Modeling

CMSC 435/634

Modeling?

Modeling

Creating a *model* of an object, usually out of a collection of simpler *primitives*

Primitive

A basic shape handled directly the rendering system

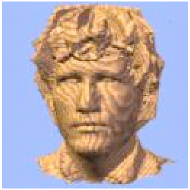
Primitives

Some common primitives

- Triangles & Polygons
  - Most common, usually the only choice for interactive
- Patches, Spheres, Cylinders, ...
  - Often converted to simpler primitives within the renderer
- Volumes
  - What's at each point in space?
  - Often with some transparent material
  - Few renderers handle both volume & surface models

Composing primitives

- Collections of large numbers of primitives
  - Sometimes called Boundary Representation (*BRep*)
- Constructive Solid Geometry (*CSG*)
  - Set operations (union, intersection, difference)
- Implicit Models & Blobs
  - Surface where f(x,y,z)=0
  - Sum, product, etc. of simpler functions



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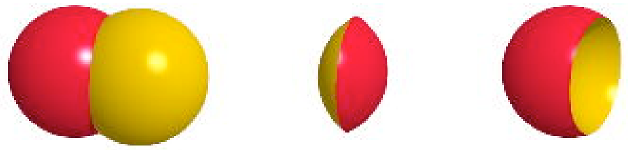

Images: Friedrich Lohmueller

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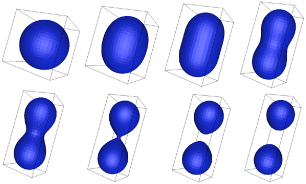

Images: Paul Bourke

Modeling Approaches

- Manual primitive creation
- Procedural
- Scan from physical object
- From data (visualization)
- Through image capture (image-based rendering)

Modeling Approaches

- Manual primitive creation
- Procedural
  - Fractals
  - Implicit Functions
  - Grammars
  - Simulations
- Scan from physical object
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Manual Creation

- Text editor
  - Only very simple primitives and scenes
- High-level primitives
  - Still need to combine several somehow
- Modeling programs
  - Maya, 3D Studio, Houdini, Autocad, Blender, ...

Modeling Approaches

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Procedural Modeling

- Describe physical attributes through code
  - Shape
    - Output primitives
  - Density
    - Voxels
    - Couple with a conversion or rendering algorithm
  - Color, Texture
    - Enhance an existing shape

Procedural Approaches

- Fractals
- Implicit Functions
- Grammars
- Simulations

Fractals

Complex structure through self-similarity across scales

- Recursive structure
- Small features look *similar* to larger features

Iterated Equations / Mandelbrot Set

$$p' = p^2 + c$$

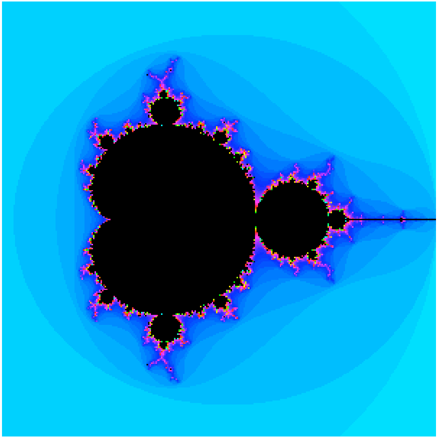
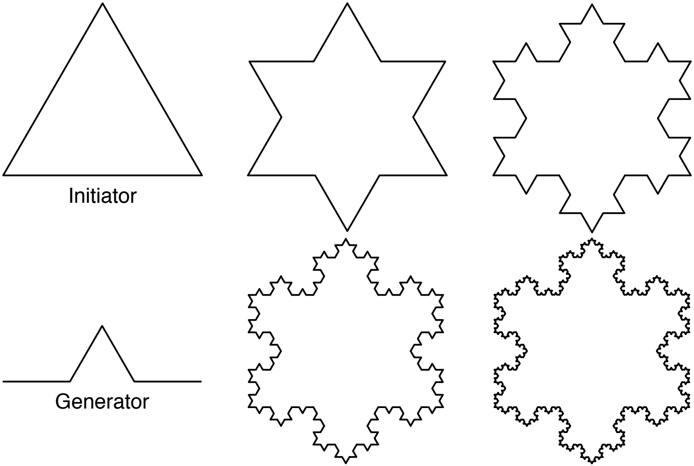


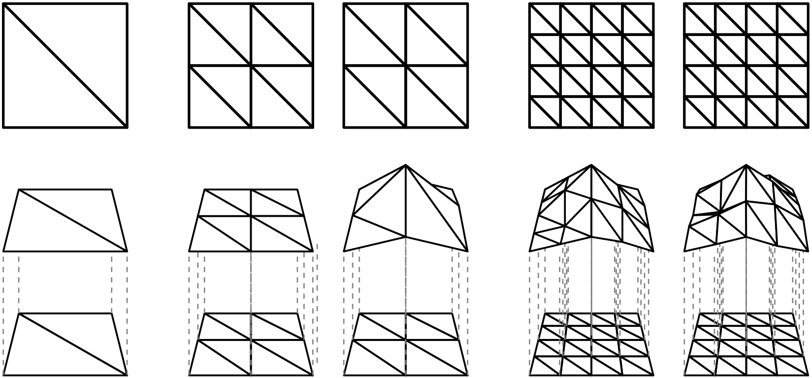
Image: David E. Joyce

Iterated Replacement / Koch Curve



Iterated Replacement / Mountains

Randomness in replacement



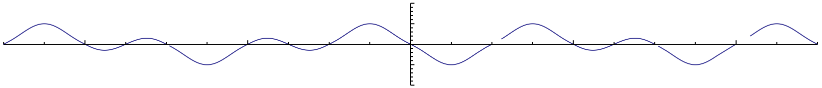
Spectral Synthesis

- Spectral energy a function of frequency
  - Higher frequency, less energy
  - Characterizes roughness of surface
  - Natural phenomena tend to be $1/f$

Noise-Based Synthesis

Band-limited *Perlin noise* function

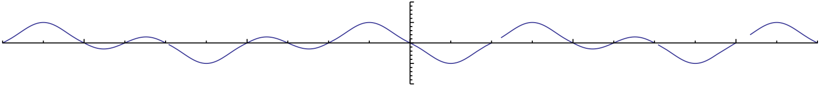
- Most energy between 1/2 and 1 cycle per unit
- Average value is 0
- Random, but repeatable
- 1D, 2D, 3D & 4D versions common



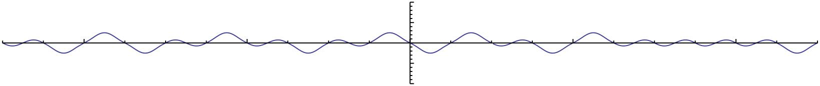
Spectral Synthesis

Sum noise *octaves*

- $n(x) + \frac{1}{2}\ n(2\ x) + \frac{1}{4}\ n(4\ x) + \ldots$
- Stop adding "…" when frequency is too high to see
- Also called *fractional Brownian motion* or *fBm*



$+$



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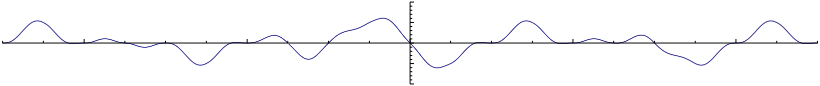

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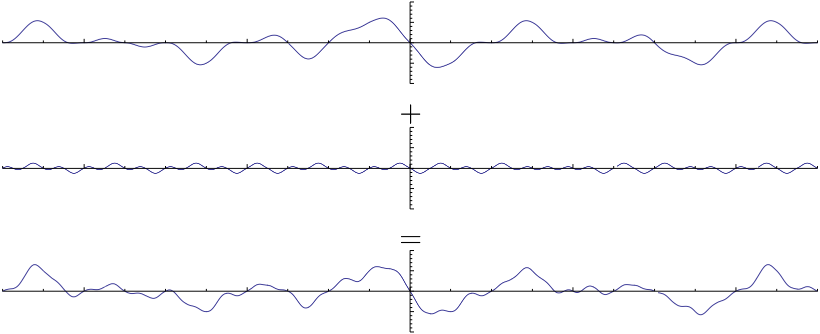

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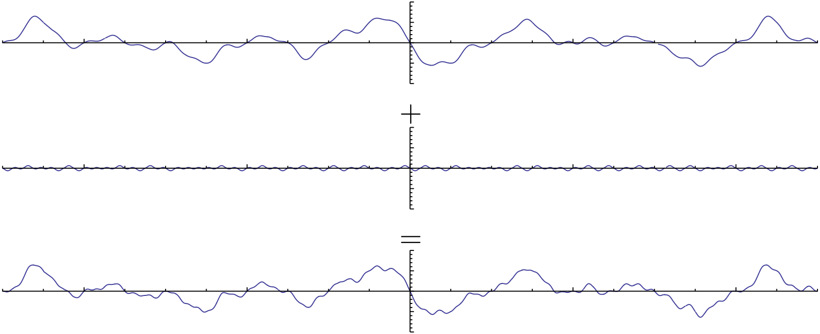


Fractal Landscape

Landscape height is a fractal function of x,y

- Plus whatever embellishments make it look good

Image: Ken Musgrave

Multifractal

- Change roughness across fractal
  - Scaling $(\frac{1}{2}, \frac{1}{4}, \ldots)$ becomes a function
- Here, scale is a function of altitude

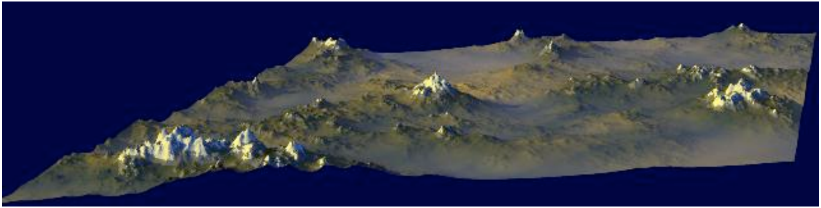
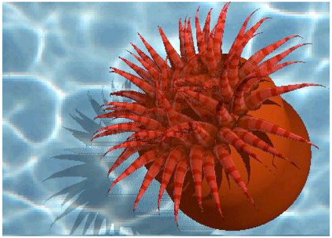


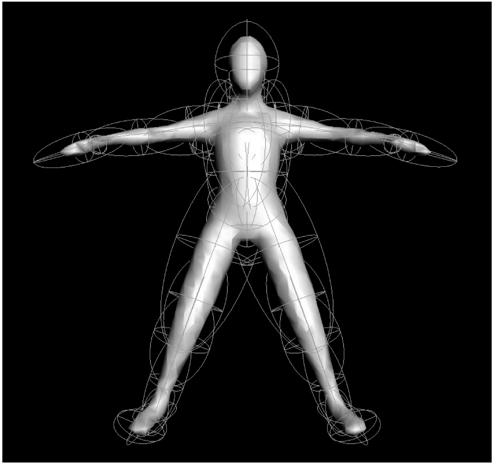
Image: Ken Musgrave

Implicit Functions or Blobby Modeling

- Model as sum of implicit functions
- Surface at threshold



Liang, et al., PG'01

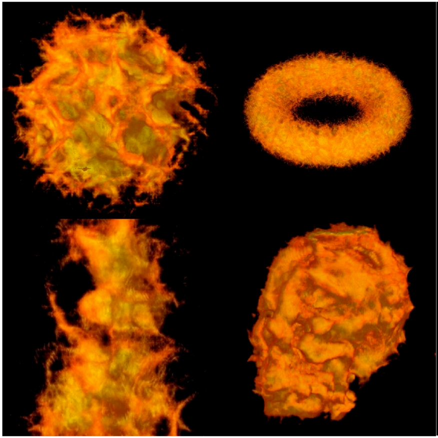
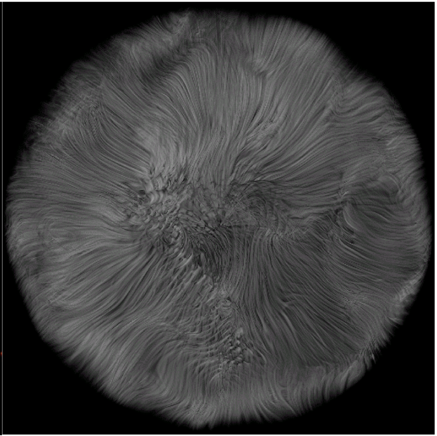


Hybrid Implicit & Polygonal

Bloomenthal, SIGGRAPH 85

Hypertexture

Add noise or turbulence to functions

Perlin & Hoffert, SIGGRAPH 89

Grammar-Based Modeling

- Use (mostly) context-free grammars (CFG) to specify structural change over generations
- Often used to simulate a biological growth process
  - Plants
  - Seashells
- L-systems (Lindenmeyer)

Context-Free Grammar

A CFG $G = (V, T, S, P)$ where

- V is a set of non-terminals
- T is a set of terminals
- S is the start symbol
- P is a set of productions (rules) of the form:
  - $A \to x$, where $A \in V, x \in (V \cup T)^*$

Applying Grammar Rules

- Symbols
  - A, B, straight line segments
  - [ ], branch left 45°
  - ( ), branch right 45°
- Rules
  - $A \to AA$
  - $B \to A[B]AA(B)$
- Strings
  - B
  - $A[B]AA(B)$
    $AA[A[B]AA(B)]AAAA(A[B]AA(B))$

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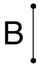

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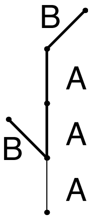

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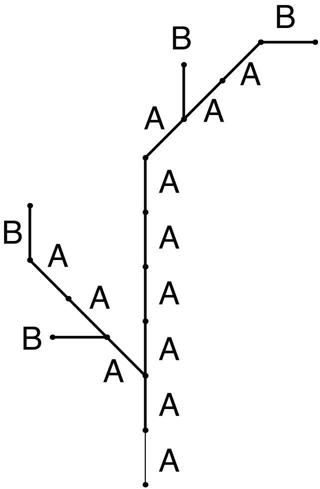
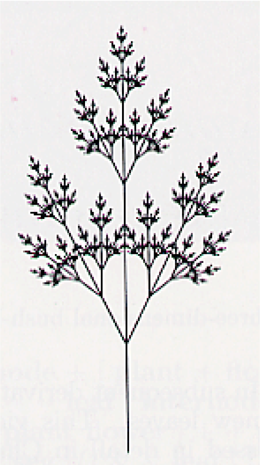


L-System Examples

- Symbols
  - $[/]$ = push/pop
  - $+/-$ = rotate left/right
  - $A - Z$ = straight segment
- Rules
  - $25.7°$, 7 generations
  - $X \rightarrow F[+X][-X]FX$
  - $F \rightarrow FF$



L-System Examples

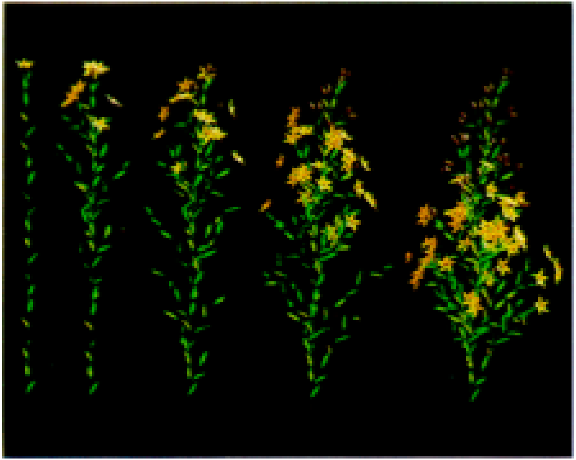
- Rules
  - 22.5°, 5 generations
  - $X \rightarrow F{-}[[X]{+}X]{+}F[{+}FX]{-}X$
  - $F \rightarrow FF$

L-System Examples

- Rules
  - 22.5°, 4 generations
  - $F \to FF - [F + F + F] + [+F - F - F]$

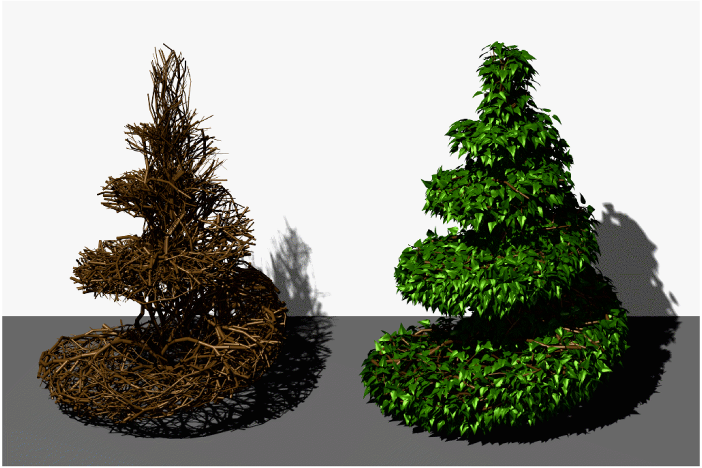
Additions

- 3D structure
- Randomness
- Leaves
- Flowers



Prusinkiewicz, et al., SIGGRAPH 88

Pruning



Prusinkiewicz, et al., SIGGRAPH 94

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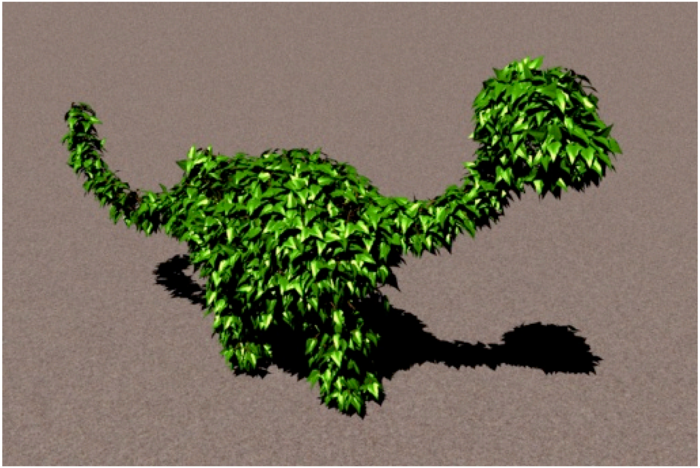


Prusinkiewicz, et al., SIGGRAPH 94

Simulations

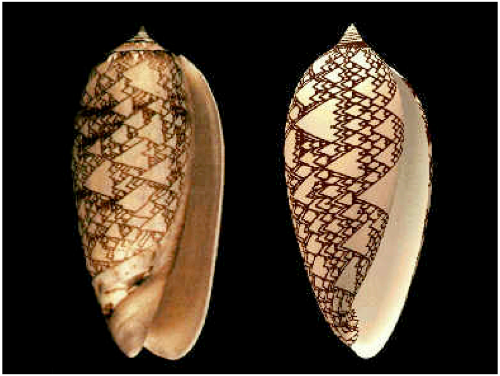
Biological

- Simulate growth, development

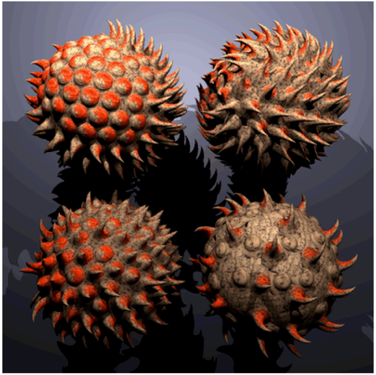
Physical

- Simulate formation or erosion

Biological Simulations



Fowler, et al., SIGGRAPH 92



Fleischer, et al., SIGGRAPH 95

Biological Simulations

Fowler, et al., SIGGRAPH 92

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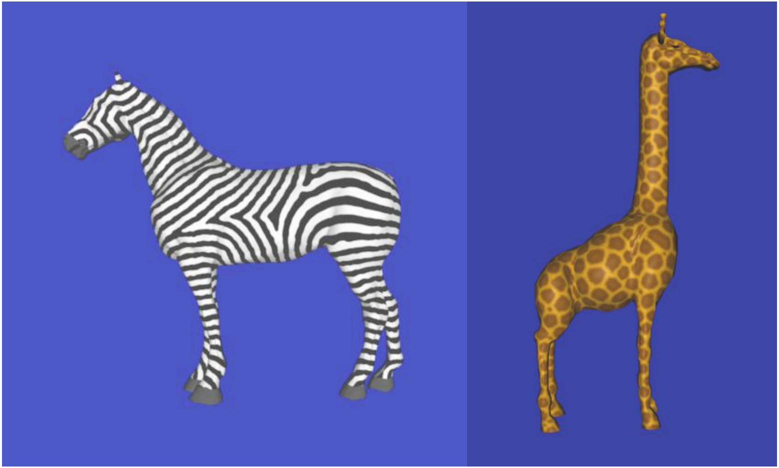
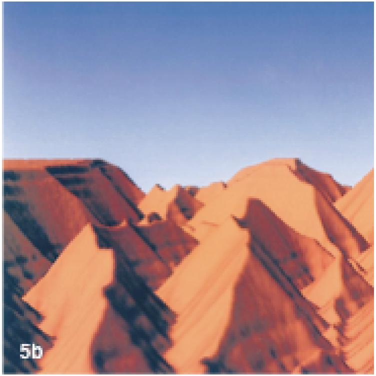


Turk, SIGGRAPH 91

Physical Simulation

Erosion, Deposition



Kenji Nagashima, Visual Computer 1997

Modeling Approaches

- Manual primitive creation
- Procedural
  - Fractals
  - Implicit Functions
  - Grammars
  - Simulations
- Scan from physical object
- From data (visualization)
- Through image capture (image-based rendering)

Scan from Objects

- General concept
  - Find points on surface
  - Connect into mesh
- Mechanical
- Triangulation
  - Laser
  - Structured Light
  - Multiple Cameras
- CAT scan / MRI

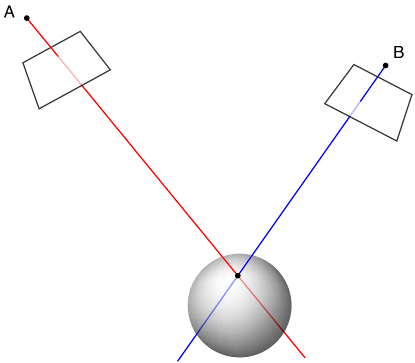
Mechanical

- Touch tip to surface
- Measure angles

Triangulation

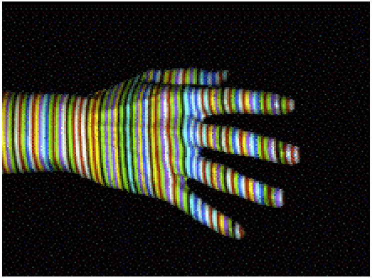
Point in space at intersection

- Ray from light A
- Ray through pixel B

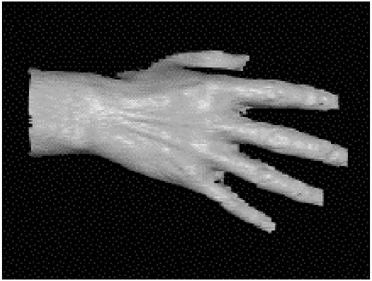


Structured Light

- Point in space at intersection of color edge from light source/projector and ray through camera pixel



projected pattern



resulting model

Zhang, Curless and Seitz, 3DPVT 2002

Modeling Approaches

Manual primitive creation

Procedural

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Scan from physical object

From data (visualization)

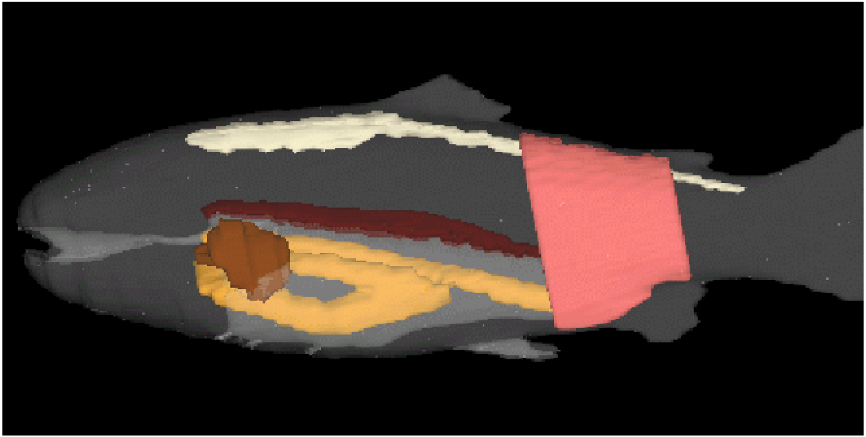
Through image capture (image-based rendering)

Visualization

- Data
  - measurements
  - simulation
  - information
- Present visually
  - Increase understanding
  - Recognize patterns

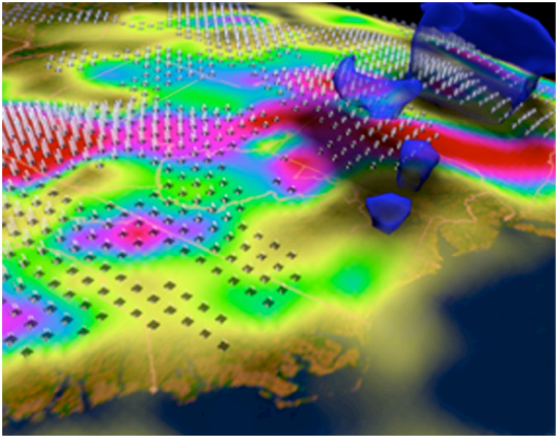
Visualization

Can be 3D Object



Visualization

Can be 3D, but showing non-visual aspects.



Visualization

Can be not traditionally geometric at all

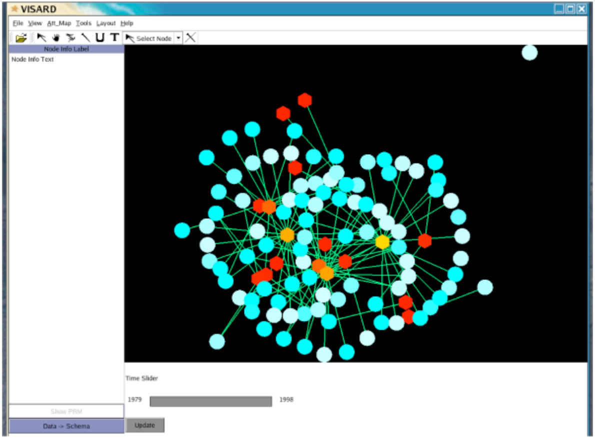


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Image-based Rendering

- Pixels in one or more cameras
  - Color of point in space
  - Color of light along one ray
- IBR
  - Construct new *novel* view using only image data