Visualizing Electromagnetic Fields: The Visualization Toolkit

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Visualization

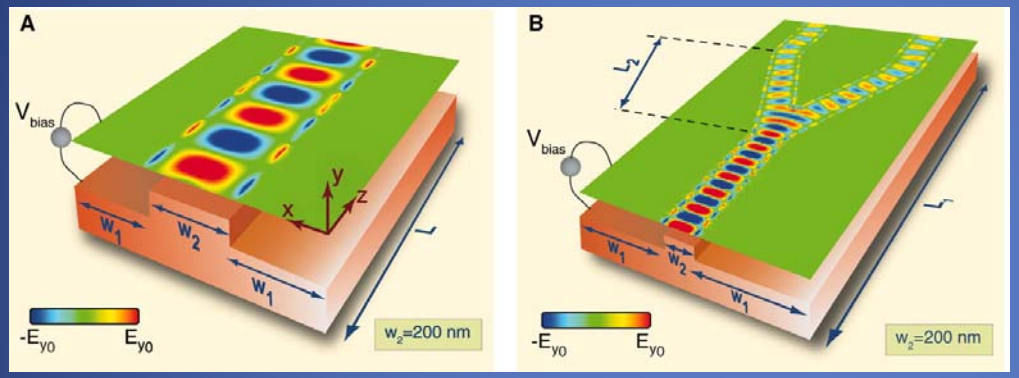
What is the purpose of visualizing electromagnetic (EM) Fields?

Visualization

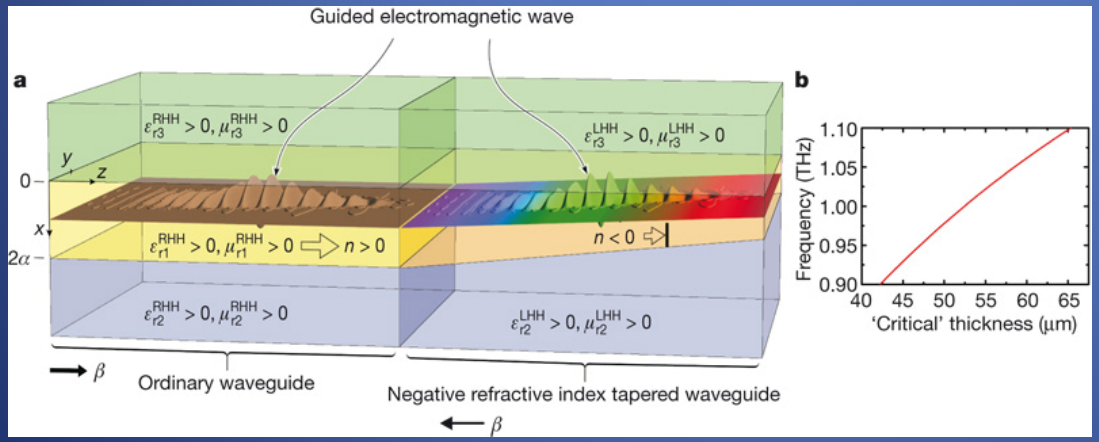
1. Understand the geometry of the problem
2. Show the properties of the EM field
3. Communicate functionality

Examples

- Good Visualization:



Transformation Optics Using Graphene, Ashkan Vakil and Nader Engheta
Science 10 June 2011: 332 (6035), 1291-1294.



Kosmas L. Tsakmakidis, Allan D. Boardman & Ortwin Hess
Nature **450**, 397-401
(15 November 2007)

Motivation

- Generate ‘professional’ looking figures
- Convey both geometry and electromagnetic properties
  - This allows the audience to understand how things work in an easier fashion

Motivation

- Useful for Research:
  - Help yourself to understand the problem
  - Help the audience to understand the problem
- Useful for Teaching:
  - Demonstrate basic physics in a visually appealing manner

Possible Approaches

- Existing CAD tools:
  - HFSS, SEMCAD, CST, COMSOL….
- Software packages

Visualization Toolkit (VTK)

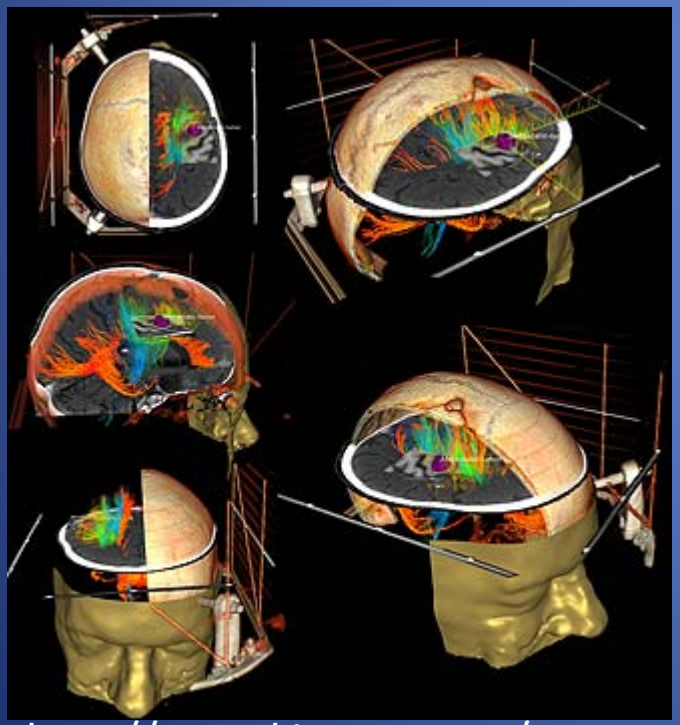
- A Graphics API for drawing 3D graphics
- Open source
- Use the API in C++, Java, Tcl, Python
  - Python in this talk. Also allows use of numpy/scipy

Visualization Toolkit (VTK)

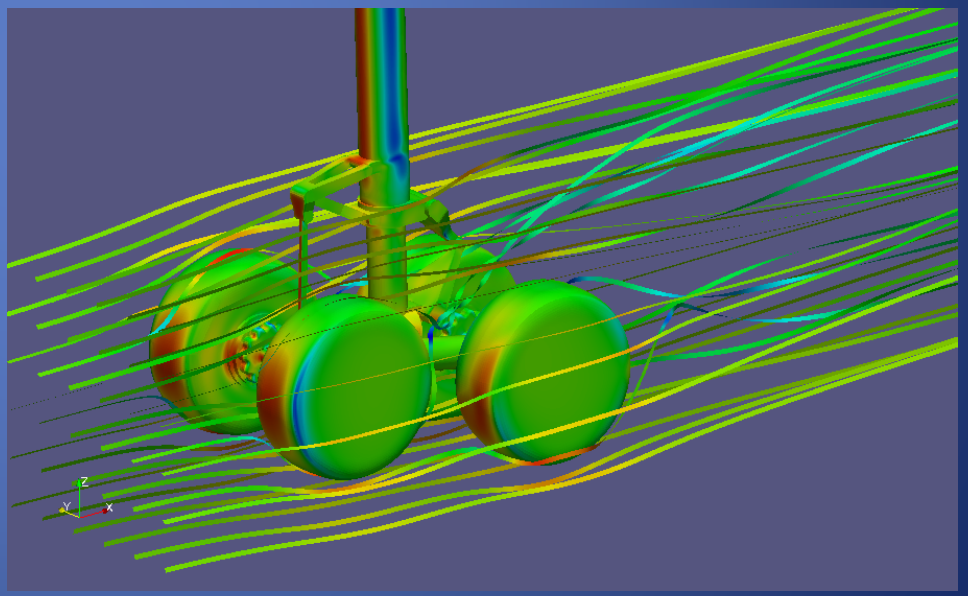
- Object Oriented Framework
- Sits on top of OpenGL
- There are GUI environments:
  - ParaView, Mayavi

VTK History and Uses

- Written by former GE engineers
- Popular in CFD and medical imaging



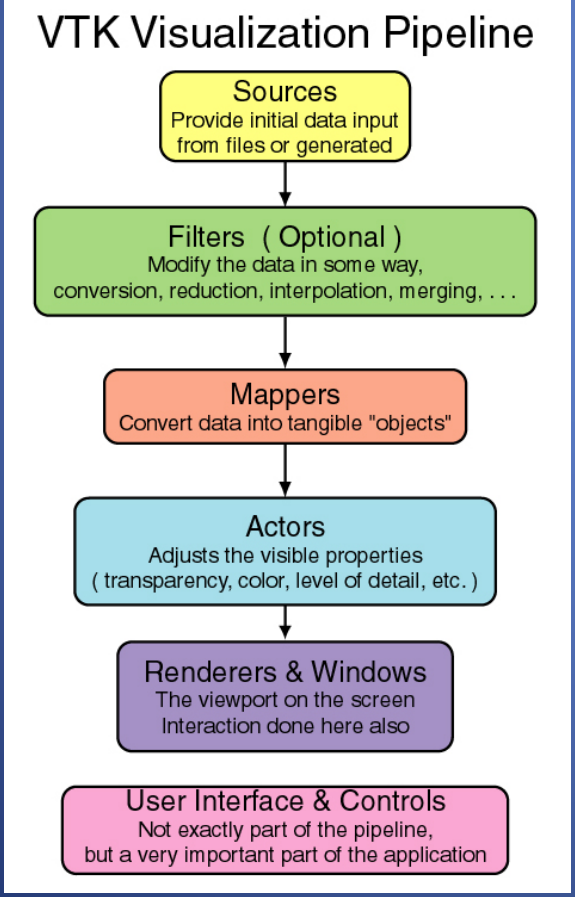
http://www.kitware.com/viscontest/img/brainconnectivity.png



http://cmg.soton.ac.uk/people/kvm/

VTK Basics

- The elements of a VTK program



Pipeline Metaphor

From: http://www.cs.uic.edu/…
~jbell/CS526/Tutorial/VTK_Pipeline.jpg

VTK Basics

- To Build A ‘Scene’ You Need:
  1. A Rendering Window (vtkRenderWindow)
  2. A Light Source (vtkLight)
  3. A Camera (vtkCamera)
  4. Mappers (vtkMapper)
     - Map data and geometry to computer graphics
  5. Actors (vtkActor)
     - Define their properties (vtkProperty)

Examples (Photonics)

- The Hybrid Waveguide:
  - An optical waveguide with good mode confinement
  - A hybrid between a dielectric and plasmonic waveguide
  - See [1].

[1] M. Alam, J. Meier, J. Aitchison, and M. Mojahedi, "Propagation characteristics of hybrid modes supported by metal-low-high index waveguides and bends," Opt. Express 18, 12971-12979 (2010).

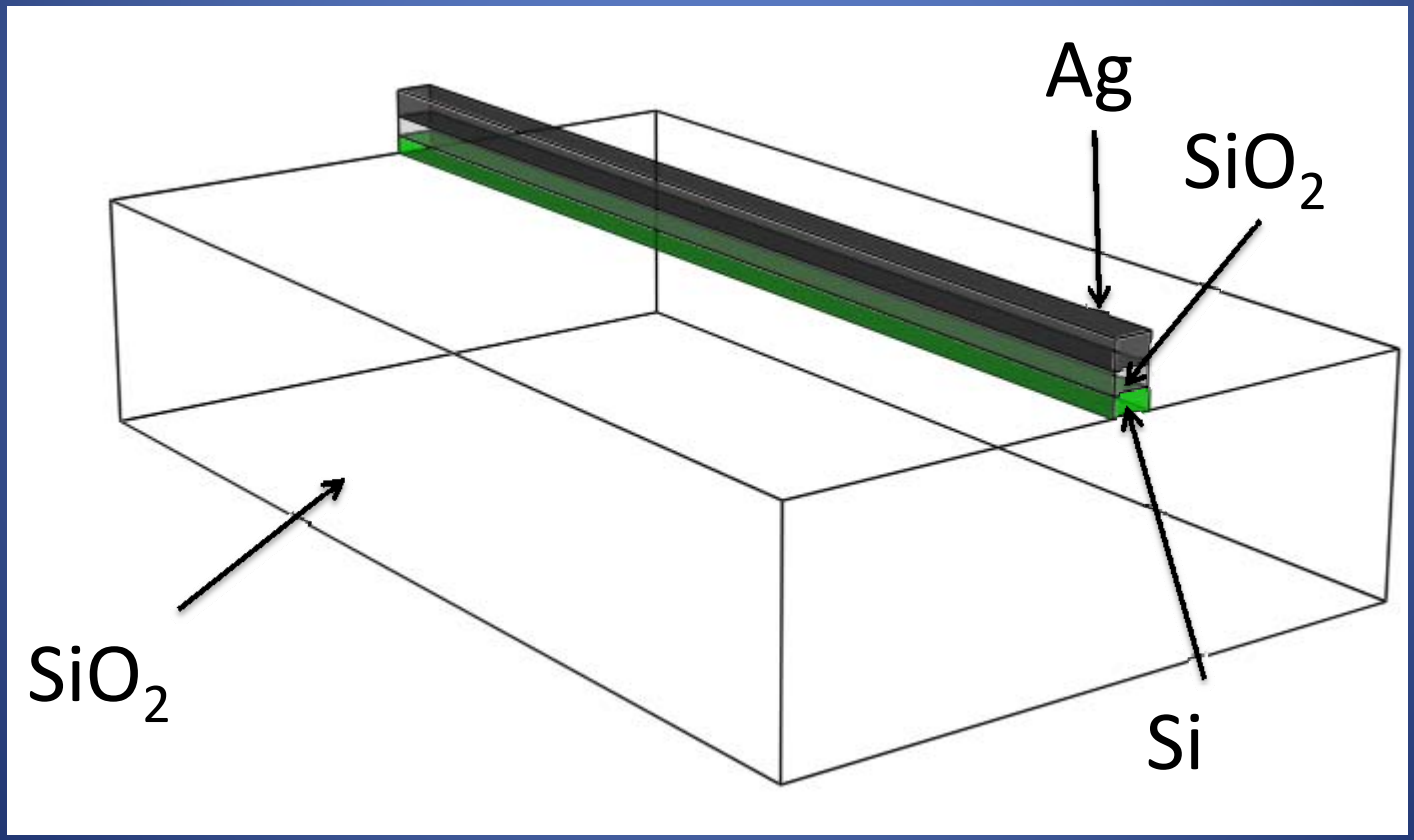
Examples (Photonics)

- The Hybrid Waveguide:

  1. Show the geometry of the waveguide
  2. Show how the EM mode is confined in the waveguide

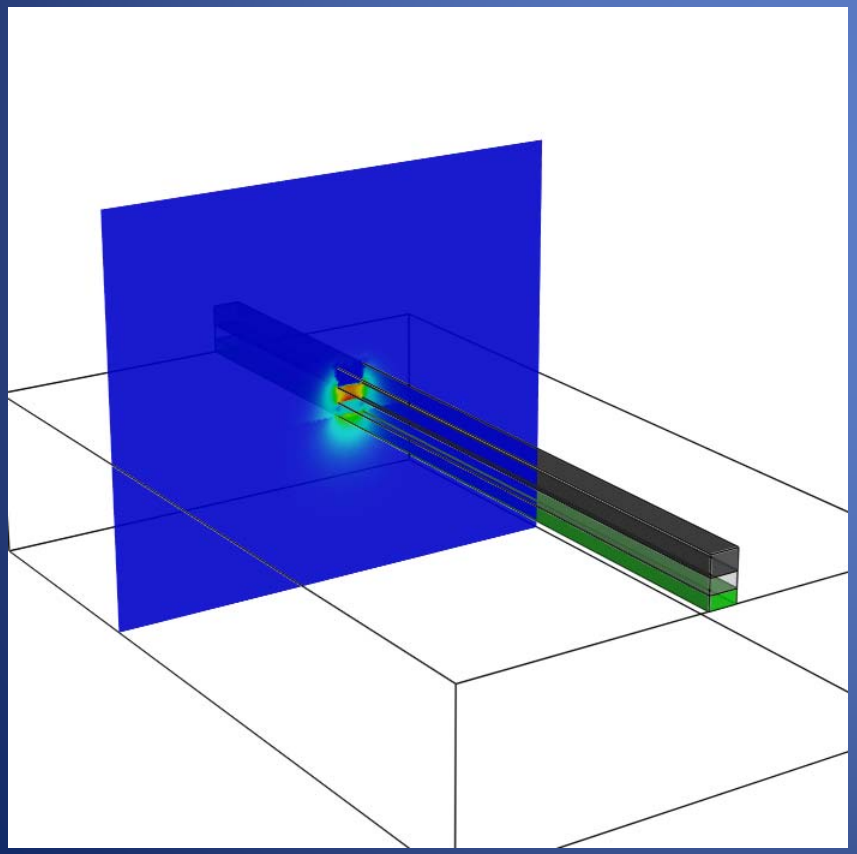
Examples (Photonics)

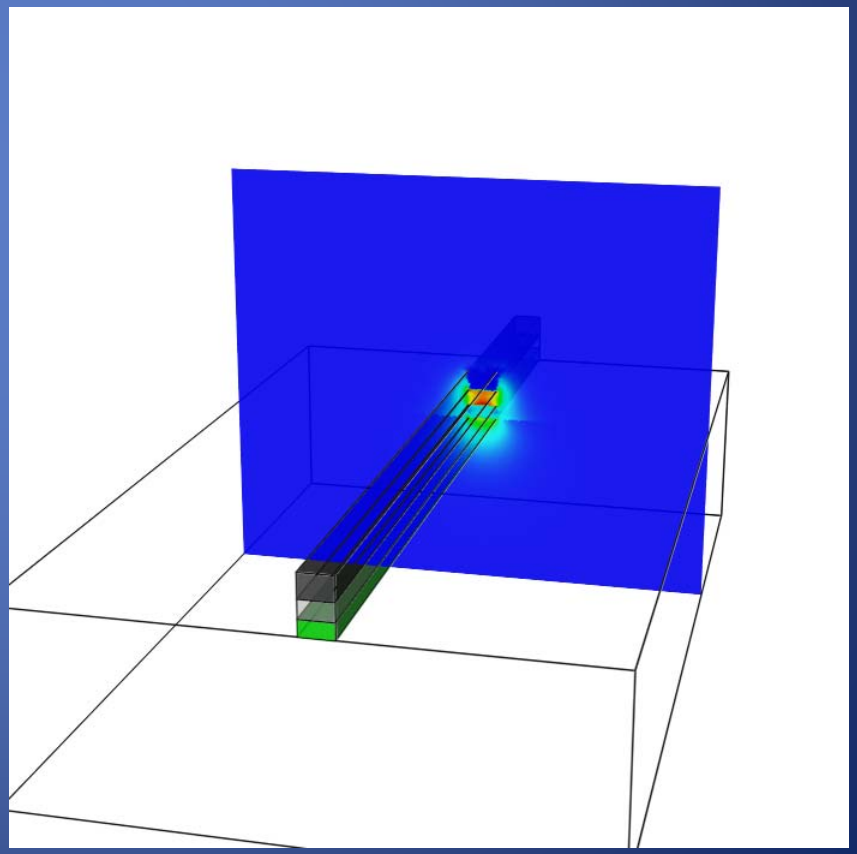
- Schematic



Examples (Photonics)

- Hybrid Mode Plot



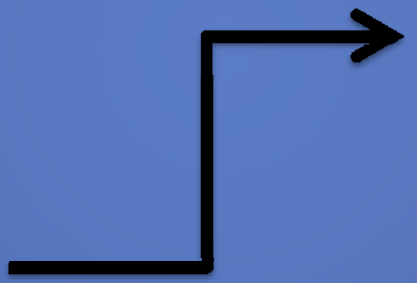


Examples (Photonics)

- Code

1. Read in Data

2. Define Scene
   - Set up camera
   - Set up Renderer and Window



```
cam1=vtk.vtkCamera()
cam1.SetFocalPoint(x0,y0,z0)
cam1.SetPosition(x1,y1,z1)
cam1.Zoom(1.5)

ren1=vtk.vtkRenderer()
ren1.SetActiveCamera(cam1)
ren1.ResetCamera()

renWin=vtk.vtkRenderWindow()
```

Examples (Photonics)

- Code Continued

3. Draw Geometry

```
Substrate=vtk.vtkCubeSource()
Substrate.SetXLength(x)
Substrate.SetYLength(y)
Substrate.SetZLength(z)
Substrate.SetCenter(cen)

mapSub=vtk.vtkPolyDataMapper()
mapSub.SetInput(Substrate.GetOutput()

aSub=vtk.vtkActor()
aSub.SetMapper(mapSub)
ren1.AddActor(aSub)
```

Examples (Photonics)

- Code Continued

4. Draw Surface Plot
   a. Setup Grid
      - Add Points and Data
   b. Set up filter and lut
   c. Map surface plot
   d. Add to scene as an actor

```
grid=vtk.vtkStructuredGrid()
grid.SetPoints(points)
grid.GetPointData().SetScalars(Efield)
```

```
filter = vtk.vtkStructuredGridGeometryFilter()
filter.SetInput(grid)
```

```
lut=vtk.vtkLookupTable()
lut.Build()
```

```
map=vtk.vtkPolyDataMapper()
map.SetInput(filter.GetOutput())
map.SetLookupTable(lut)
```

```
vecActor=vtk.vtkActor()
vecActor.SetMapper(map)
ren1.AddActor(vecActor)
```

Examples (EM)

- Ray Tracer
  - We need to understand how EM waves propagate inside very large domains like tunnels
  - Use a ray tracer to study the problem. (Written By Neeraj Sood)

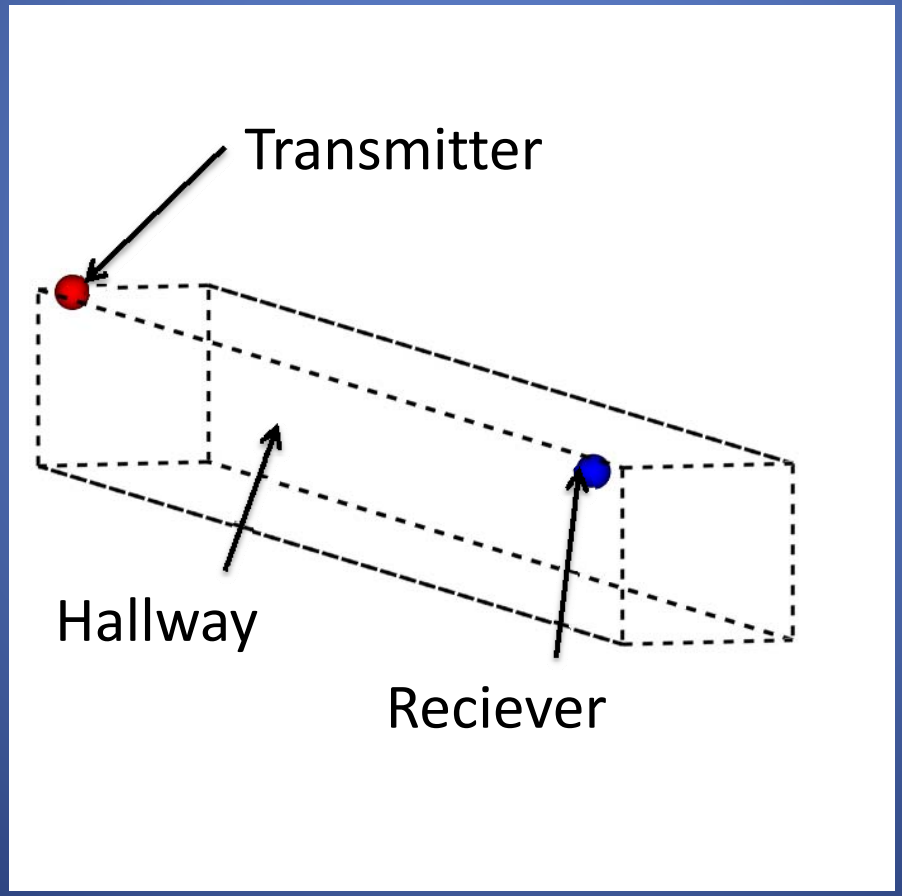
Examples (EM)

- Ray Tracer

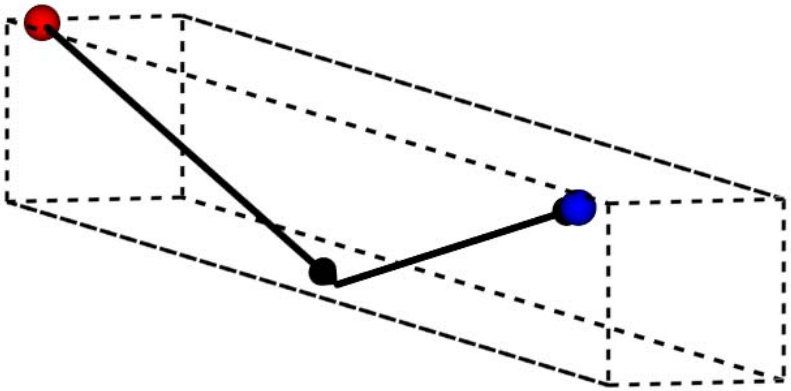
  1. Show the geometry of the problem being studied
  2. Visualize the rays in that geometry

Examples (EM)

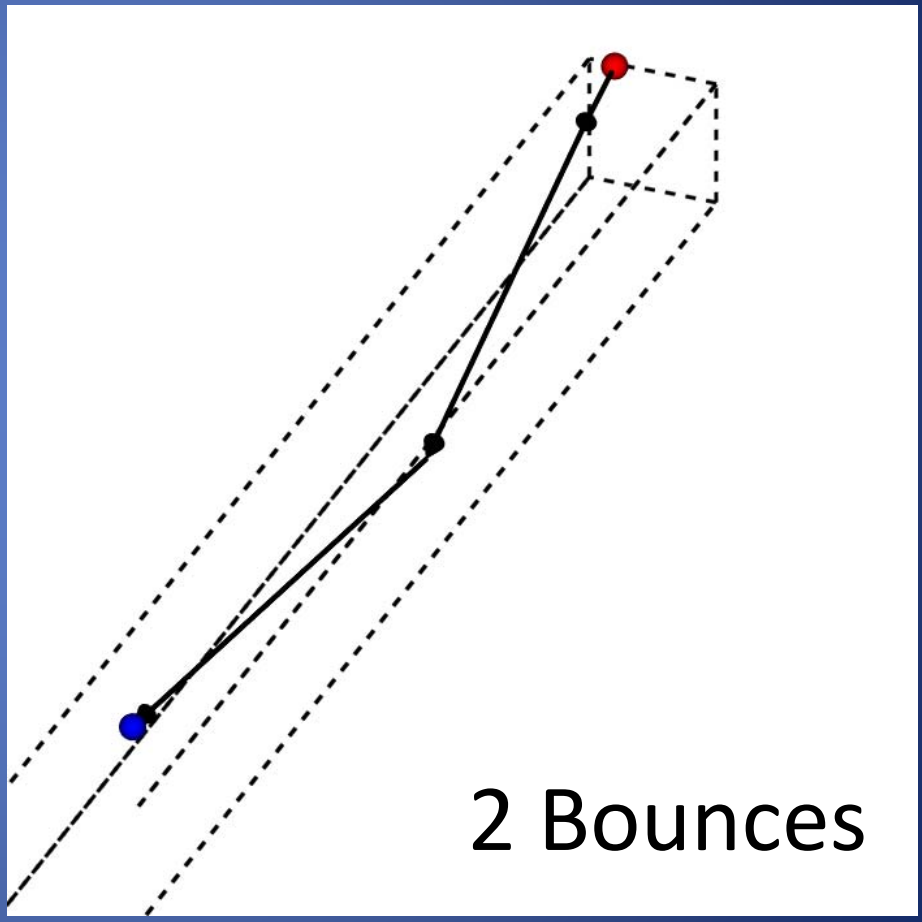
- Schematic



Examples (EM)

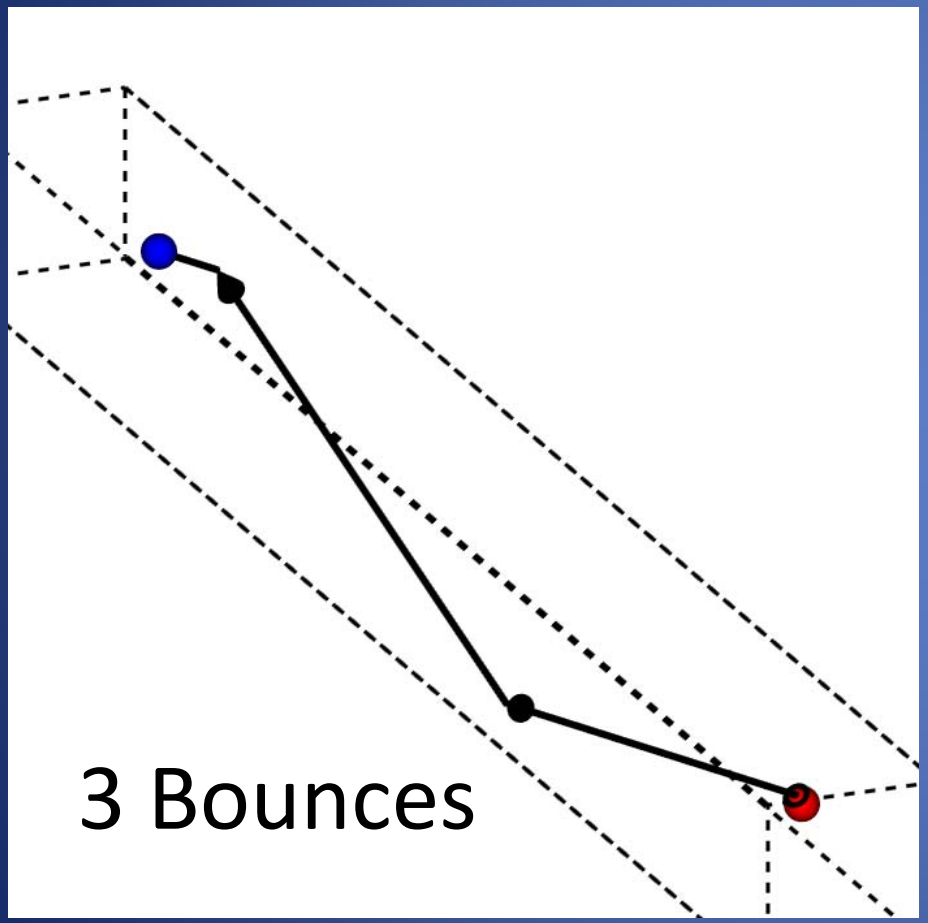


1 Bounce

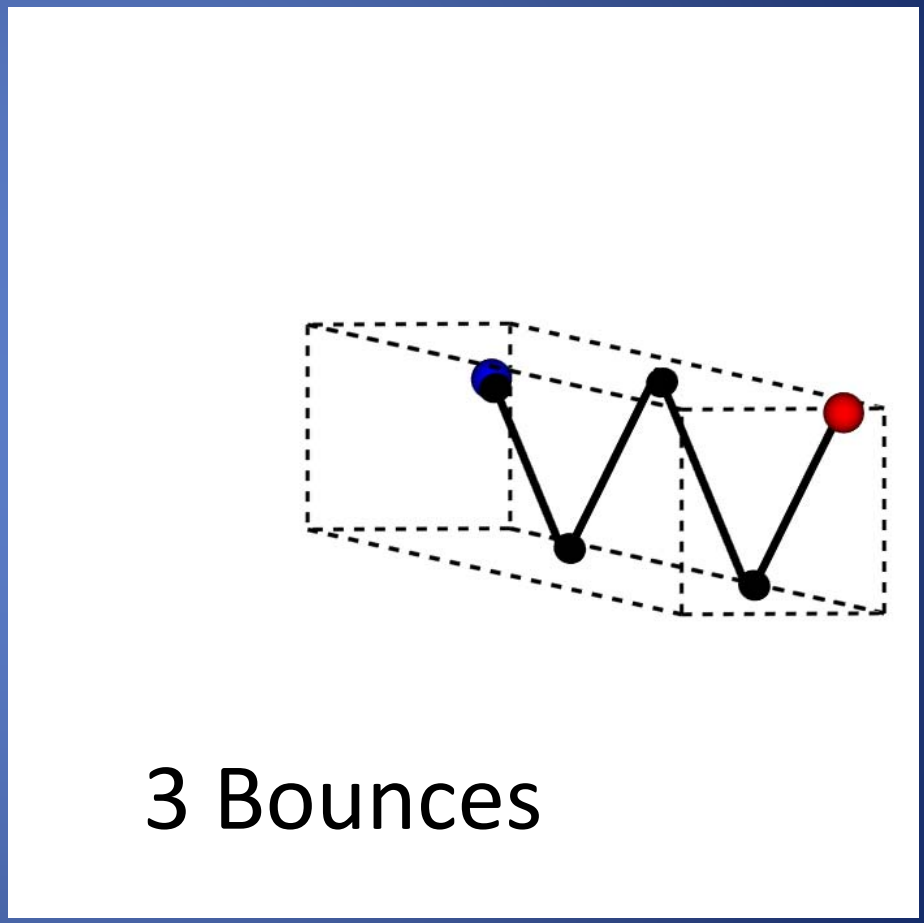


2 Bounces

Examples (EM)



3 Bounces



3 Bounces

Examples (EM)

- Code:

1. Define Scene
2. Read in Geometry
3. Draw Geometry
4. Read in Rays
5. Draw Rays
    a. Draw Arrows

VTK Pros and Cons

- Pros:
  1. A very powerful tool. Can `visualize' almost anything:
     - scalars, vectors, tensors, complex numbers..
  2. A lot of examples online
  3. Reusable code

VTK Pros and Cons

- Cons:
  1. Setup is difficult
  2. Very steep learning curve
     1. Need to learn intricacies of API
     2. Need to understand the framework
     3. Lots of implicit assumptions

Final Thoughts

- VTK is a tool for 3D visualization
- If you want to play around with 3D visualization it is worth investigating
- Code is available if you're curious