Visualizing Smoke and Fire

Goal: Improve quality and efficiency of methods used to visualize smoke and fire

Time: 0.0

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Fire and Evacuation Modeling
Technical Conference
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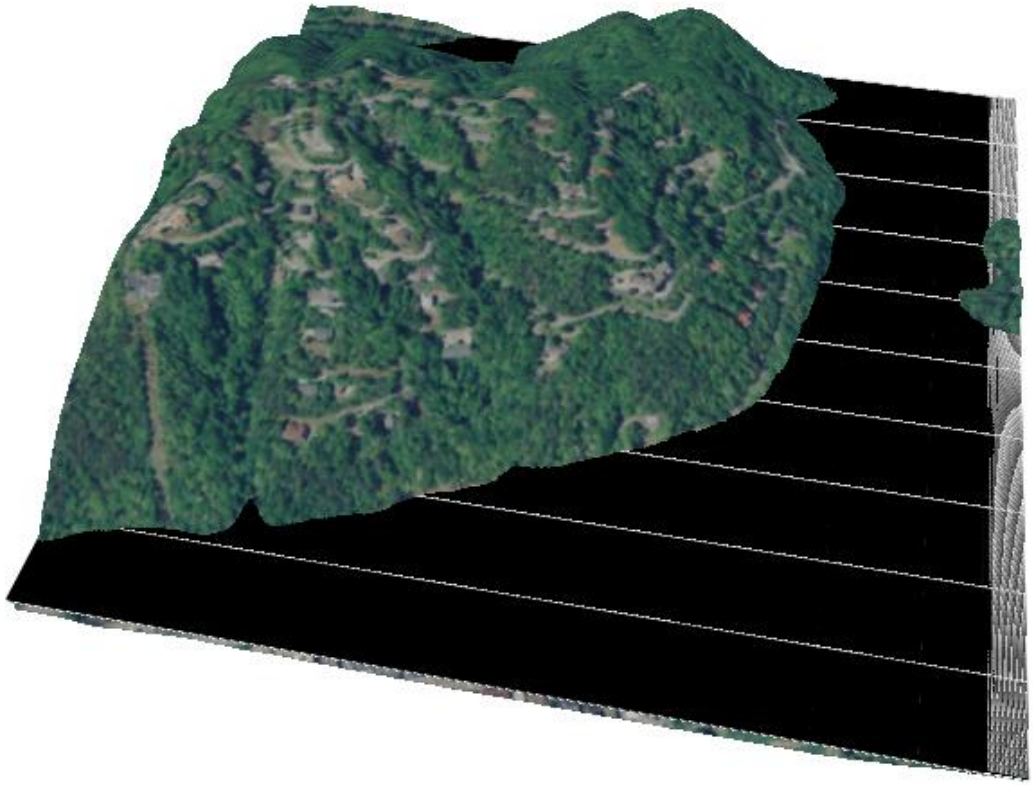
NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Overview

- Smoke/Fire Visualization Examples
- Brief overview of new visualization algorithms
- Exploit the GPU (video card) to perform computations more efficiently
- Making movies using ffmpeg

100x100x60
400 meshes
800+ time frames
240 million grid cells
192 GB data



Challenges

- Memory
- Computation
- Data load time

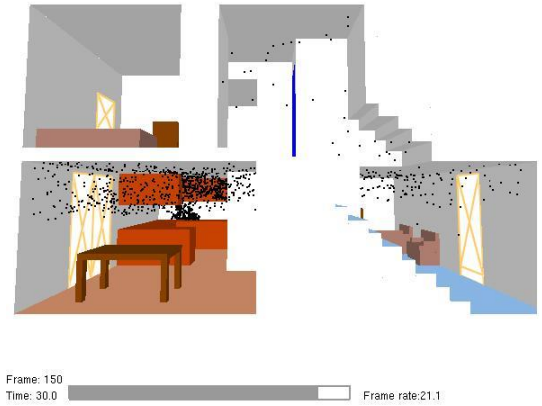
Time sinks

- FDS – multiplications
- Smokeview – drawing triangles

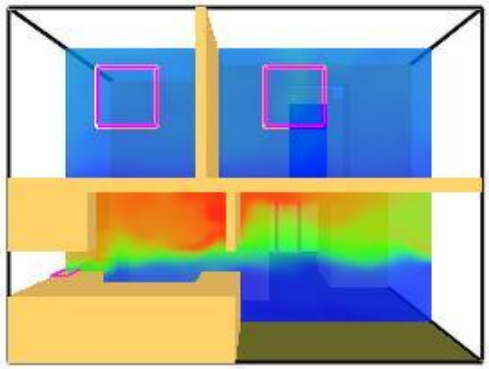
Solution Approaches

- compress data
- use the video card (GPU)
- load data in the background (while it is being displayed)
- Display only data that is visible

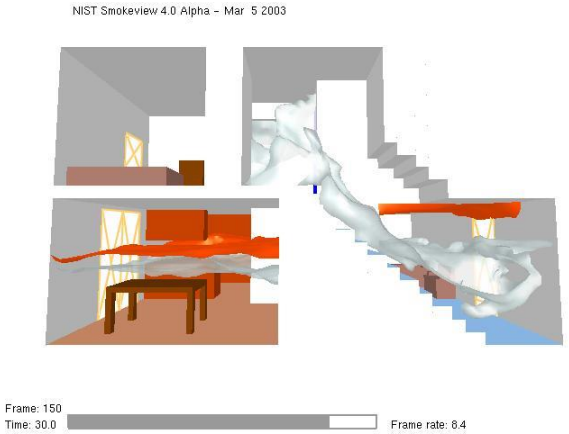
Smoke Visualization Methods



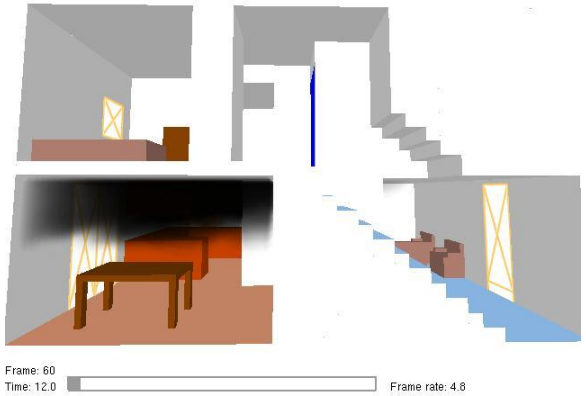
particles



2d contours



3d contours



realistic/3D smoke

Light/Smoke interactions

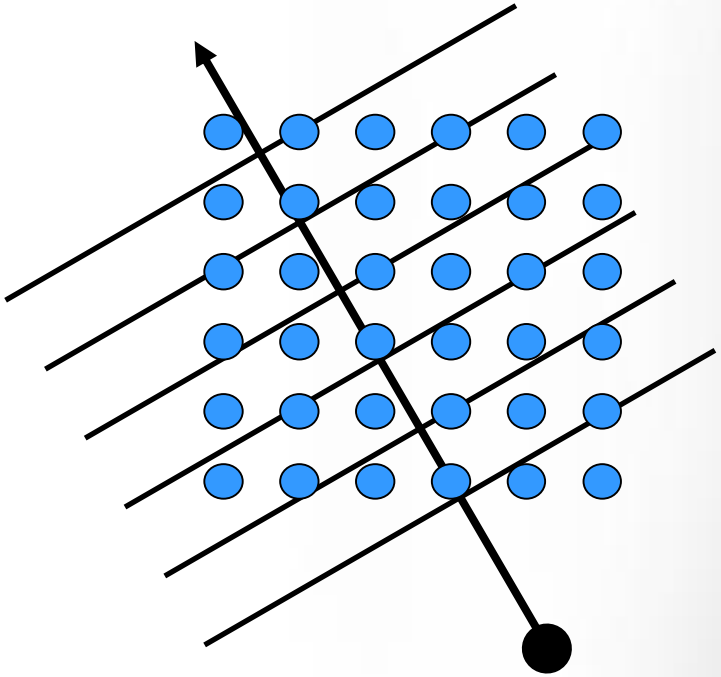
absorption out-scattering emission in-scattering

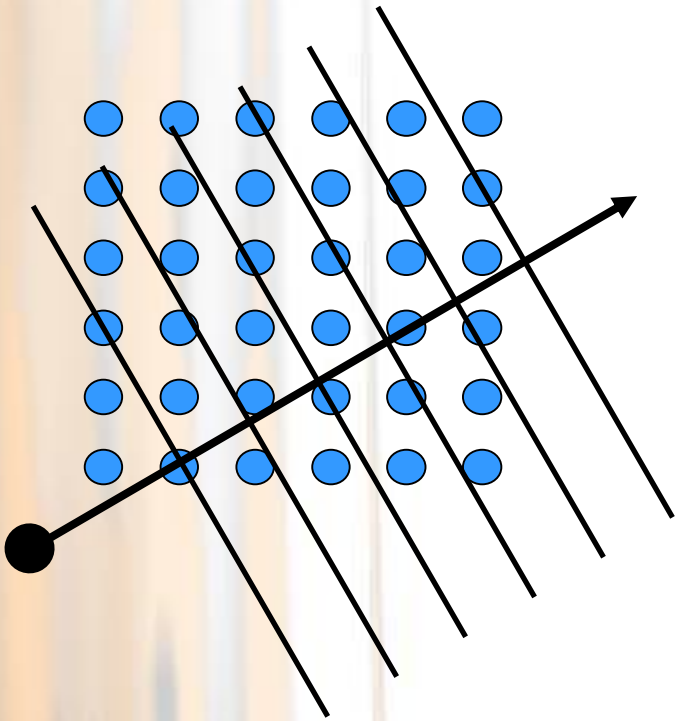
Volume Rendering Equation – Radiation Transport Equation

$$(\omega \cdot \nabla) L(x,\omega) = -\sigma_a(x)L(x,\omega) - \sigma_s(x)L(x,\omega) + \sigma_a(x)L_e(x,\omega) + \sigma_s(x)\int_{4\pi} p(x,\omega,\omega')L_i(x,\omega')d\omega'$$

$$\frac{dL(x)}{dx} = -\sigma_t(x)L(x) \quad \Longrightarrow \quad \frac{L(x)}{L_0} = e^{-\sigma_t x}$$

Beer's law

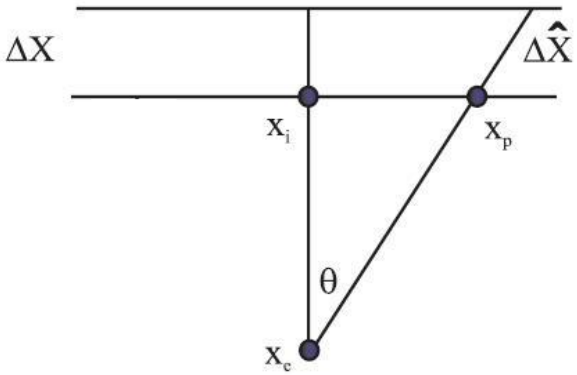




Orient planes to be perpendicular to line of sight

Beer's law

$I/I_0=\exp(-k_s\Delta x)$



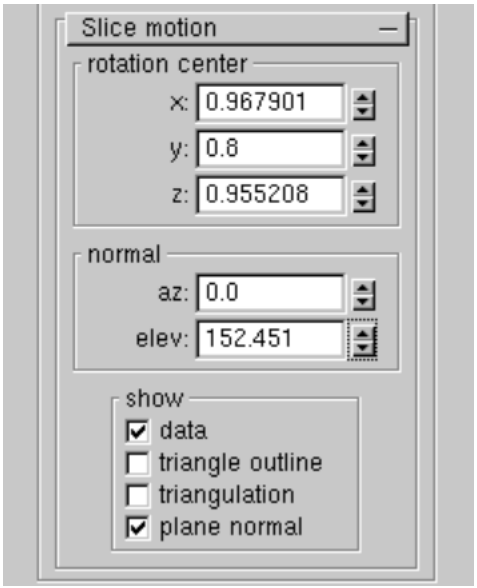
ΔX

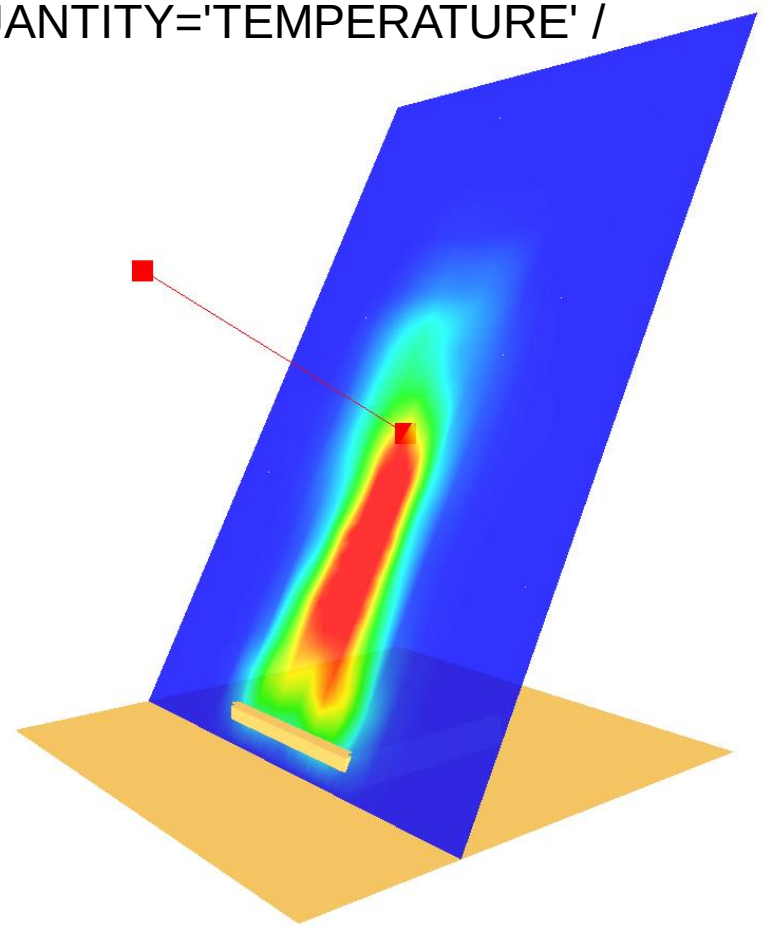
3D Slices

(like 3d smoke/fire uses 3d interpolation)

- FDS input file

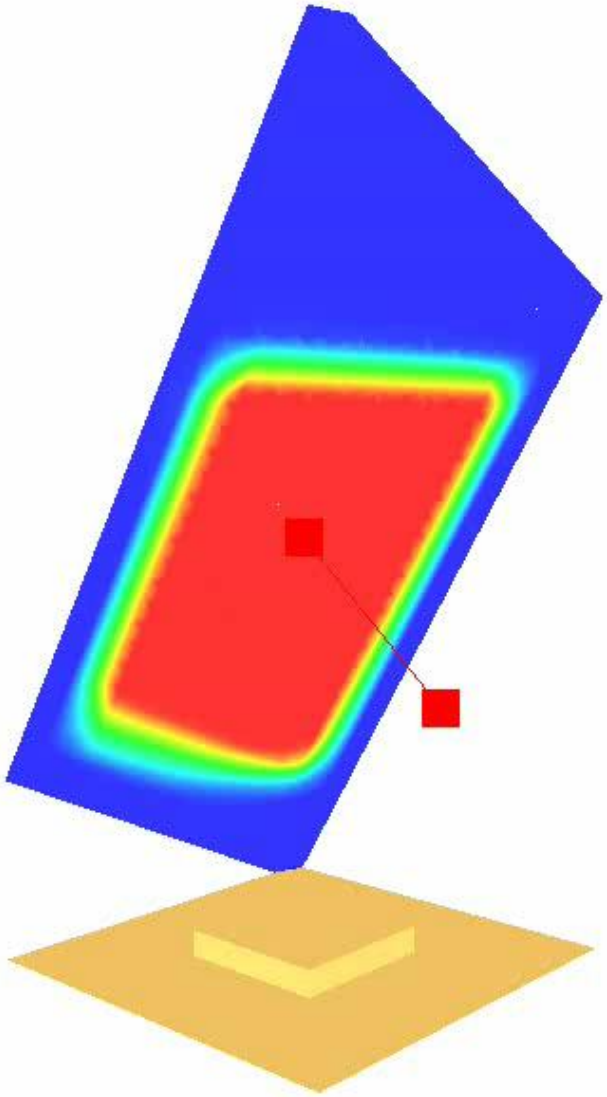
&DUMP NFRAMES=100, DT_SL3D=0.1 /
&SLCF XB=0.0,1.6,0.0,1.6,0.0,3.2, QUANTITY='TEMPERATURE' /





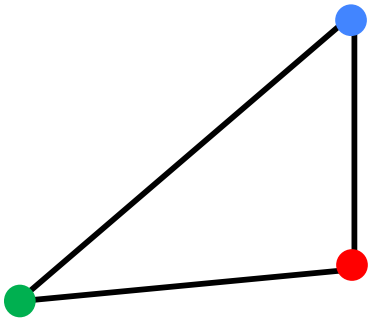
keyboard shortcut: w

3D Slices

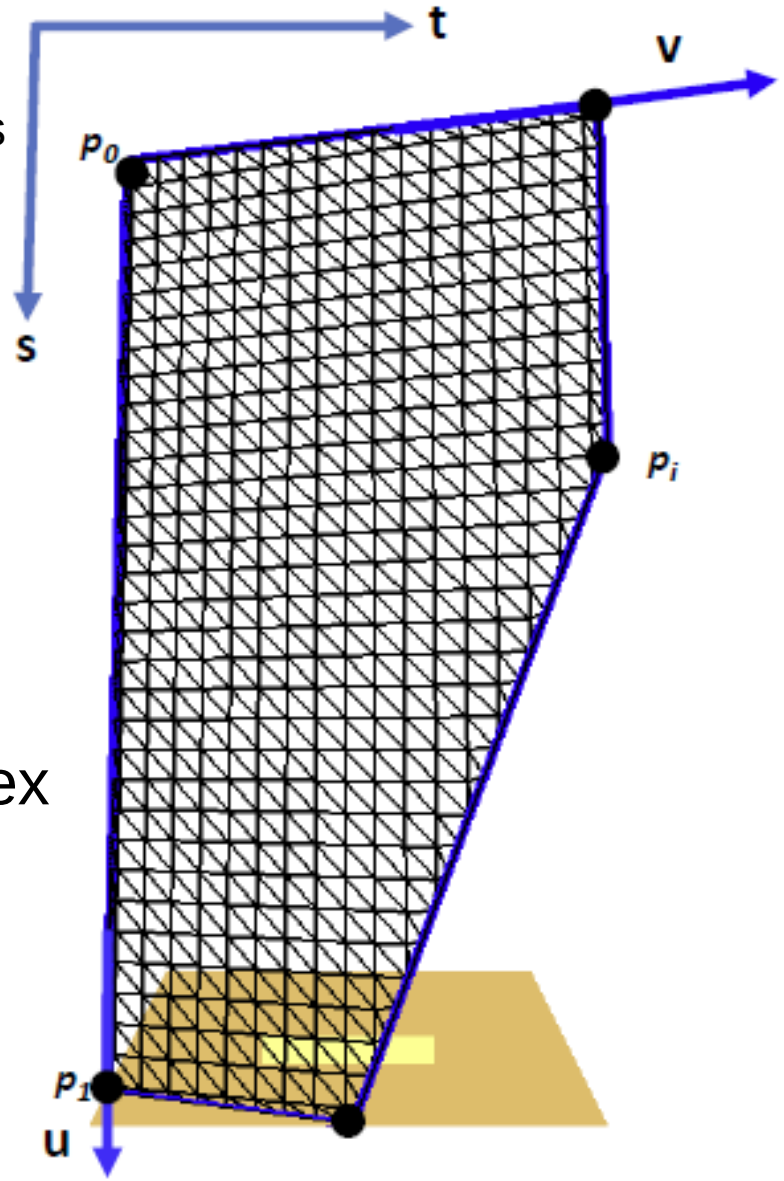


Overview of Smoke/Fire Visualization Method

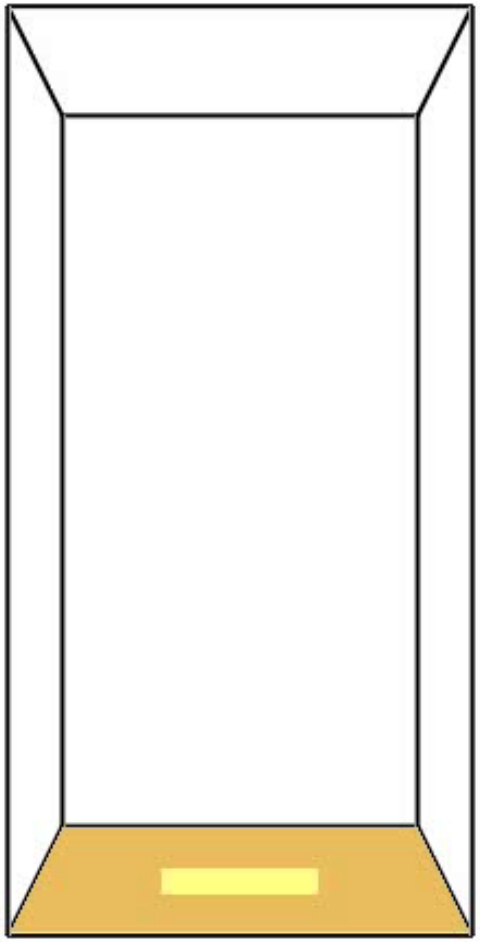
- Intersect a series of equally spaced planes with each mesh
- Generate triangles in each plane
- Obtain smoke and fire data at each triangle vertex
- Draw each triangle using smoke and fire data to generate opacity and color



Assign color and opacity to each vertex



Overview of Smoke/Fire Visualization Method



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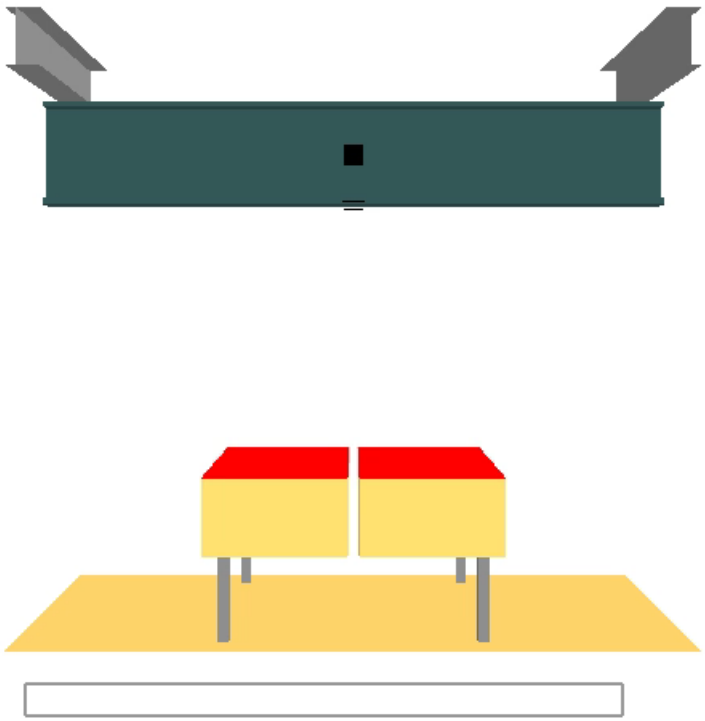
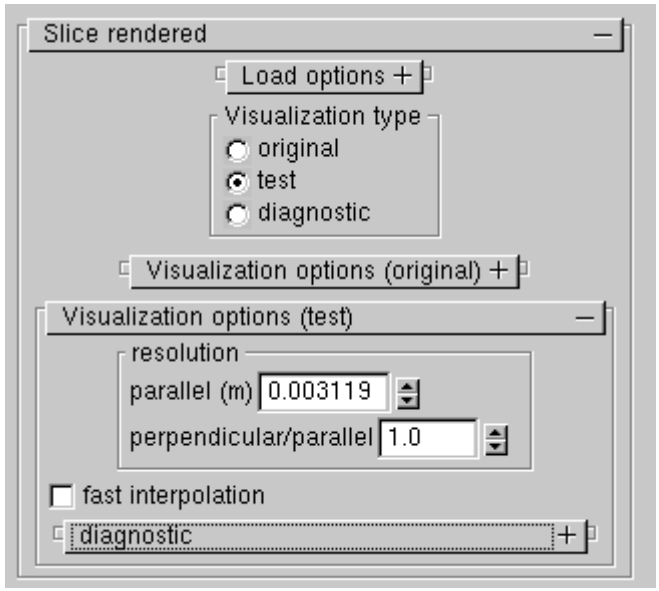
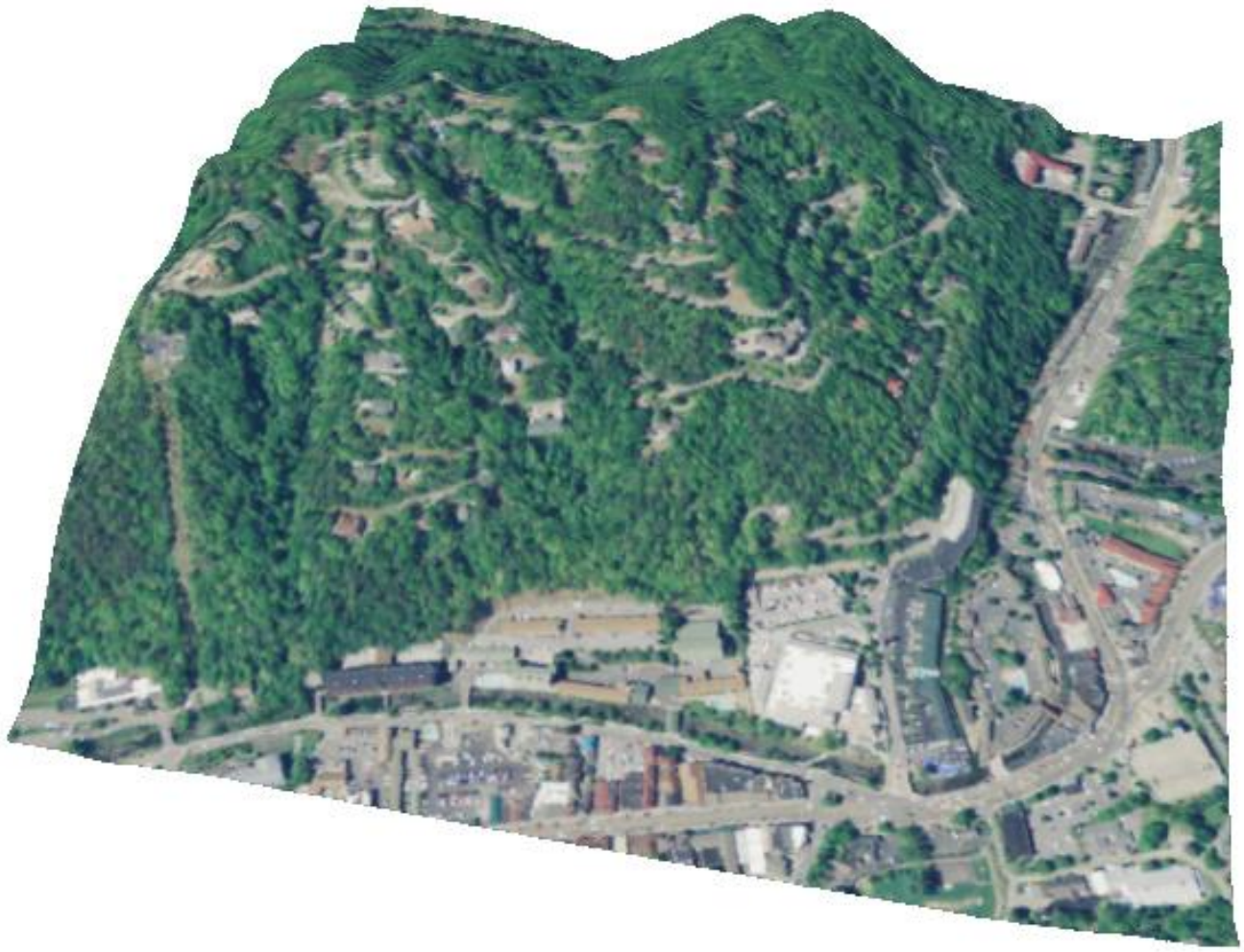
Smoke/Fire Visualization Using ‘New’ Triangulation Method







Time: 0.0

Compress Data – Run Length Encoding

- Replace four byte soot density with one byte opacity
  Compress using “run length encoding”
- Replace repeated runs with a count and a data value

000022222333344 → #40#52#5344

- This step is performed automatically by FDS when outputting 3D smoke files

Fire Visualization Using Slice files – max blending method

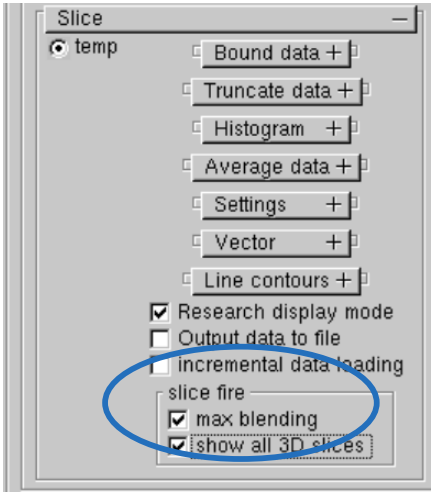
- Replace color only if it is ‘greater’ than current color in screen buffer

FDS input file

&DUMP NFRAMES=1000, DT_SL3D=0.1 /
&SLCF XB=…. QUANTITY=‘TEMPERATURE’ /

Smokeview

- Select ‘slice fire’ options



- Select ‘fire 3’ color bar

Max Blending Method - Examples

Color drawn	192,192,192	64,64,64
Current screen buffer	128,128,128	128,128,128
Updated screen buffer	192,192,192	128,128,128

Compress Data – Smokezip

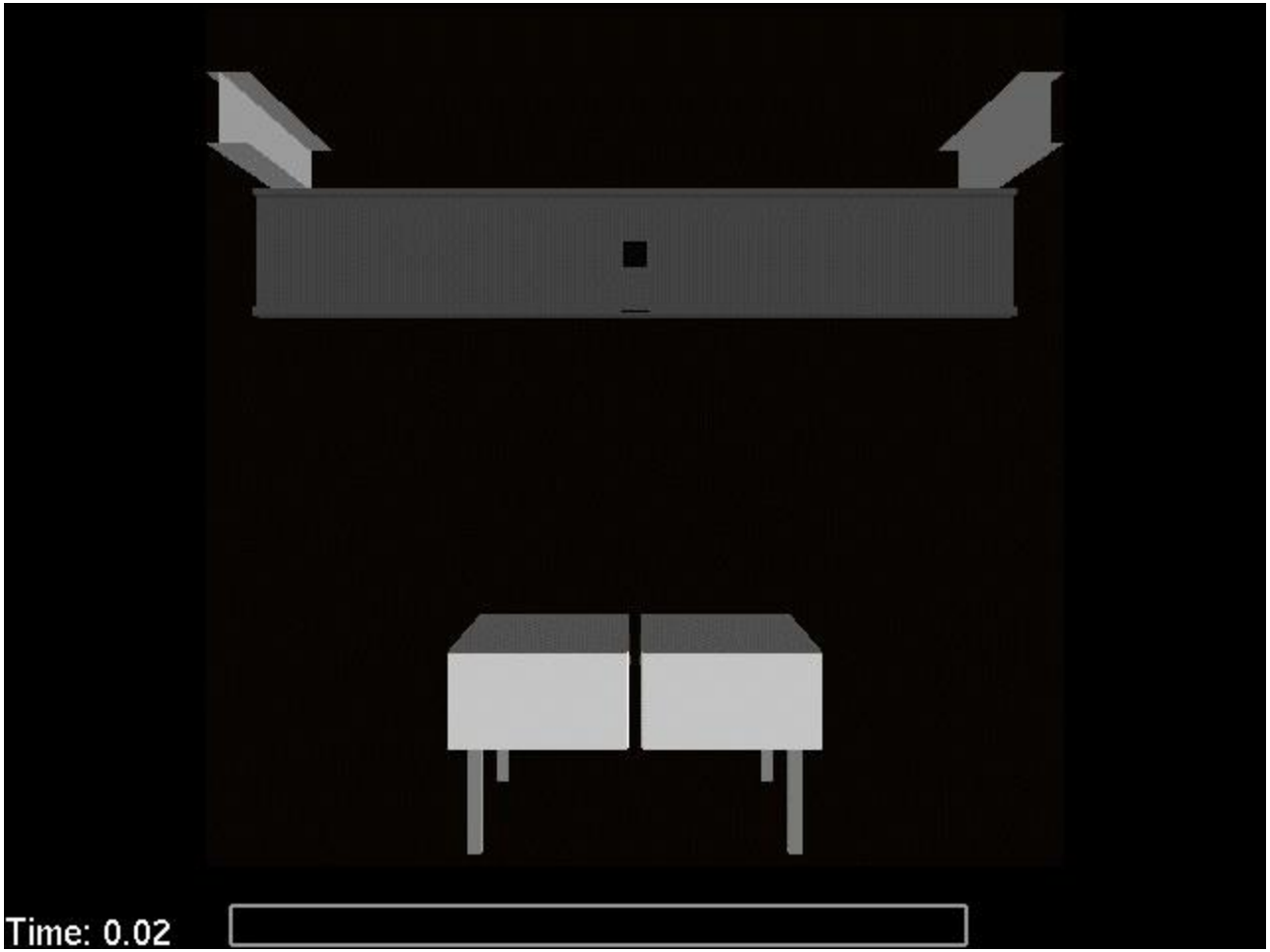
- Use Smokezip for 3D slice files (max blending example)
  Smokezip uses the ZLIB library for compression https://zlib.net

- Open case in smokeview and define min and max slice temperature
- Save a .ini file
- Run smokezip

smokezip –t n casename

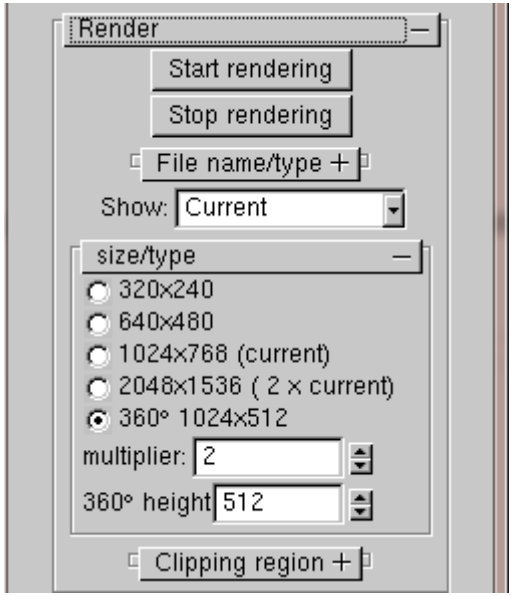
Set n simultaneous processes you want to run

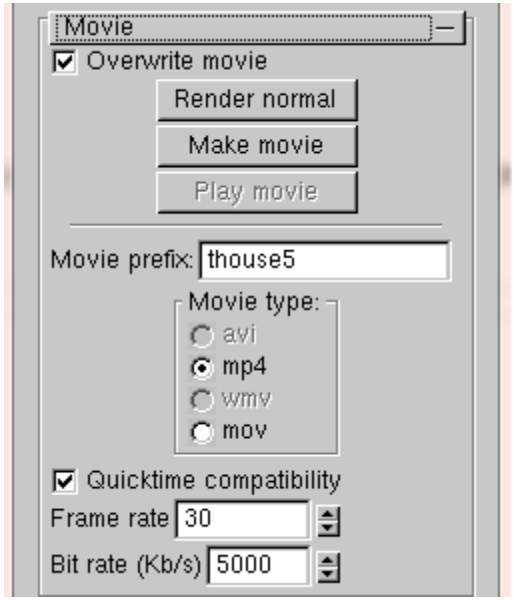
Max Blending Example



Making Movies

- Download ffmpeg and ffmplay from:
  https://www.ffmpeg.org/download.html
- Smokeview adds a movie dialog box if it finds ffmpeg in your path

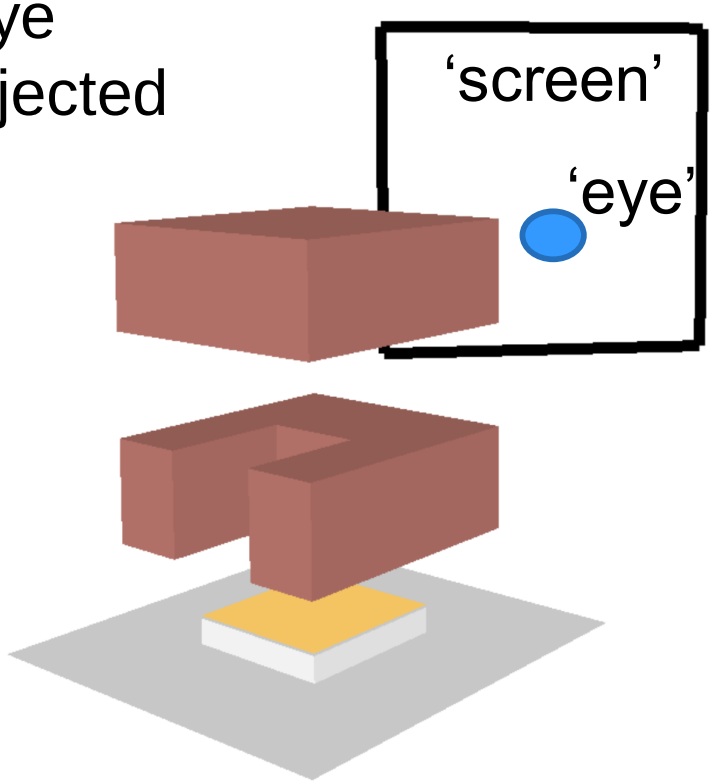




Making Movies

Normal view – one screen

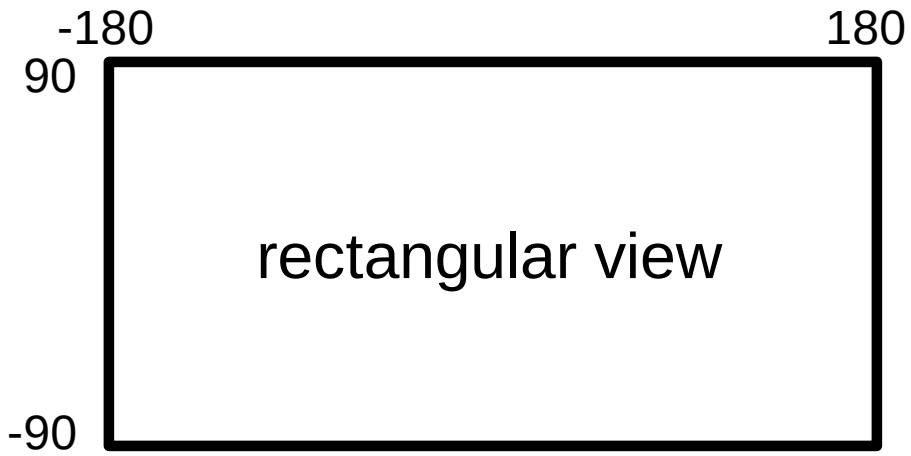
- Objects between the eye and the screen are projected onto the screen

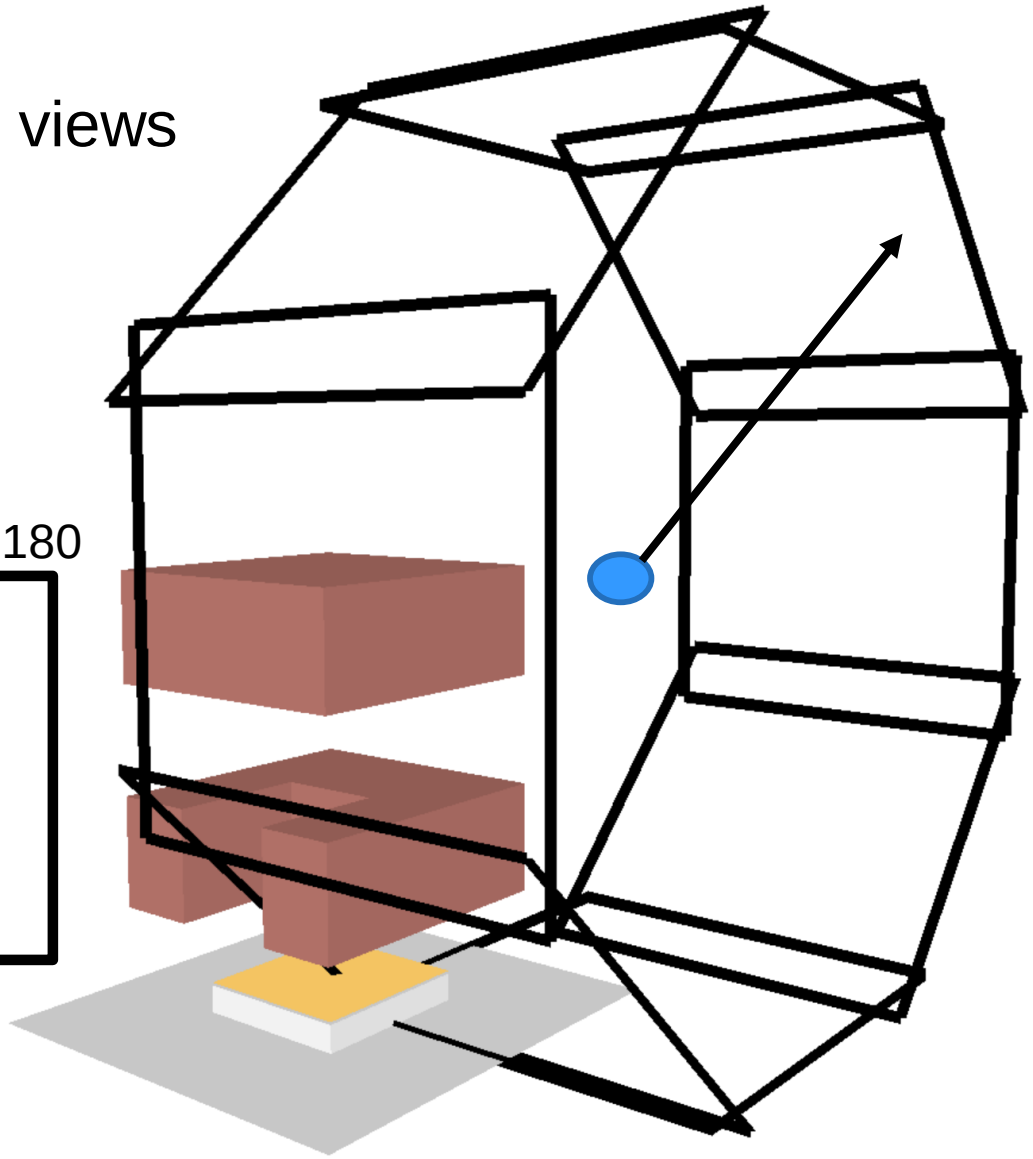


Making Movies

360 rendering – use 8 of 26 views

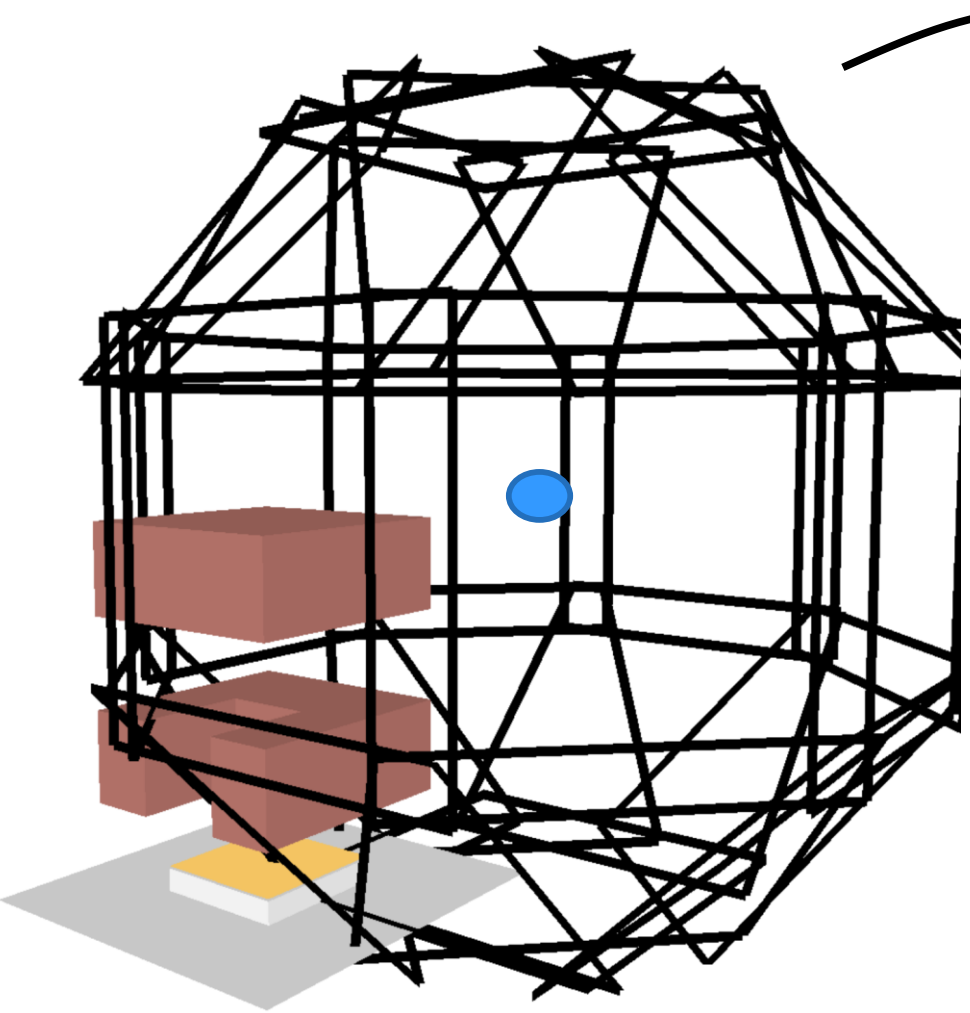
- Compute azimuth and elevation of each pixel in rectangular view
- Find pixel with same azimuth and elevation (or close) in one of the 26 views

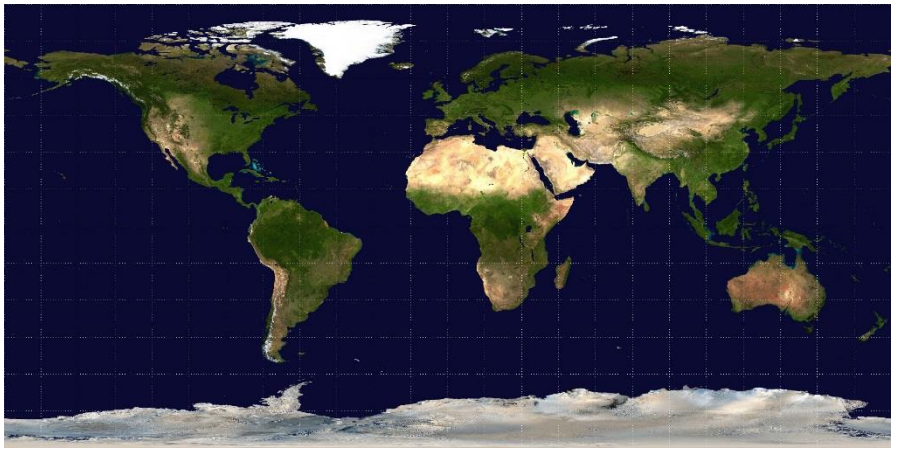




Making Movies

360 rendering – use 26 views to ‘flatten’ the sphere





Making Movies

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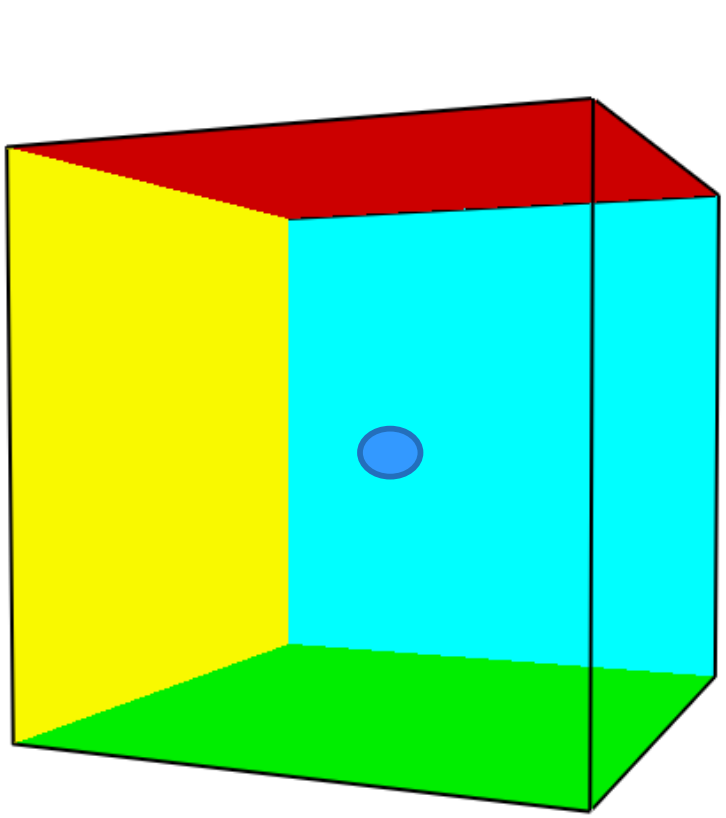
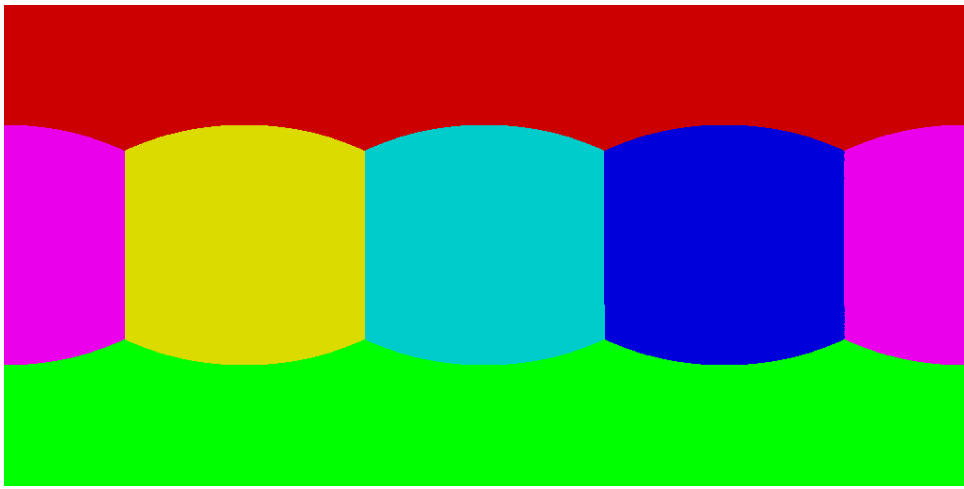
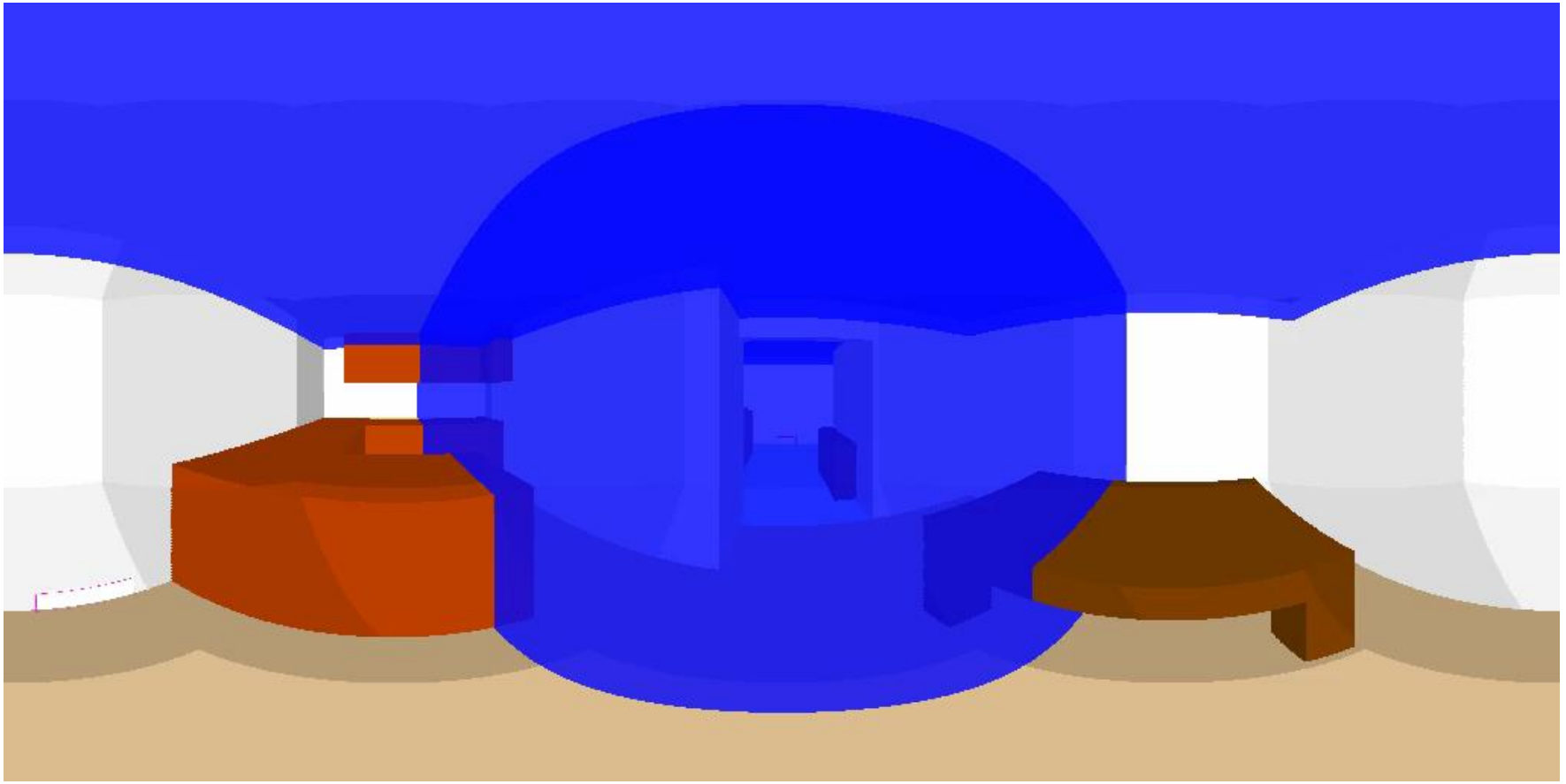
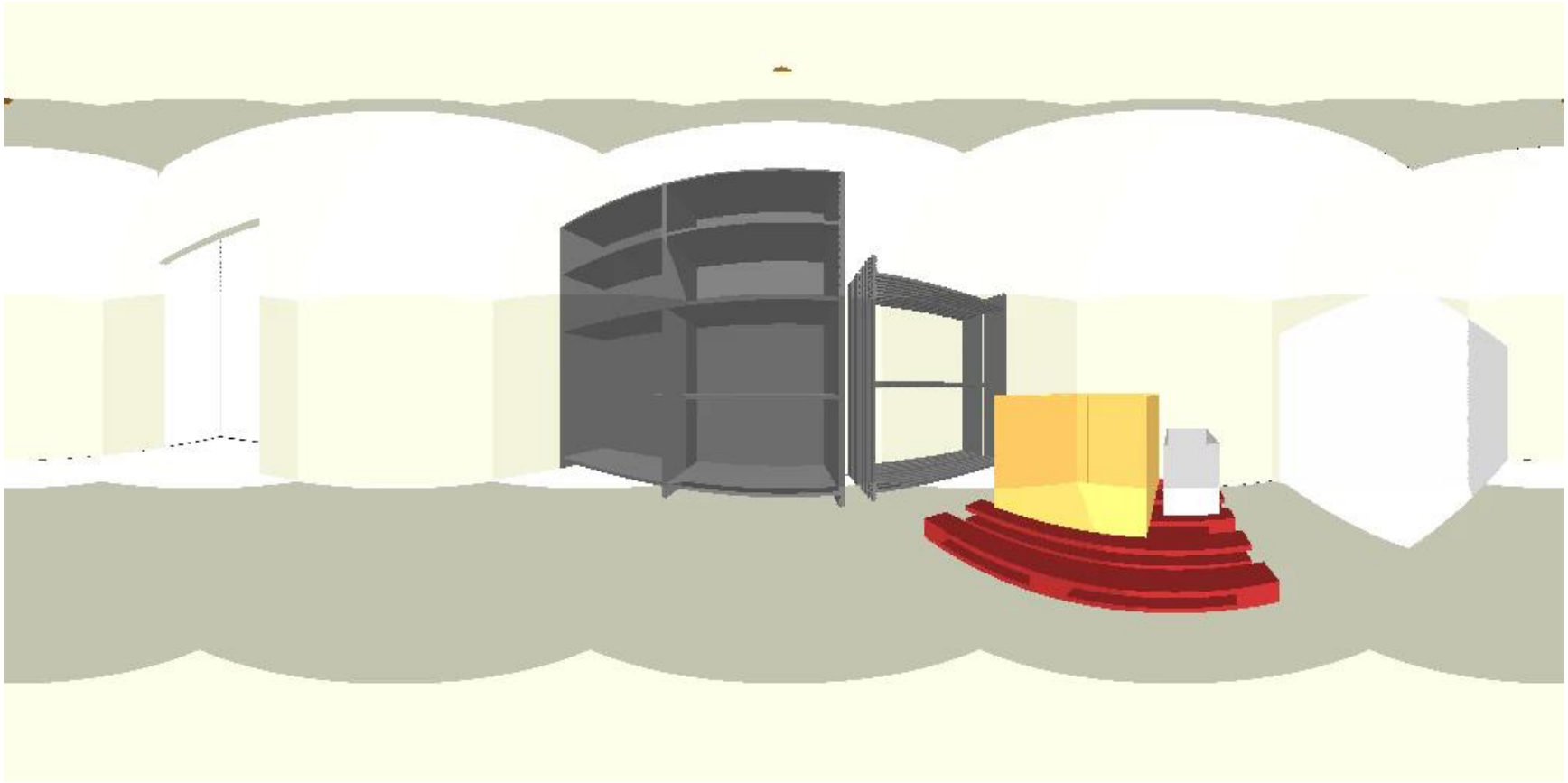




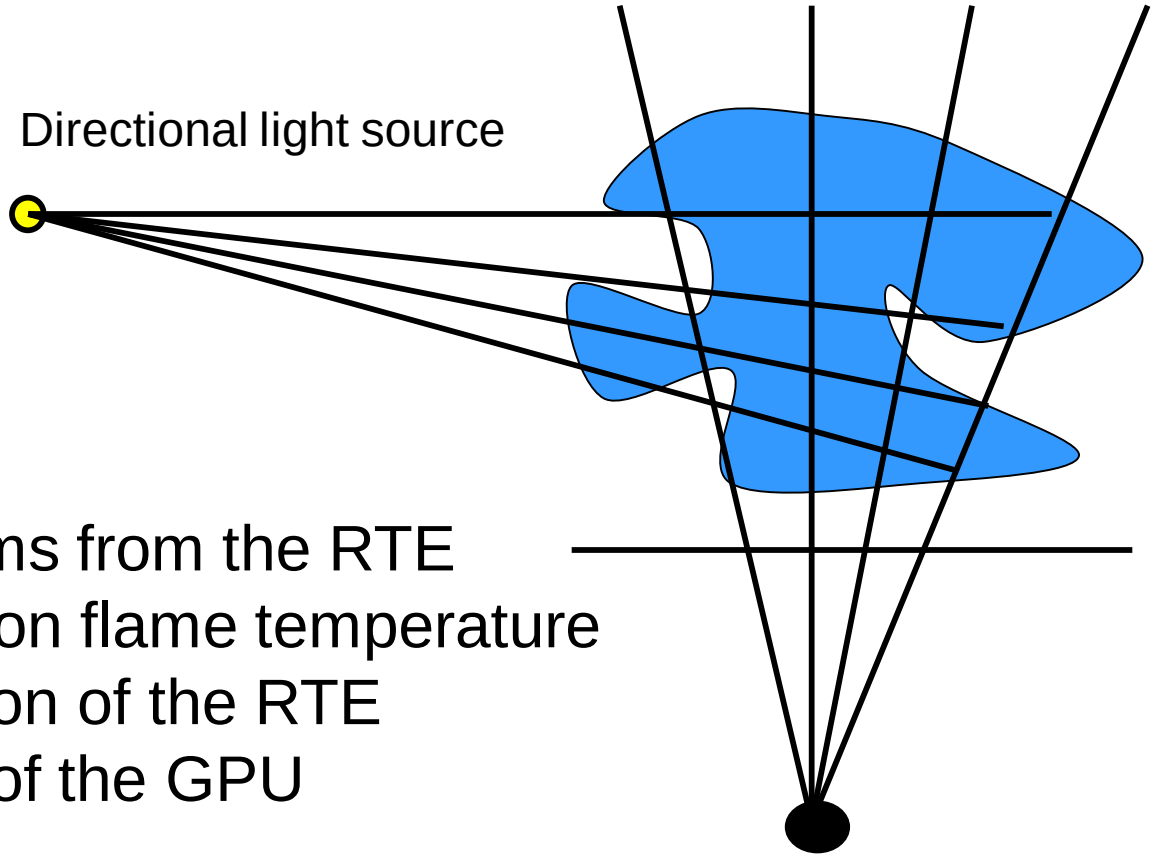
Making Movies



Making Movies



Future Possibilities



- Include more terms from the RTE
- Use color based on flame temperature
- Improve integration of the RTE
- Make better use of the GPU

Thank You and Questions