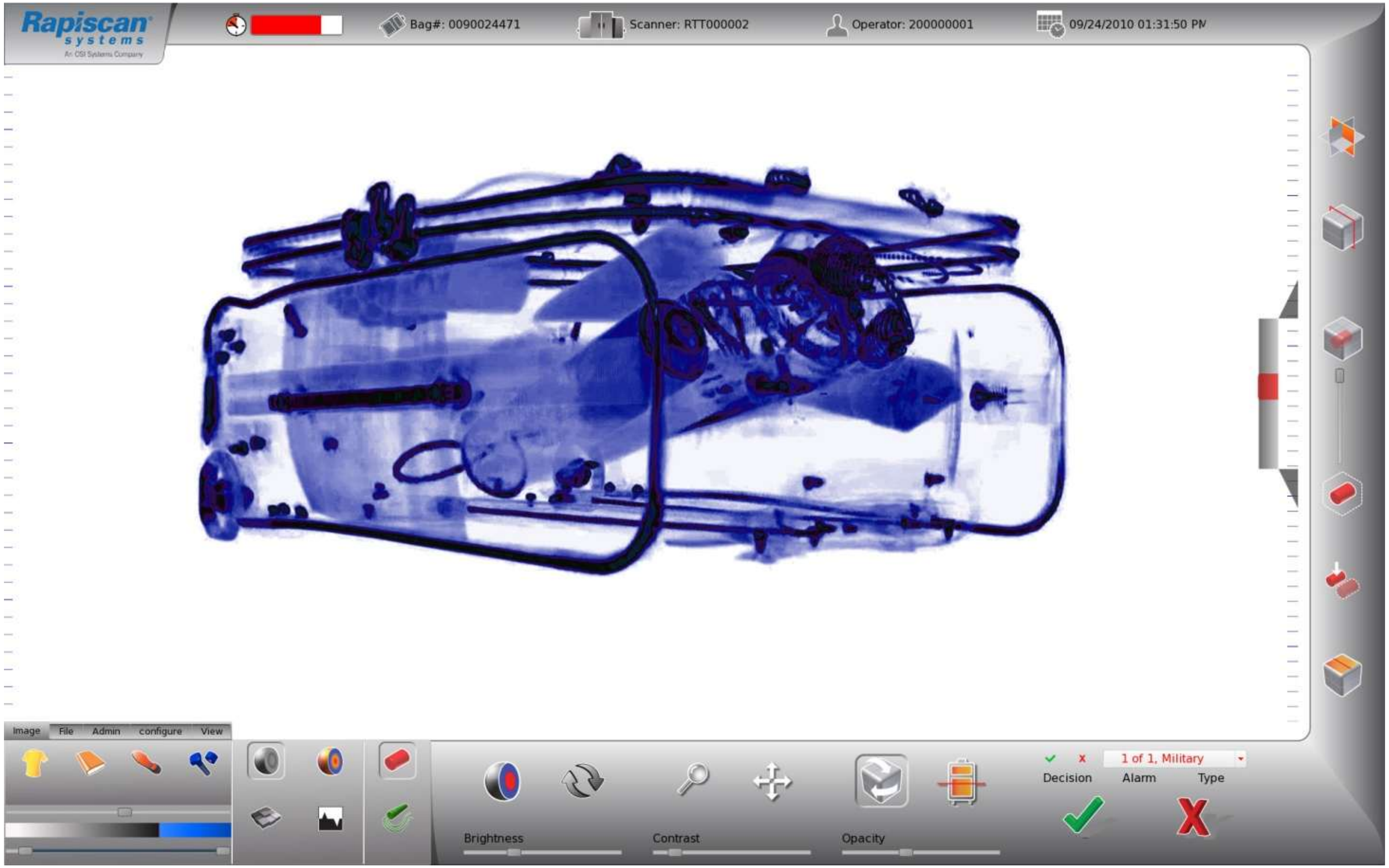
In Proceedings of EuroVis 2005, pages 69-76. May 2005.

Illustrative Context-Preserving Volume Rendering

Real-Time Volume Rendering

- Very state of the art
- Gareth's company pioneering this technology
- 1.5 seconds to process CAT slice data!
- Could be a lot faster!
- CUDA

Real-Time Volume Rendering



Real-Time Volume Rendering

- MOVIE 1
- MOVIE 2

Area/Volume Subdivision using Quadtrees & Octrees

An octree is a tree data structure in which each internal node has up to eight children. Octrees are most often used to partition a three dimensional space by recursively subdividing it into eight octants. Octrees are the three-dimensional analogue of quadtrees.

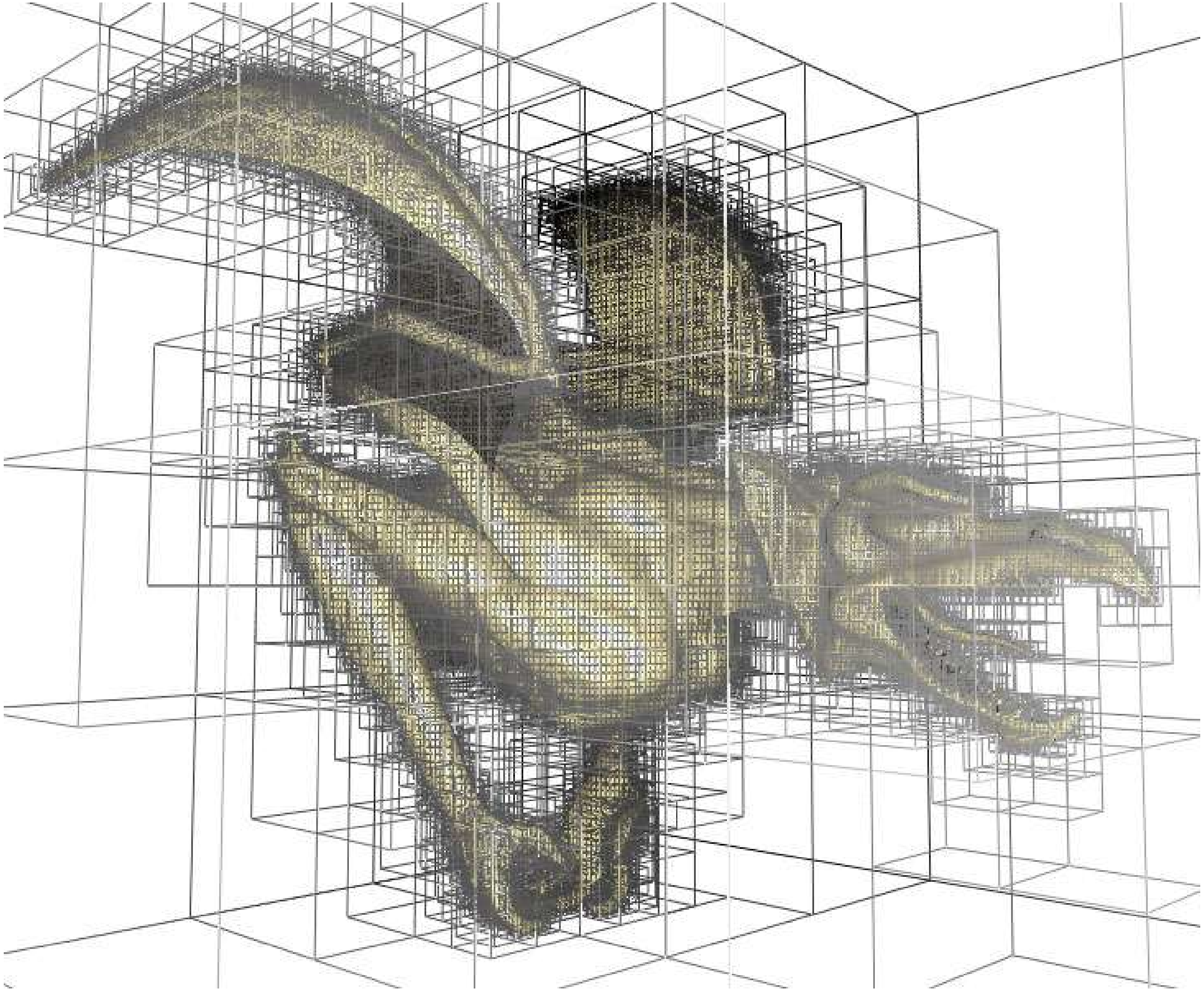
Each node in an octree subdivides the space it represents into eight octants. In a point region (PR) octree, the node stores an explicit 3-dimensional point, which is the "centre" of the subdivision for that node; the point defines one of the corners for each of the eight children.

There are other types of Octrees, such MX and kD.

Common uses of Octrees:

- Spatial indexing
- Efficient collision detection in three dimensions
- View frustum culling
- Unstructured grid
- Finite element analysis
- Etc...

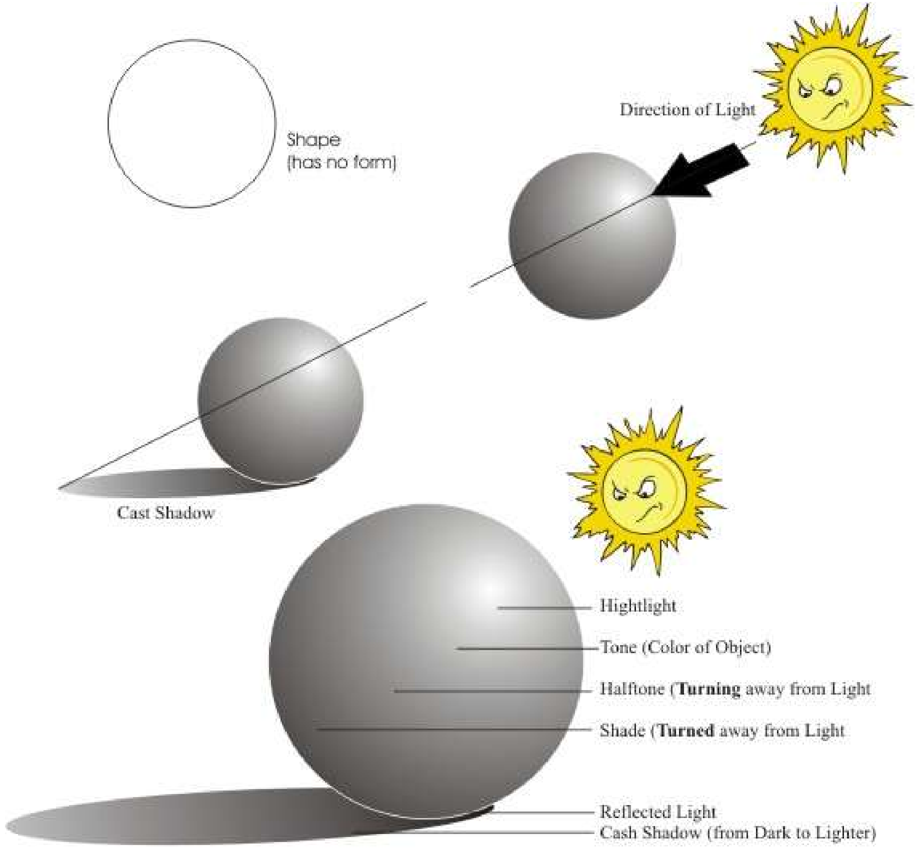
Area/Volume Subdivision using Octrees



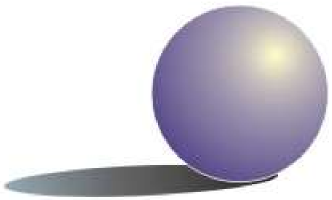
Shading

In computer graphics, Shading refers to the process of altering a colour based on its angle to lights and its distance from lights to create a photorealistic effect. Shading is performed during the rendering process.
Shading is interpolated based on how the angle of these light sources reaches the objects within a scene.

Shading



Shape
(has no form)
Direction of Light
Cast Shadow
Hightlight
Tone (Color of Object)
Halftone (**Turning** away from Light
Shade (**Turned** away from Light
Reflected Light
Cash Shadow (from Dark to Lighter)



Anti-aliasing

Anti-aliasing means removing signal components that have a higher frequency than is able to be properly resolved by the recording (or sampling) device. This removal is done before (re)sampling at a lower resolution.

Typically anti-aliasing is effected in Rendering by super-sampling visible surfaces within each pixel.

There are many different types of super-samplings, including:

- Grid
- Random
- Jitter

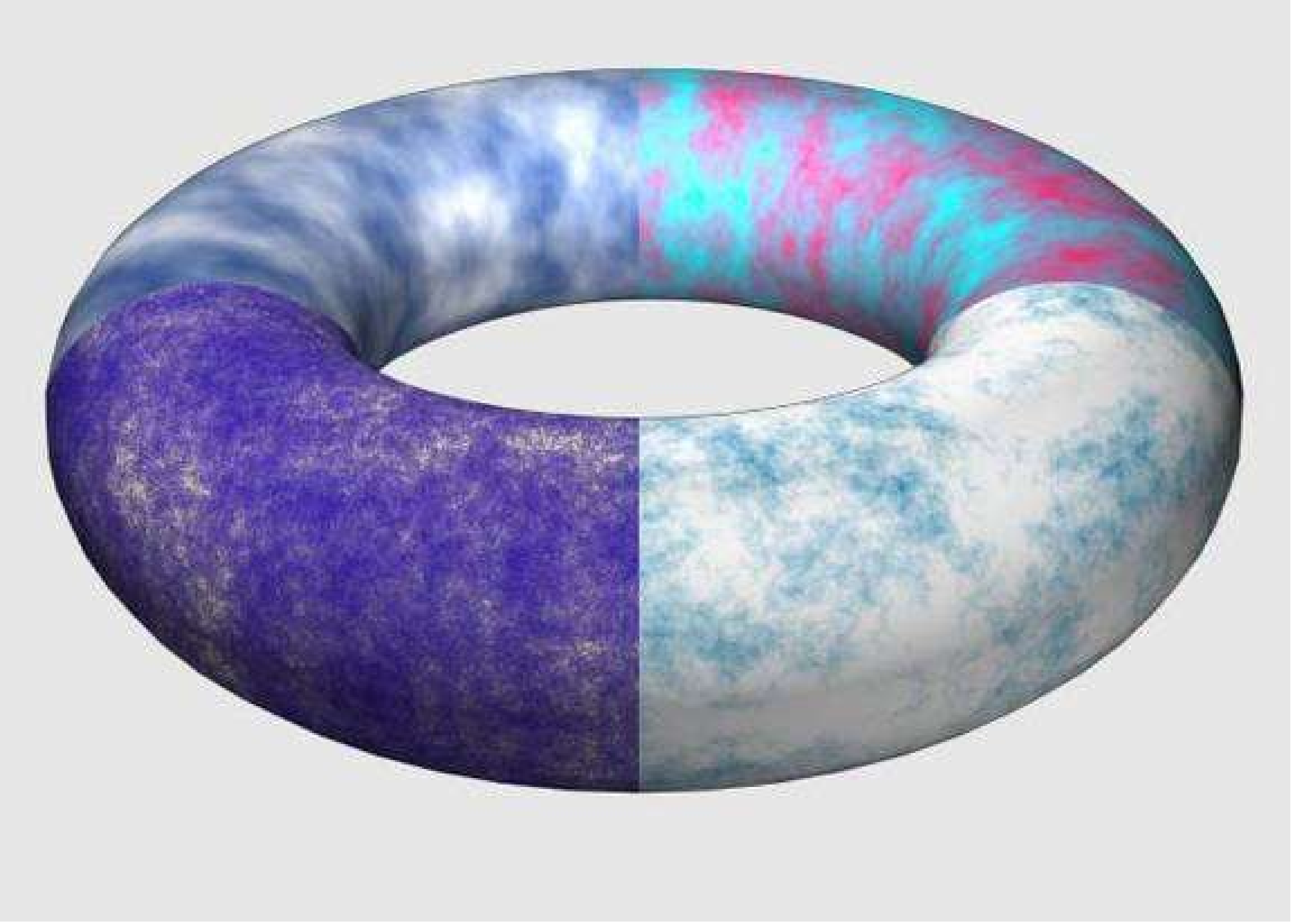
Texturing

There are many different types of texturing, including:

- Colour
- Bump
- Displacement
- Light
- Normal

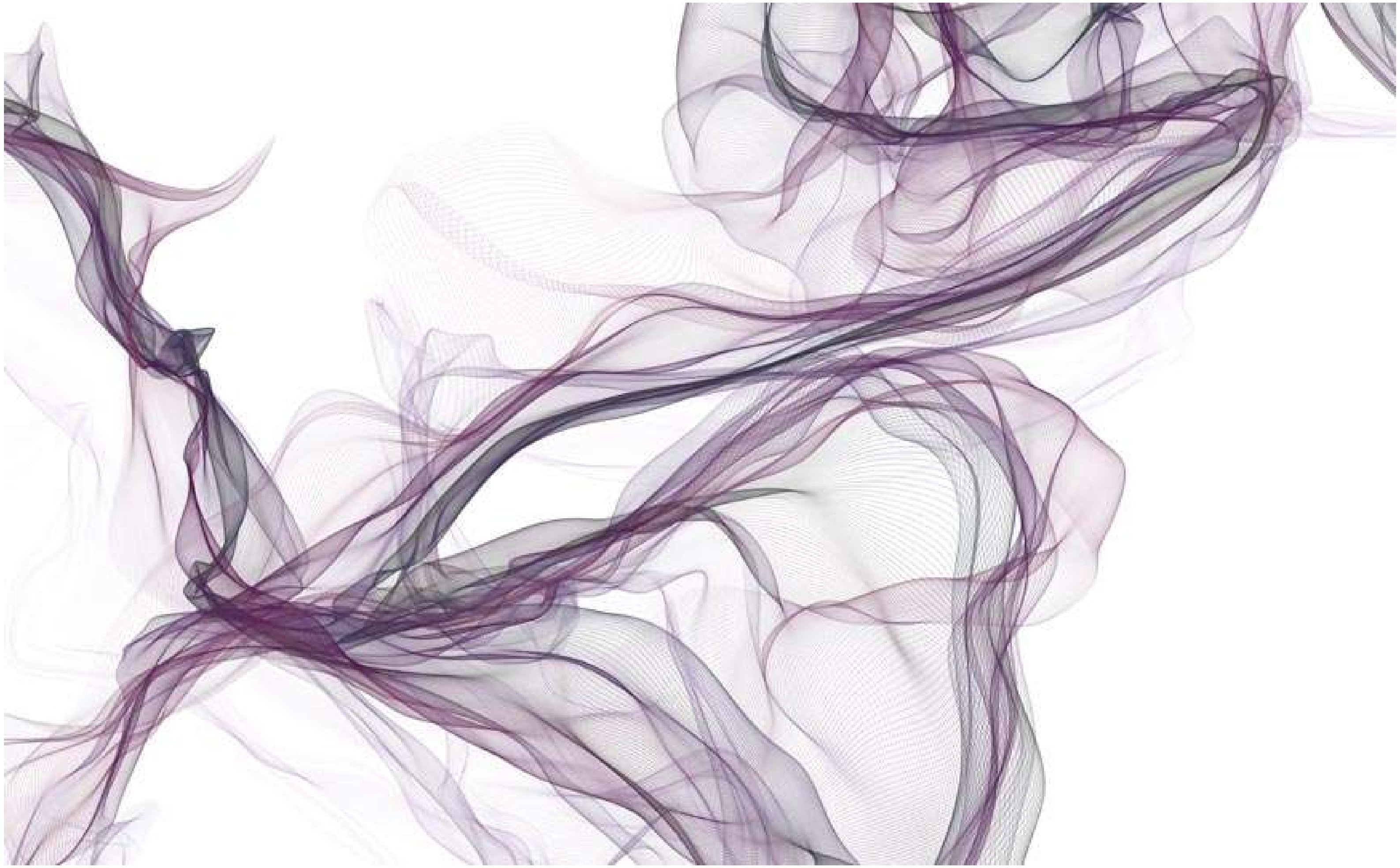
Solid Texturing

Ken Perlin - Doughnuts



Solid Texturing

Ken Perlin - Ribbons



PAPER

An Image Synthesizer

Movie

Source International Conference on Computer Graphics and Interactive Techniques
Proceedings of the 12th annual conference on Computer graphics and interactive techniques
Pages: 287 – 296

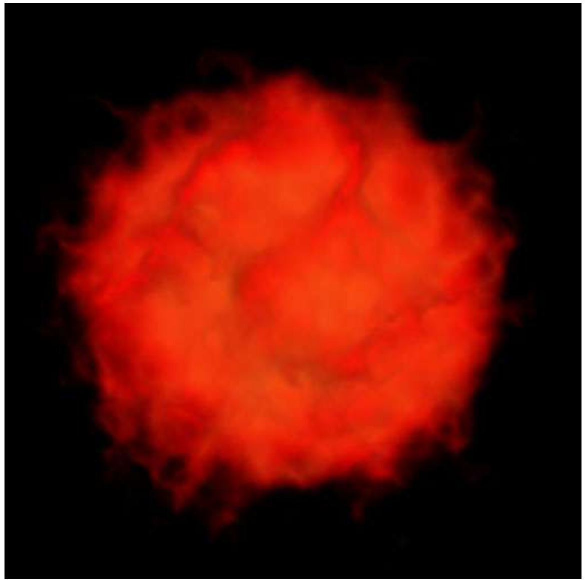
Year of Publication: 1985

ISBN:0-89791-166-0

Author: Ken Perlin Courant Institute of Mathematical Sciences, New York University

PAPER

Hypertexture



[Movie]

Source International Conference on Computer Graphics and Interactive Techniques
Proceedings of the 16th annual conference on Computer graphics and interactive techniques
Pages: 253 – 262

Year of Publication: 1989

ISBN:0-89791-312-4

Authors
K. Perlin, Courant Institute of the Mathematical Sciences, New York University
E. M. Hoffert, AT&T Pixel Machines

END

Reading for next term.....

- Dunn & Parberry Chapter 15 & 16
- Lengyel Chapters 5 through to 10

Future Reading (or as soon as you can) .....

- For future reading – a very good book:
  - **Physically Based Rendering: From Theory To Implementation“**

    Matt Pharr;