Cornell University
Center for Advanced Computing

Introduction to Scientific Visualization

Aaron Birkland
Cornell Center for Advanced Computing

Data Analysis on Ranger
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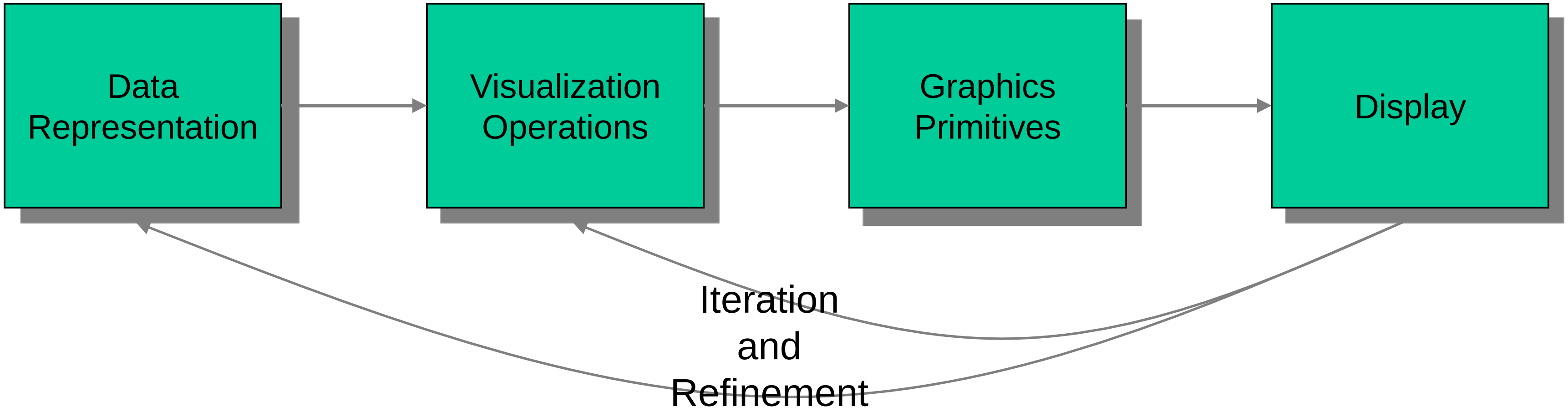
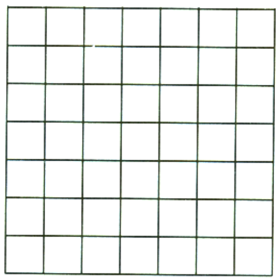
A lab-intensive workshop

- Start off with basic concepts
  - Data, transformations, graphics, techniques
- Learn the tools
  - Hands on with ParaView and VisIt
- Learn the resources
  - Longhorn visualization cluster, large scale parallel visualization.
- Try it out!

From data to Insight

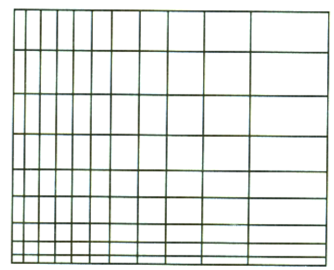


Points, Meshes & Coordinates

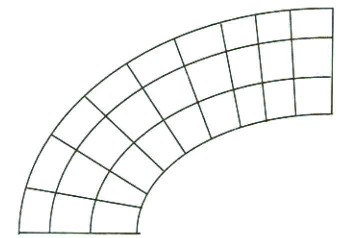


(a) Structured Points

Medical scan



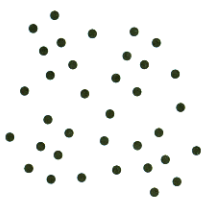
(b) Rectilinear Grid



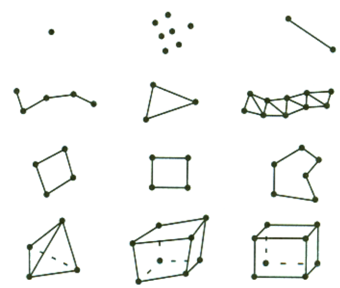
(c) Structured Grid

Engineering Model

N-body simulation

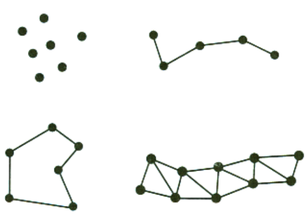


(d) Unstructured Points



(f) Unstructured Grid

Extracted Surface

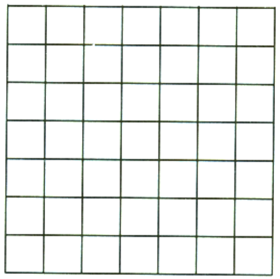


(e) Polygonal Data

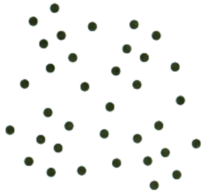
From *The Visualization Toolkit* by Schroeder et al.

Data

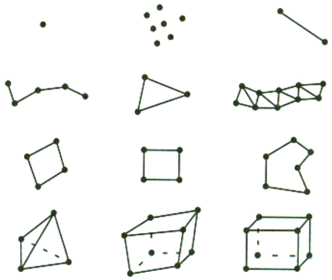
- Values at each point
- Type and nature will determine applicable techniques
  - Scalar, Vector, Tensor?
  - Discrete? Continuous?
  - Nominal, Ordinal, Interval, Ratio?



(a) Structured Points



(d) Unstructured Points



(f) Unstructured Grid

Data Example: Mummy (.vtk)

- Mummy.vtk
  - 128x128x128 regular grid (structured points)
  - Single scalar value at every point

```
# vtk DataFile Version 2.0
test volume
BINARY
DATASET STRUCTURED_POINTS
DIMENSIONS 128 128 128
ASPECT_RATIO 1.886 1.886 1.913
ORIGIN 0.0 0.0 0.0
POINT_DATA 2097152
SCALARS scalars unsigned_char
LOOKUP_TABLE default
^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^
@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@
```

Data Example: Simple unstructured grid (.vtu)

- Two Points: {(1, 3, 5), (2, 4, 6)}
  - Vector data: Force: {(0, 2, 4), (1, 3, 5)}
  - Scalar data: Radii: {1, 3}, Material: {0, 1}

```
<VTKFile byte_order="LittleEndian" type="UnstructuredGrid" version="0.1">
 <UnstructuredGrid>
  <Piece NumberOfCells="0" NumberOfPoints="2">
   <Points>
    <DataArray NumberOfComponents="3" format="ascii" type="Float32">
     1 3 5 2 4 6
    </DataArray>
   </Points>
   <Cells>
    <DataArray Name="connectivity" format="ascii" type="Int32">0</DataArray>
    <DataArray Name="offsets" format="ascii" type="Int32">0</DataArray>
    <DataArray Name="types" format="ascii" type="UInt8">1</DataArray>
   </Cells>
```

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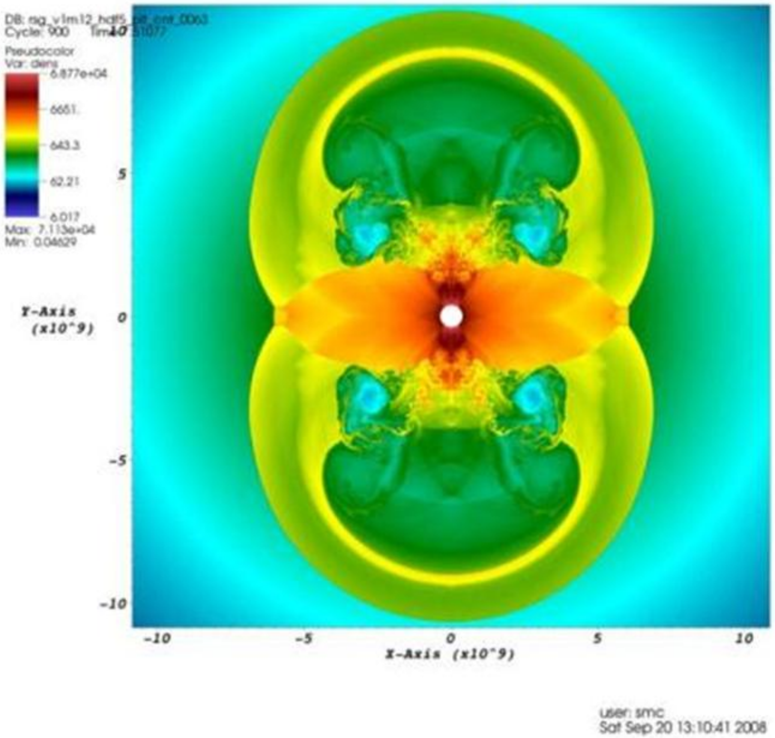
```
<PointData>
 <DataArray Name="Points" NumberOfComponents="3" format="ascii"
  type="Float32">
  1 3 5 2 4 6
 </DataArray>
 <DataArray Name="forces" NumberOfComponents="3" format="ascii"
  type="Float32">
  0 2 4 1 3 5
 </DataArray>
 <DataArray Name="radii" format="ascii" type="Float32">
  1 3
 </DataArray>
 <DataArray Name=“material" format="ascii" type=“UInt8">
  0 1
 </DataArray>
</PointData>
```

Visualization Operations

- Surface Shading (Pseudocolor)
- Isosufacing (Contours)
- Volume Rendering
- Clipping Planes
- Streamlines

Surface Shading (Pseudocolor)

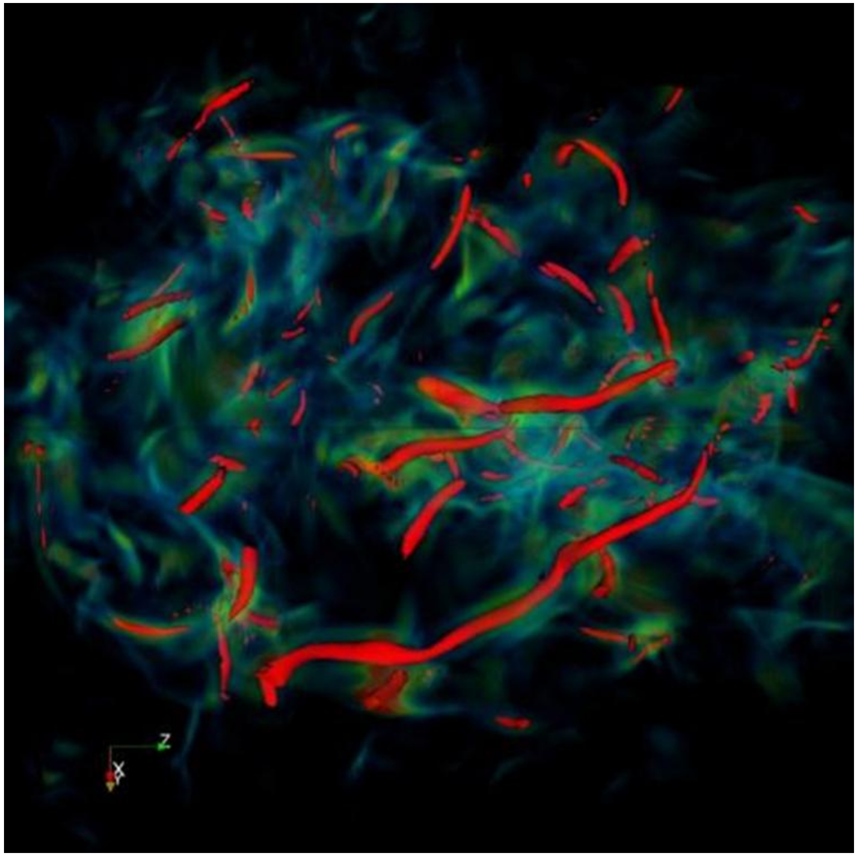
Given a scalar value at a point on the surface and a color map, find the corresponding color (and/or opacity) and apply it to the surface point.



Most common operation, often combined with other ops

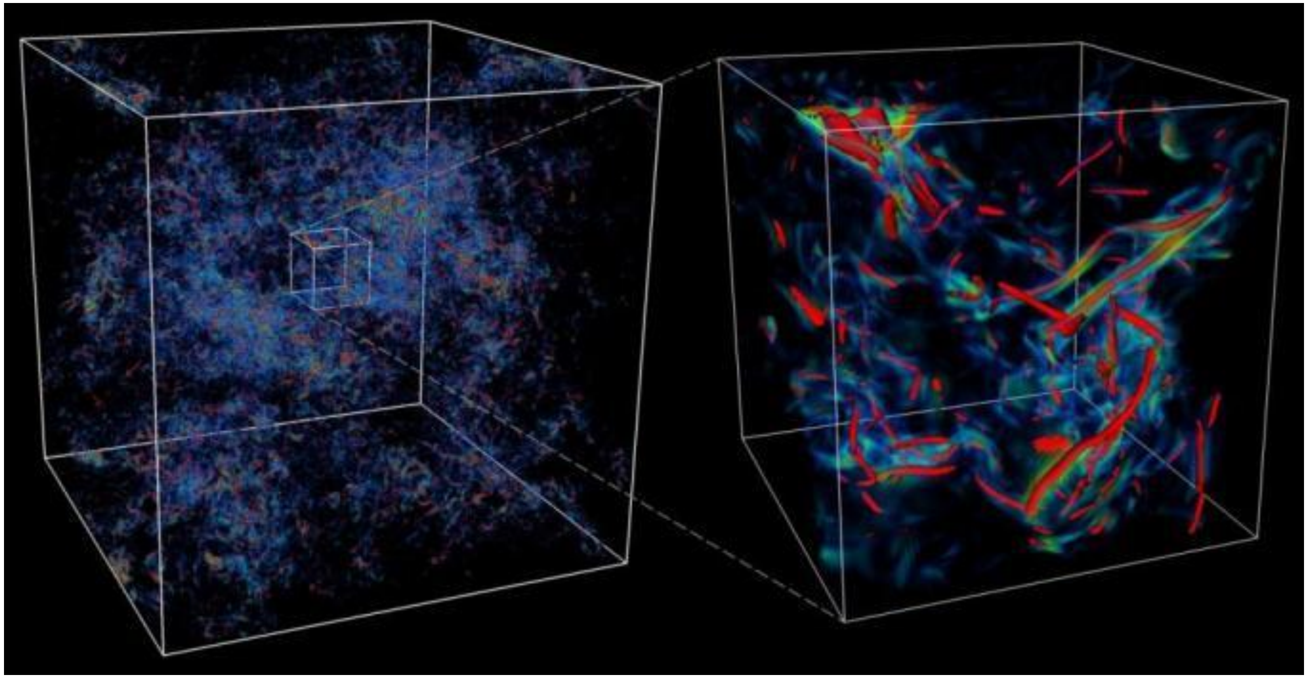
Isosurfaces (Contours)

- Surface that represents points of constant value with a volume
- Plot the surface for a given scalar value.
- Good for showing known values of interest
- Good for sampling through a data range



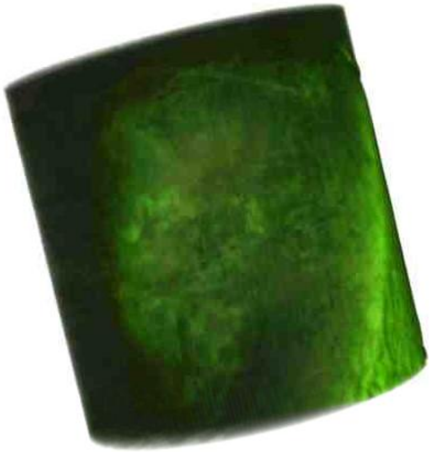
Volume Rendering

- Expresses how light travels through a volume
- Color and opacity controlled by transfer function
- Smoother transitions than isosurfaces



Volume Rendering

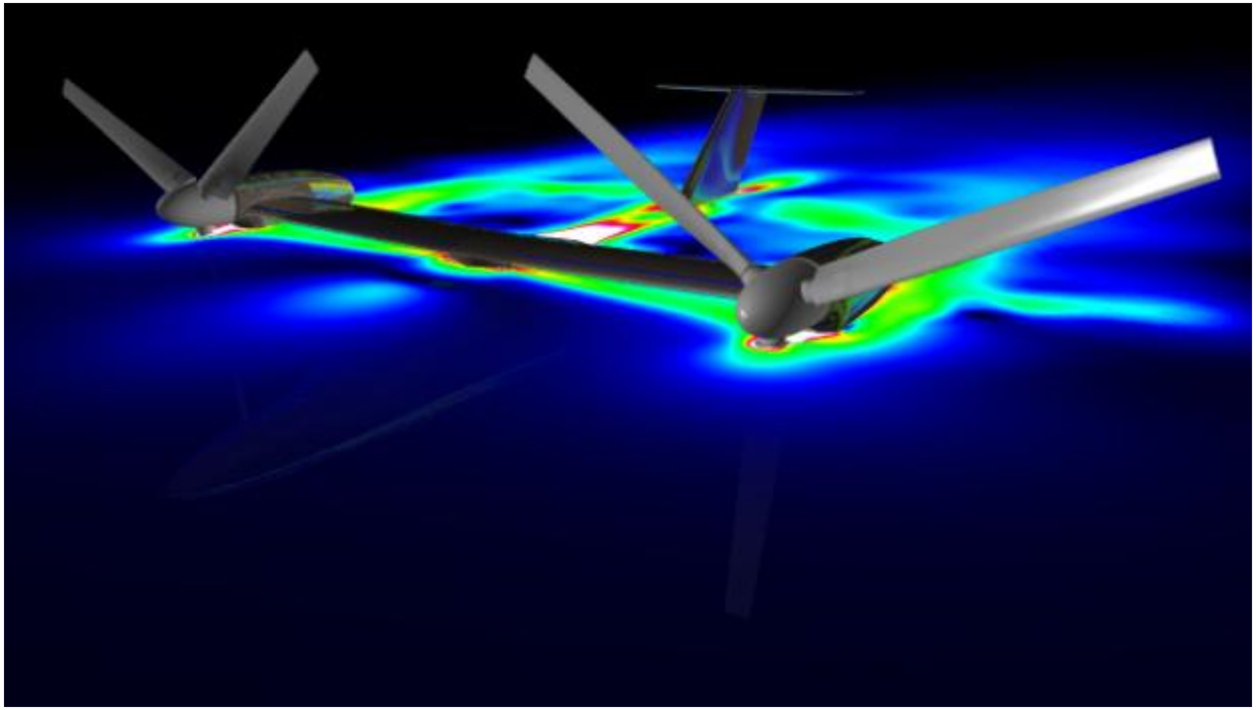
Transfer function (maps scalars to color, opacity) very important!



Clipping/Slicing planes

Extract a plane from the data to show features

Hide part of dataset to expose features



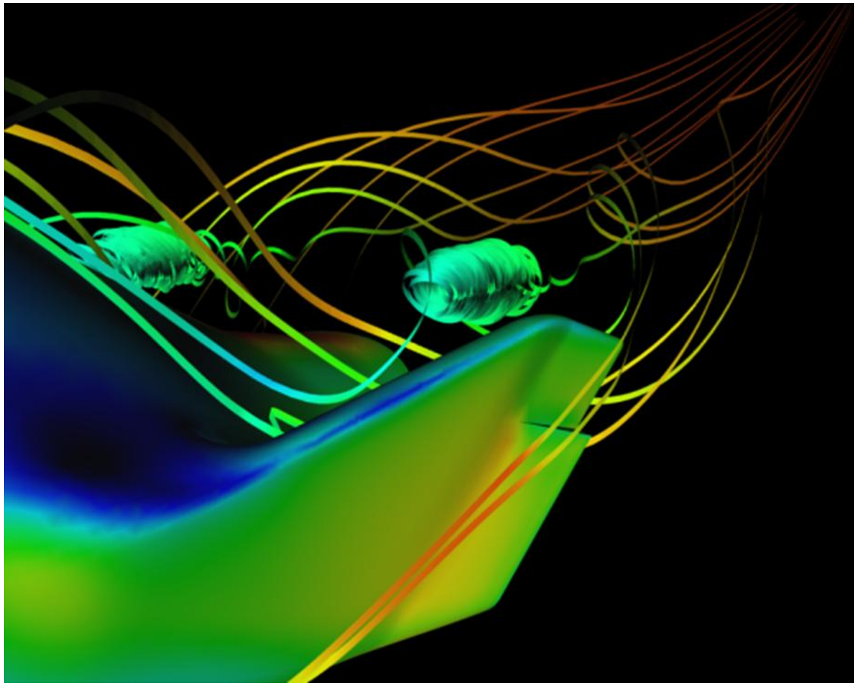
Particle Traces (Streamlines)

Given a vector field, extract a trace that follows that trajectory defined by the vector.

$P_{new} = P_{current} + V_P\Delta t$

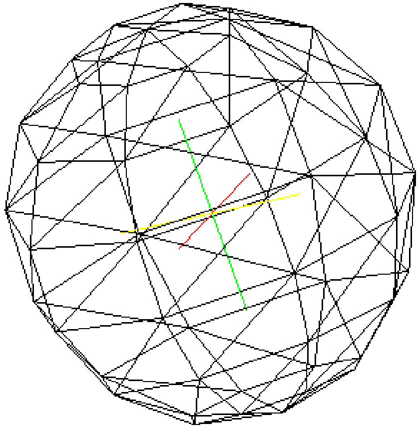
Streamlines – trace in space

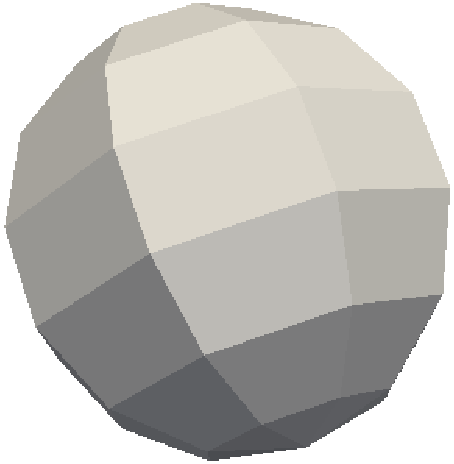
Pathlines – trace in time

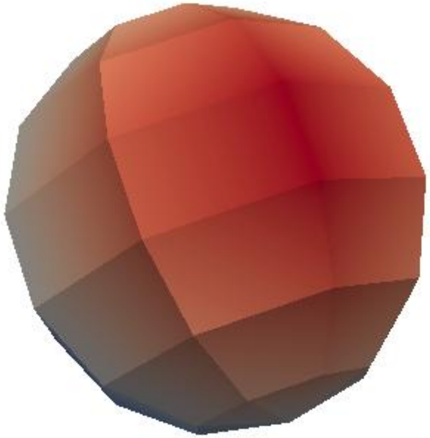


Graphics Primitives

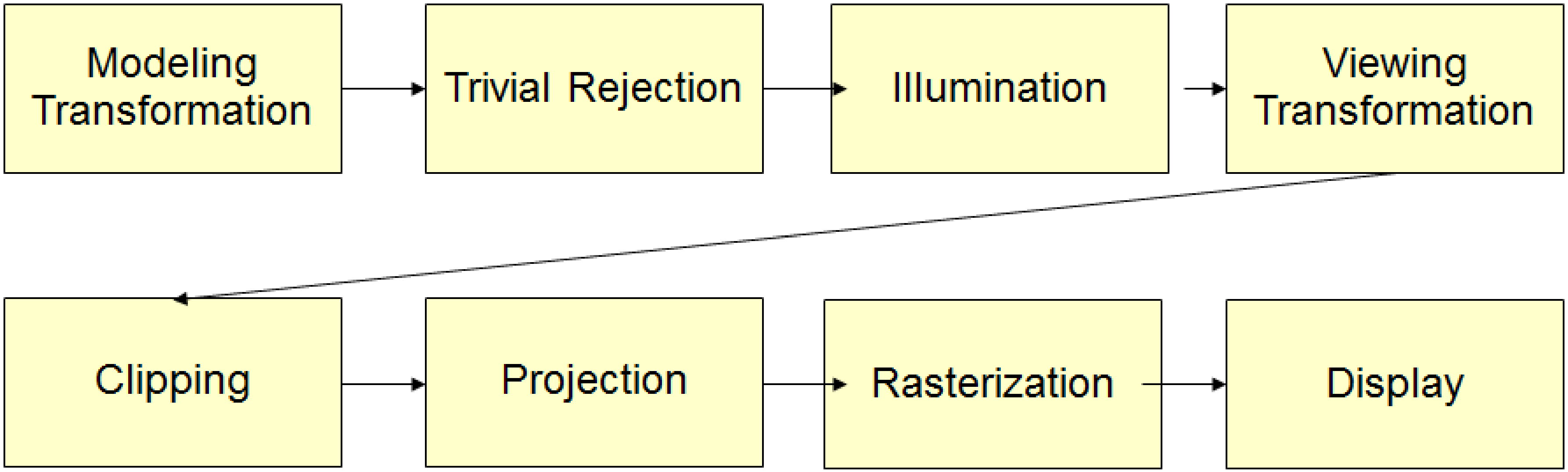
- Basic unit: Polygons, Colors, Textures, Opacity
  - Flat surface formed between points
  - This surface may have an associated color or texture, or opacity
- Complex surfaces composed of several polygons







Graphics Pipeline



Graphics pipeline in English

- Squeeze the world of your polygons into a normalized box.
- Rotate, translate, and scale them according to camera and model positions.
- Figure out what color they should be from lighting.
- Flatten them to a 2D world.
- Scan through the lines, turning them into pixels.
- (Along the way, cut out anything that won't be visible.)

Geometry, then Rasterization.

Graphics Pipeline

- Given polygons, show them on the screen.
  - Point 0: x,y,z
  - Point 1: x,y,z
  - Point 2: x,y,z
  - Color
- OpenGL does this for you

```
glColor3f(0.0, 1.0, 0.0); // blue
glBegin(GL_QUAD);
  glVertex2f(0.0, 0.0);
  glVertex2f(1.0, 0.0);
  glVertex2f(1.0, 1.0);
  glVertex2f(0.0, 1.0);
glEnd();
glTranslate(-1.5, 0.0, 0.0); // move
object
```

From data to Insight