MeshPotato: A C++/Python API for Production Volumetric Rendering

Kacey Coley

Committee Members:
Dr. Jerry Tessendorf (chair)
Dr. Donald House
Dr. Timothy Davis
The Hobbit: An Unexpected Journey

Rise of the Guardians
Overview

• Background

• What is MeshPotato

• Volume Modeling and Rendering

• Tools
Background
Implicit Function

\[ F(x_1, x_2, x_3) = 0 \]

• Levelset - set of points on a grid which evaluate to the same value
Implicit Function

**Sphere:**

\[ R - |(P - C)| = 0 \]

- **R** = radius
- **C** = center
- **P** = point in space
Narrow Band Levelset

- Inactive Interior Voxels
  - B

- External Narrow Band

- Inactive Exterior Voxels
  +B

- Surface

- B = background value
Volume Modeling Techniques

Constructive Solid Geometry (CSG)

Mesh to Levelset

Procedural Modeling and Advection
Resolution Independent Volumes

- can mix gridded and non-gridded volume types
- can combine grids with different properties
Ray Marching

\[ L(x_C, n_p) = \sum_{j=0}^{M-1} C^T(x_j)T_j \frac{1 - \Delta T_j}{\kappa} \]

\[ x_j = x_{j-1} + \Delta s n_p \]

\[ L^+ = C^T(x_j)T_j \frac{1 - \Delta T_j}{\kappa} \]

\[ T_{j+1} = T_j \Delta T_j \]
Dense Grid

Sparse Grid

Frustum Grid

Sparse Frustum Grid

Field3D
sparse grid structures
Sony Imageworks

hierarchical sparse tree
collection of tools
Dreamworks Animation

OpenVDB
Static Library

Application Code

Static Library

Compiler

Application Executable

Library Code
Dynamic Library
Plugin System

Application Code → Compiler → Application Executable

Plugin Code → Compiler → Plugin Library
What is MeshPotato

- Future-proof extensible API
- Volumetric Modeling capabilities
- Python Scripting
- Deep Image Support
- Multithreading support
- OpenVDB backend
- Integrated in DPA pipeline
Architecture
MeshPotato Core

MPPlugins

MPConvert

Mesh Conversion

MPUtils

Volume Renderer

MPMesh

Mesh Viewer

MPVolume

MPVolumeRender

MeshViewer

MPNoise

Plugin API

Cameras

Vertices

Images

Mesh Classes

Volume Classes

Noise Classes

Registration of Plugins and Data Types
MeshPotato Plugin Manager

Plugin library A

Plugin library B

Plugin library C

Inspired by OpenImageIO’s plugin system
Volume Modeling
Union between Two Implicit Functions

C++:

```cpp
sphere1 = PyroclasticSphere(2.0, pos1, noise);
sphere2 = ImplicitSphere(1.0, pos2);
unionSpheres = UnionVolumeFloat(sphere1, sphere2);
```

Python:

```python
sphere1 = PyroclasticSphere(2.0, pos1, noise);
sphere2 = ImplicitSphere(1.0, pos2);
unionSpheres = UnionFloat(sphere1, sphere2);
```
Union between Two Implicit Functions
def pyroLoop():
    height = drange(0.0, 6.5, 0.5)
    
    *sphere1* = PyroclasticSphere(0.01, position, noise)

    for h in height:
        *sphere2* = PyroclasticSphere(0.01, [cos(h), math.sin(h), 0.0], noise)
        
        *sphere1* = UnionFloat(*sphere2, *sphere1*)

    return *sphere1*
Volume Rendering
Volume Rendering

- RGB lighting
- fast using Intel’s Threading Building Blocks (TBB)
- creates deep images
Deep Images

Sample point cloud

2D image
Deep Images

\[ L(x_C, n_p) = \sum_{j=0}^{M-1} C^T(x_j)T_j \frac{1 - \Delta T_j}{\kappa} \]

\[ x_j = x_{j-1} + \Delta s n_p \]

\[ L = C^T(x_j) \frac{1 - \Delta T_j}{\kappa} \]

\[ \alpha = 1 - \Delta T \]
Deep Images

- Convert to 2D by over operation: $C_o = C_a \alpha_a + C_b \alpha_b (1 - \alpha_a)$
- Generate hold out mattes in Nuke
- View 3D structure of image
Boost.Python

- Wraps C++ classes to Python modules
- Manually expose each class
- Customizable Python Interface
- `boost::shared_ptr` for Python’s aggressive garbage collection
Production Use
Images from Zhaoxin Ye’s thesis
“Volumetric Cloud Rendering: An Animation of Clouds”
float / level set
352 x 196 x 193 / voxel size 0.02 (UniformScaleMap)
1,062,062 active voxels
Summary

• Simple toolset for volume modeling and rendering
• Designed to be future-proof
• Fast
• Support for Deep Image Compositing
• Available in the DPA studio and in Maya
Future Improvements

- Houdini support
- Interactive creation and placements of lights in MeshViewer
- CSG sculpting tools for Maya
- Alembic support
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