CSE 167: Introduction to Computer Graphics Lecture #16: Particle Systems

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Announcements

- Wednesday, Nov 28: Last day for late grading of project 6
- Thursday, Nov 29: Midterm exam #2
- Friday, Nov 30: Final project summary due
- Thursday, Dec 13: Final project presentations in EBU-3B room 1202, 3-6pm
- Looking for TAs and Tutors for CSE190: 3D UI

Demo

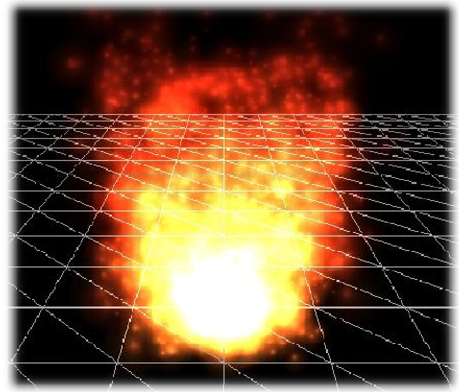
- Geisel Returns Home
  - By Robert Pardridge, Christopher Jenkins, Kevin Reynolds
  - “It is well known that Geisel Library resembles a huge spaceship. Almost every UCSD student has this thought at least once while walking past the library.“

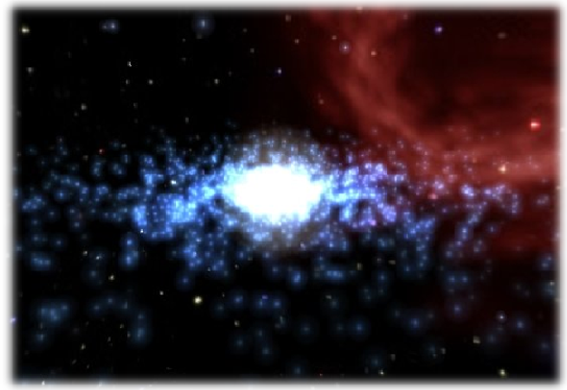
Lecture Overview

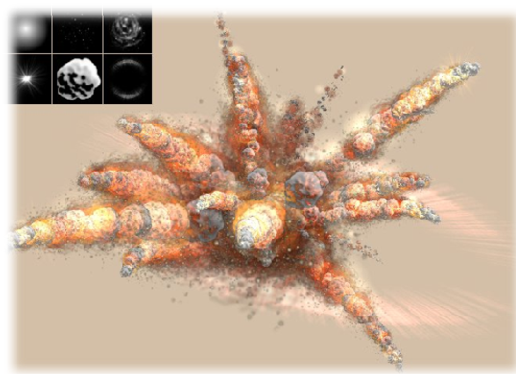
- Particle Systems
- Collision Detection
- Volume Rendering

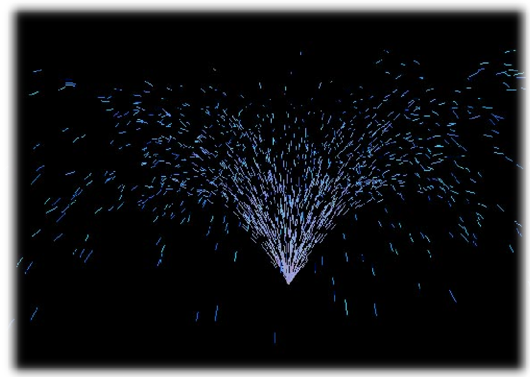
Particle Systems

- Used for:
  - Fire/sparks
  - Rain/snow
  - Water spray
  - Explosions
  - Galaxies







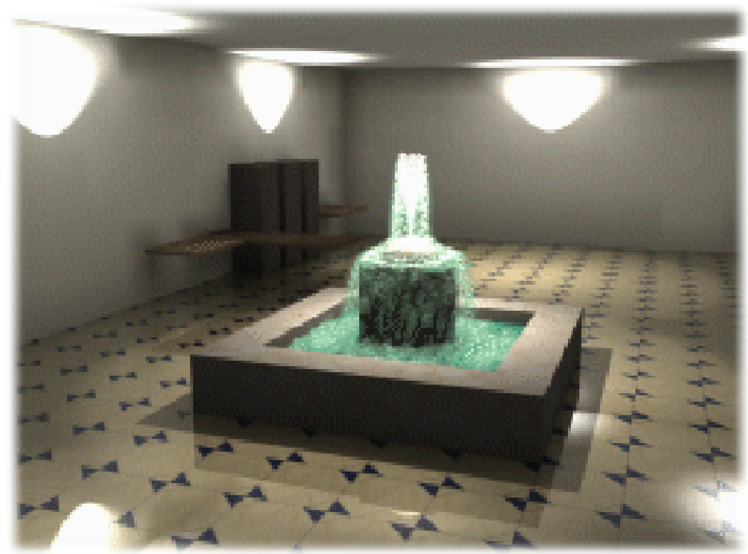


Internal Representation

- Particle system is collection of a number of individual elements (particles)
  - Controls a set of particles which act autonomously but share some common attributes
- Particle Emitter: Source of all new particles
  - 3D point
  - Polygon mesh: particles' initial velocity vector is normal to surface
- Particle attributes:
  - position (3D)
  - velocity (vector: speed and direction)
  - color + opacity
  - lifetime
  - size
  - shape
  - weight

Dynamic Updates

- Particles change position and/or attributes with time
- Initial particle attributes often created with random numbers
- Frame update:
  - Parameters: simulation of particles, can include collisions with geometry
    - Forces (gravity, wind, etc) accelerate a particle
    - Acceleration changes velocity
    - Velocity changes position
  - Rendering: display as
    - OpenGL points
    - (Textured) billboarded quads
    - Point sprites



Source: http://www.particlesystems.org/

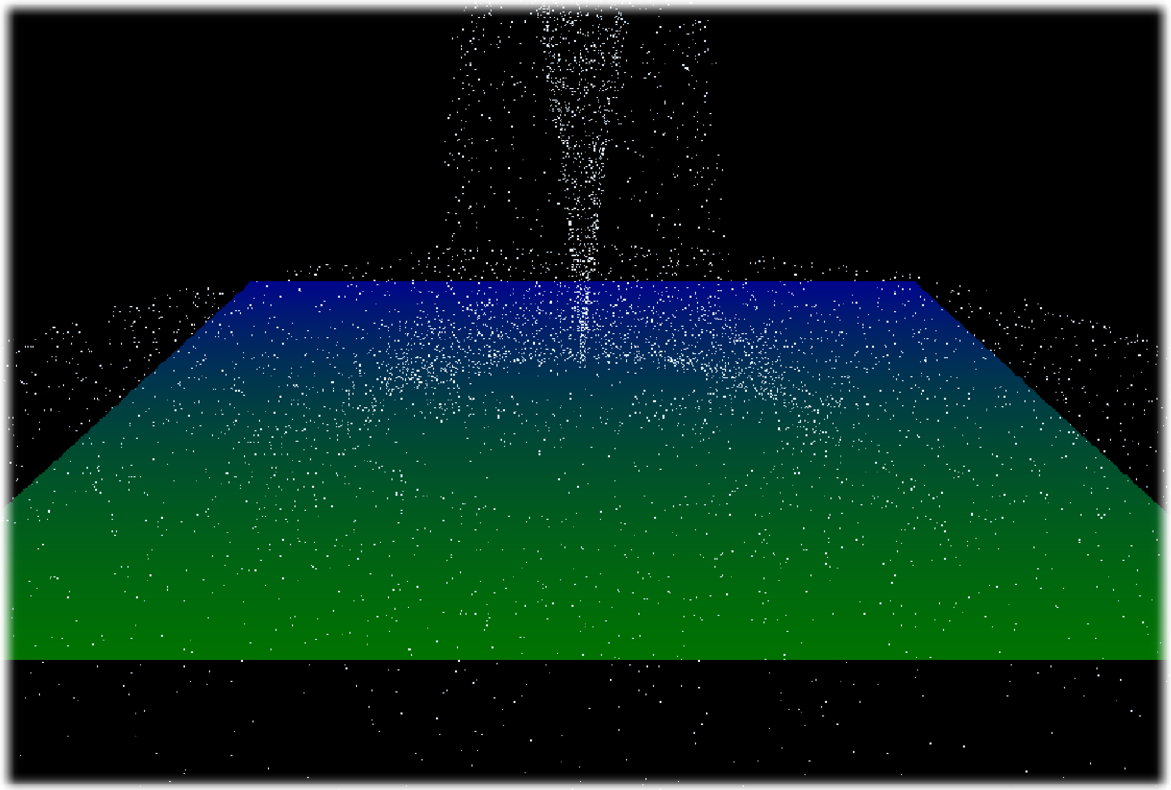
Point Sprite

- **Screen-aligned element of variable size**
- **Defined by single point**
- **Sample code:**

```
glTexEnvf(GL_POINT_SPRITE, GL_COORD_REPLACE, GL_TRUE);
glEnable(GL_POINT_SPRITE);
glBegin(GL_POINTS);
  glVertex3f(position.x, position.y, position.z);
glEnd();
glDisable(GL_POINT_SPRITE);
```

Demo

- Source:
  http://www.particlesystems.org/Distrib/Particle221Demos.zip



References

- Free particle systems API (not for final project):
  - http://particlesystems.org/
- On-line tutorial:
  - http://www.naturewizard.com/tutorial08.html
- Initial scientific paper:
  - Reeves: "Particle Systems - A Technique for Modeling a Class of Fuzzy Objects", ACM Transactions on Graphics (TOG) Volume 2 Issue 2, April 1983
- Article with source code:
  - Jeff Lander: "The Ocean Spray in Your Face", Game Developer, July 1998, http://www.darwin3d.com/gamedev/articles/col0798.pdf
- John Van Der Burg: "Building an Advanced Particle System", Gamasutra, June 2000
  - http://www.gamasutra.com/view/feature/3157/building_an_advanced_particle_.php

Lecture Overview

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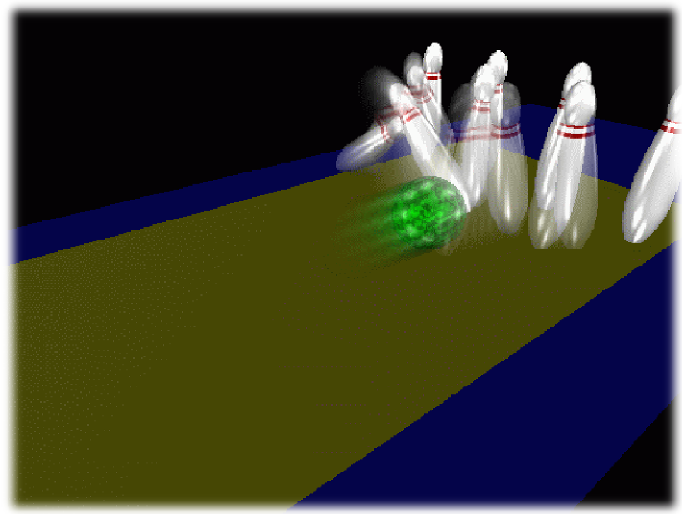
- Collision Detection
- Volume Rendering

Collision Detection

- Goals:
  - Physically correct simulation of collision of objects
    - Not covered here
  - Determine if two objects intersect
- Slow calculation because of exponential growth $O(n^2)$:
  - # collision tests = n*(n-1)/2



Intersection Testing

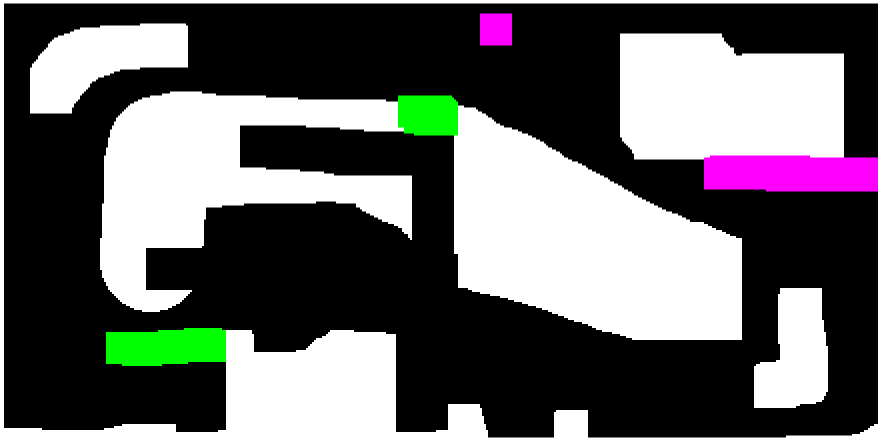
- Purpose:
  - Keep moving objects on the ground
  - Keep moving objects from going through walls, each other, etc.
- Goal:
  - Believable system, does not have to be physically correct
- Priority:
  - Computationally inexpensive
- Typical approach:
  - Spatial partitioning
  - Object simplified for collision detection by one or a few
    - Points
    - Spheres
    - Axis aligned bounding box (AABB)
  - Pairwise checks between points/spheres/AABBs and static geometry

Sweep and Prune Algorithm

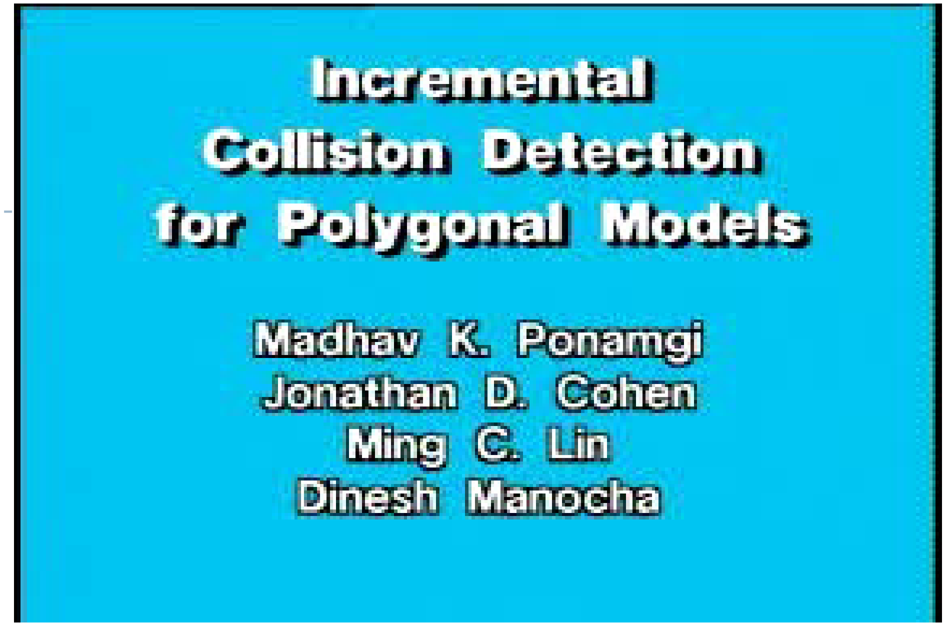
- Sorts bounding boxes
- Not intuitively obvious how to sort bounding boxes in 3-space
- Dimension reduction approach:
  - Project each 3-dimensional bounding box onto the x,y and z axes
  - Find overlaps in 1D: a pair of bounding boxes can overlap if and only if their intervals overlap in all three dimensions
    - Construct 3 lists, one for each dimension
    - Each list contains start/end point of intervals corresponding to that dimension
    - By sorting these lists, we can determine which intervals overlap
    - Reduce sorting time by keeping sorted lists from previous frame, changing only the interval endpoints
- Alternative: project bounding boxes onto coordinate axis planes and look for overlaps in 2D

Collision Map (CM)

- 2D map with information about where objects can go and what happens when they go there
- Colors indicate different types of locations
- Map can be computed from 3D model, or hand drawn with paint program
- Granularity: defines how much area (in object space) one CM pixel represents



References



- I-Collide:
  - Interactive and exact collision detection library for large environments composed of convex polyhedra
  - http://gamma.cs.unc.edu/I-COLLIDE/
- OZ Collide:
  - Fast, complete and free collision detection library in C++
  - Based on AABB tree
  - http://www.tsarevitch.org/ozcollide/

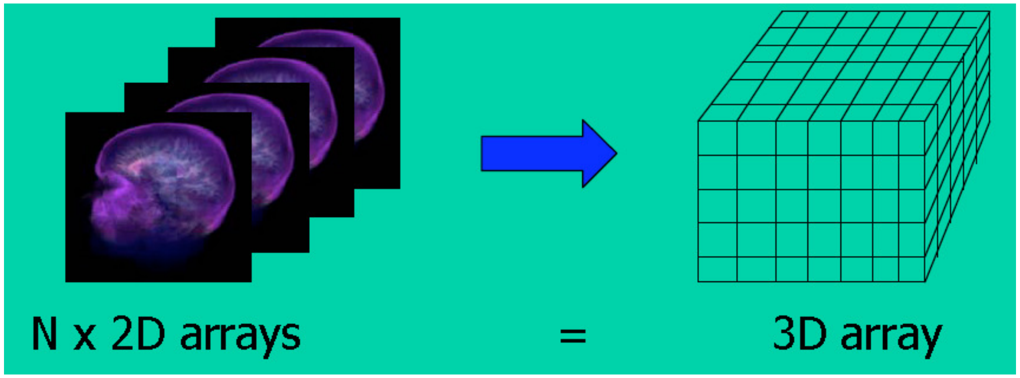
Lecture Overview

- Particle Systems
- Collision Detection
- Volume Rendering

What is Volume Rendering

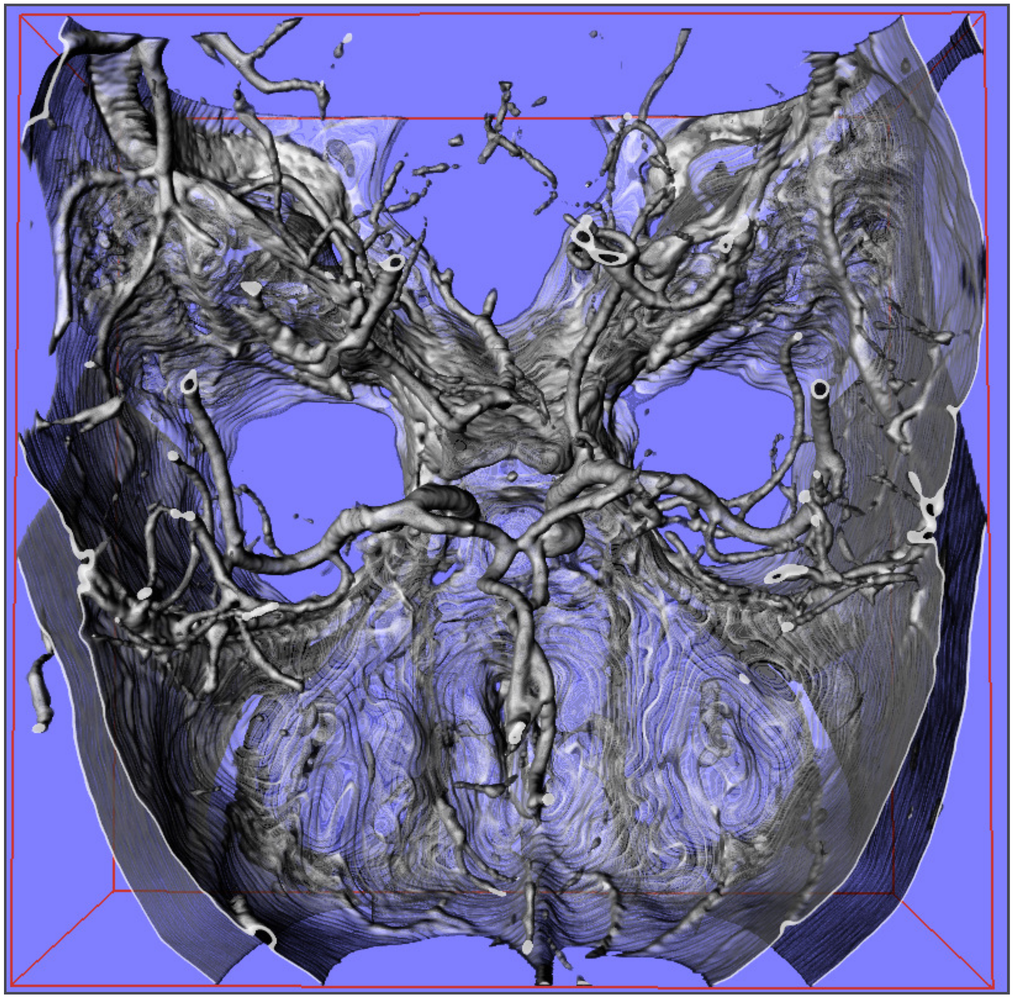
- A *Volume* is a 3D array of voxels (volume elements, 3D equivalent of pixels)
- 3D images produced by CT, MRI, 3D mesh-based simulations are easily represented as volumes
- The *Voxel* is the basic element of the volume
  Typical volume size may be 128^3 voxels, but any other size is acceptable.
- *Volume Rendering* means rendering the voxel-based data into a viewable 2D image.

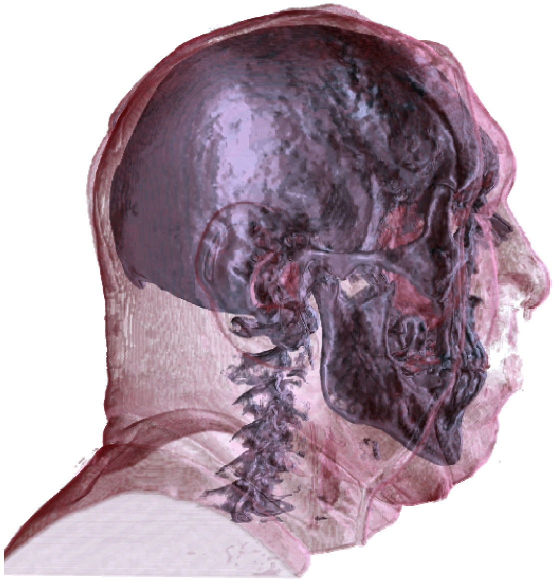
Volume Data Types



- 3D volume data are represented by a finite number of cross-sectional slices (3D grid)
- Each voxel stores a data value
  - Single bit: binary data set
  - Typical: 8 or 16 bit integers
  - Simulations often generate floating point
  - Sometimes multi-valued (multiple data values per voxel), for instance RGB, multi-channel confocal microscopy

Applications: Medicine





CT Human Head:

Visible Human Project, US National Library of Medicine, Maryland, USA

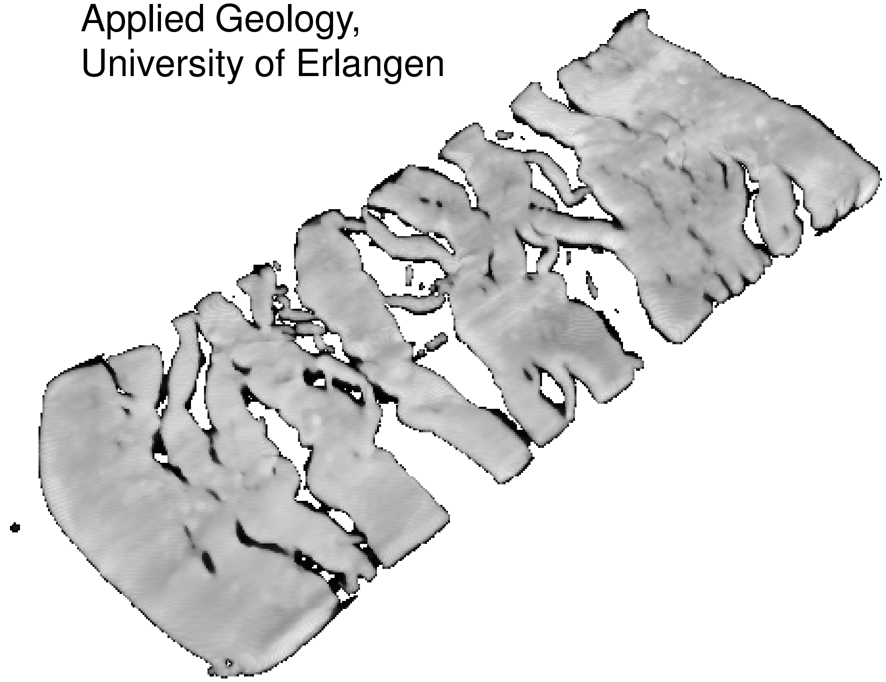
CT Angiography:

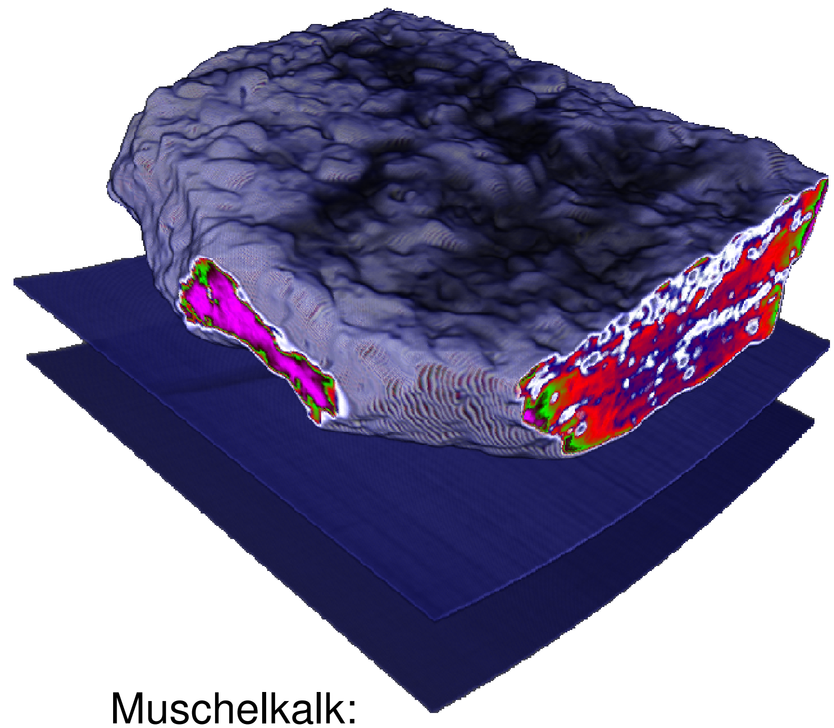
Dept. of Neuroradiology University of Erlangen, Germany

This and some of the following slides are from a Eurographics 2006 course by Dr. Christof Rezk Salama, Computer Graphics and Multimedia Group, University of Siegen, Germany

Applications: Geology

Deformed Plasticine Model,
Applied Geology,
University of Erlangen





Muschelkalk:
Paläontologie,
Virtual Reality Group,
University of Erlangen

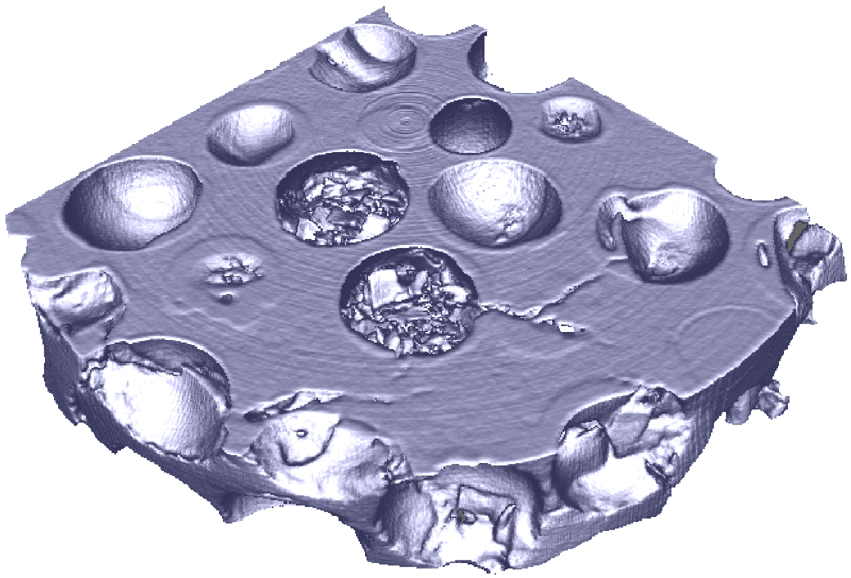
Applications: Archaeology

Hellenic Statue of Isis
3rd century B.C.
ARTIS, University of Erlangen-Nuremberg, Germany

Sotades Pygmaios Statue
5th century B.C
ARTIS, University of Erlangen-Nuremberg, Germany

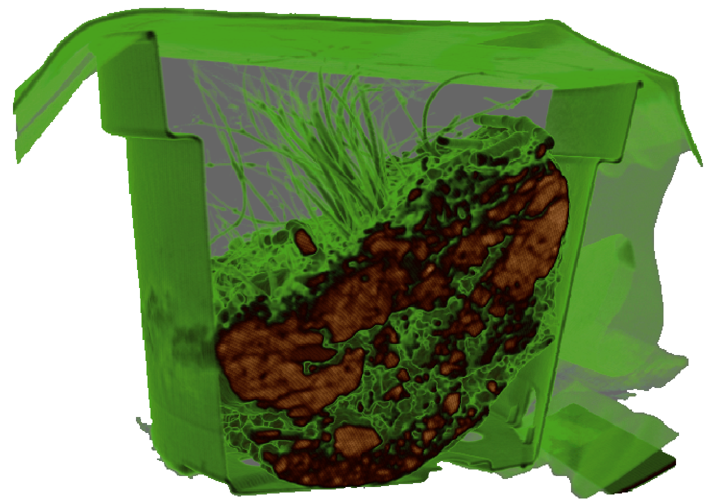
Applications

Material Science, Quality Control



Micro CT, Compound Material
Material Science Department, University of Erlangen

Biology



Biological sample of soil, CT
Virtual Reality Group, University if Erlangen

Applications

Computational Science and Engineering