Advanced Visual Medicine: Techniques, Applications and Software

Fast Tagged Multi-resolution Volume Rendering

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Overview

- Challenges
- Multi-resolution Rendering
- Slicing vs. RayCasting
- Per Tag Shading
- Transparent Geometry in Volume Rendering

Challenges

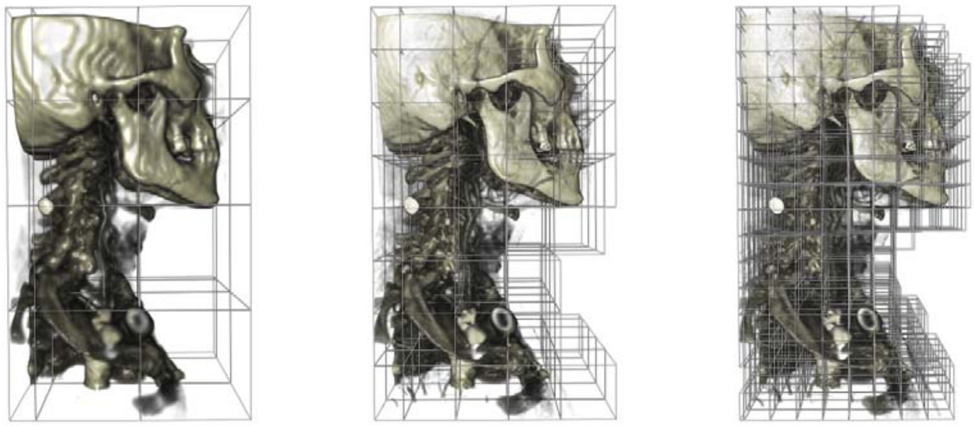
- medical datasets are getting huge
- e.g. CT 512 x 512 x 2000 Slices (12Bit) is normal as of today
- the user wants Volume Rendering without waiting
- labeling/tagging of objects in the volume data helps highlighting important structures, but adds an additional (potentially large) tag volume

Octree Approach

- Create an Octree structure [LaMar 1999]
- Node size e.g. 32x32x32 or 64x64x64
- Resampling of parent nodes
  - Rank filter
  - Average filter (for RGBA data)
- Each parent node contains the data of its 8 children in half resolution
- Cache file (approx 1.4 x original dataset)
- Trilinear interpolation requires 1 voxel overlap
- On-the-fly gradients require 3 voxel overlap

Octree Rendering

- Octree nodes are rendered back-to-front
- Node rendering order defined by viewing direction [Fang1996]
- Use different resolutions for interactive/static rendering

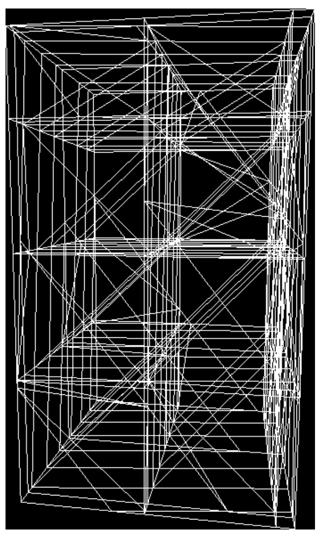


Node Slicing

- Load nodes as 3D Textures
- Render view-aligned slices (proxy geometry) for each node [LiShen2002]
- Fast node slicing is required
  - Marching cube slicing [Ben2005]

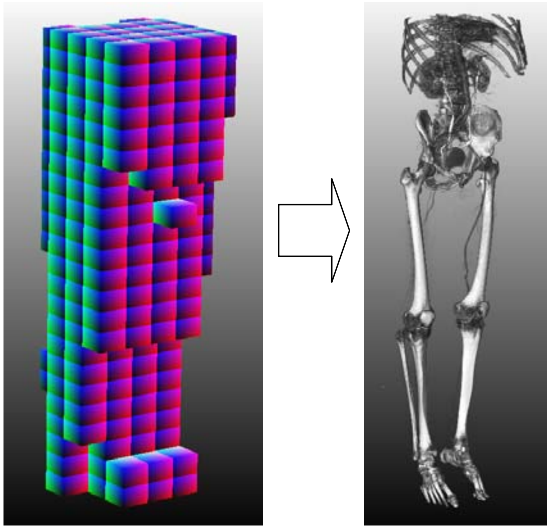
  or

  - Slicing with Vertex Program [Salama2005]



Node Ray Casting

- Alternative to Slicing:
  Individual nodes are rendered with GPU raycasting, blended to final image
- Requires only 6 faces to be rendered per node instead of multiple slices
- Single pass ray casting avoids FBO switch for each node [Stegmaier2005]
- Other approach: All nodes are stored in one large texture, requires additional texture lookup [Hadwiger2005]



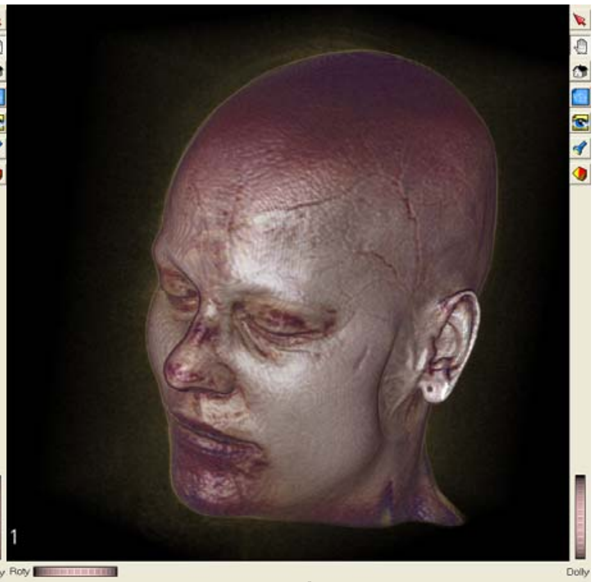
Node Ray Casting

- Advantage:
  - better image quality because of floating point blending
  - correct endoscopic rendering
  - straight-forward to implement [Stegmaier2005]
- Disadvantage:
  - requires Shader Model 3.0 hardware
  - and is still slower than traditional slicing

Slicing vs. RayCasting

- Example with transfer function that has highly transparent regions

Slicing (8bit blending)



RayCasting

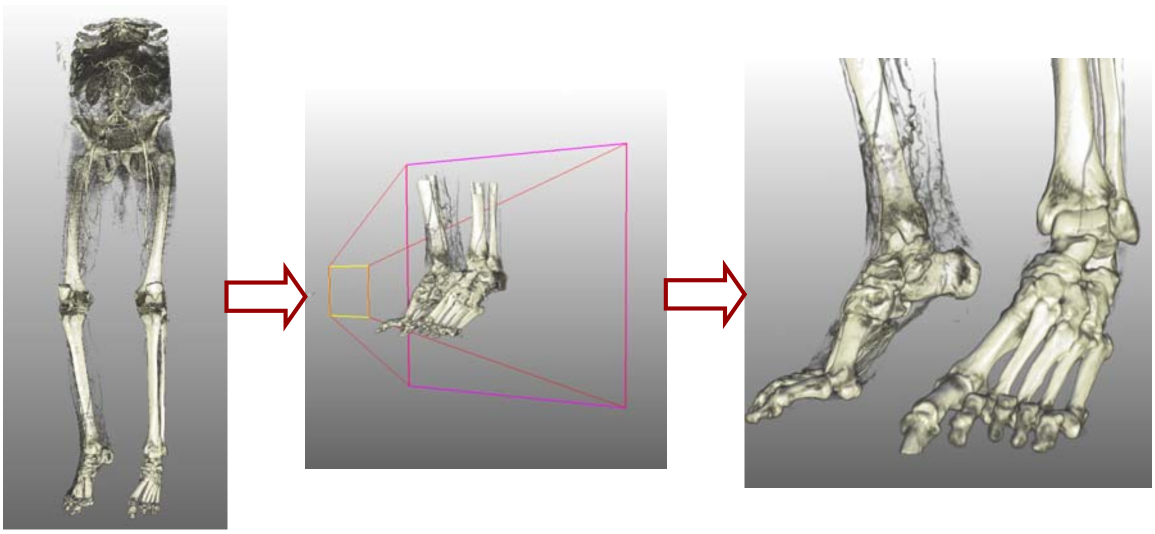
Culling

Clips nodes to:

- Selected Sub Volume
- Clipping planes
- Camera Frustum
- Visibility
  - Combine binary histogram of each node with histogram of current LUT, result != 0 means node is visible

Node	0	1	1	1	0	...
			AND			
LUT	0	0	1	1	1	...
			=			
	0	0	1	1	0	...

Culling Example



Caching

Volume Data Cache

- Hierarchical Cache based on node height
- Uses MRU strategy

Texture Memory Cache

- Manages amount of texture memory used
- Uses MRU strategy

All Volume Renderer modules share the caches

Avoids that multiple renderers use too much resources

Shading

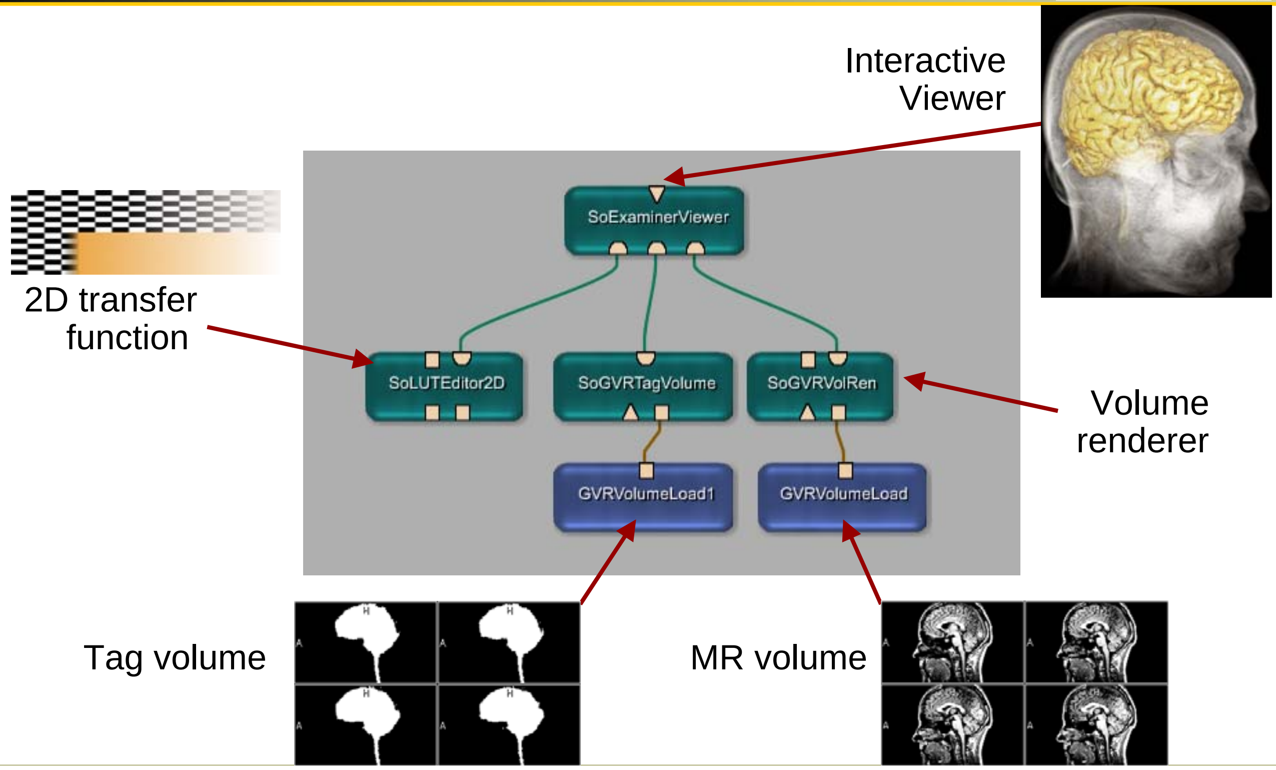
- Blinn-Phong Lights
- Tone Shading [Gooch1998]
- Silhouette/Boundary Enhancement [Ebert2000]
- Shaders written in GL Shading Language (GLSL) or ARB_FRAGMENT_PROGRAM
- Gradients either precalculated as RGBA texture or on-the-fly central difference in shader

Tag Volume

Defines an additional (sub)volume

- Same voxel size as original volume
- Tag volume labels segmented objects
- Tag range is 0-255
- per-tag LUTs [Kniss2001] and per-tag shading
- Optimization: Tag Volume Octree can use shared node images for nodes that contain only a single tag value (very efficient for sparse tag volumes)

MeVisLab Example Network



Per Tag Shading

- In addition to a per tag transfer function, select different shading modes for each individual tag
- Original idea by [Hadwiger2003], applied to multi-resolution rendering
- Use 1D RGBA texture to store 4 weights for each tag [Link2006]
  - Light1
  - Light2
  - Tone Shading
  - Boundary/Silhouette enhancement

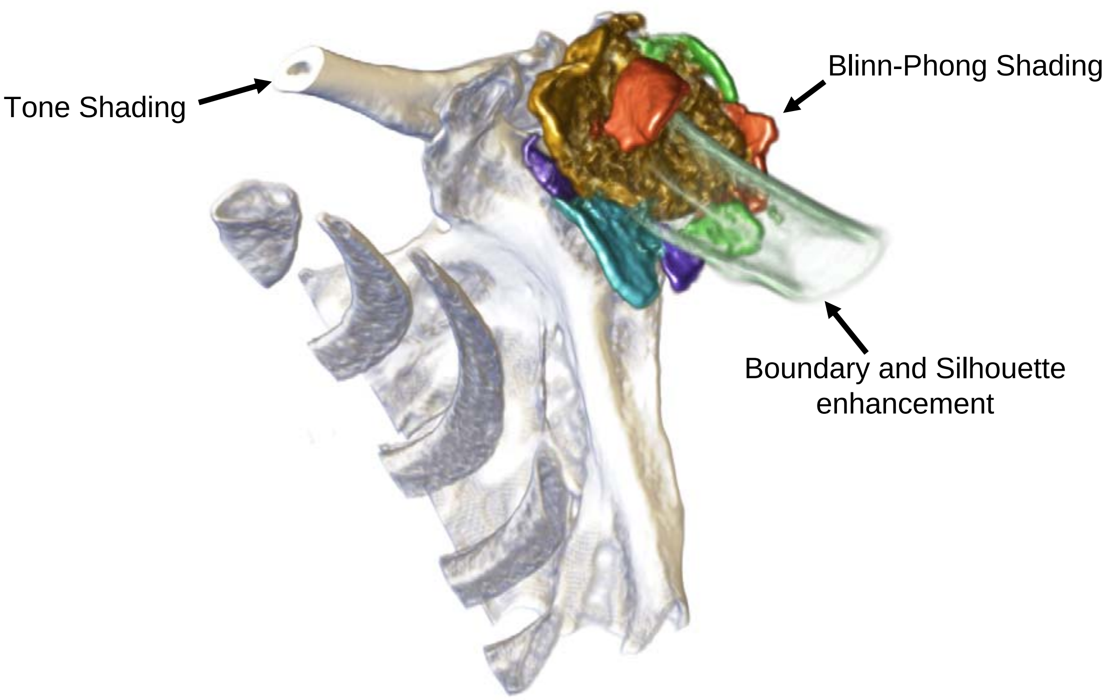
Per Tag Shading

- Optimization: Avoid branching in the shaders and select specialized shader on each octree nodes, using binary histograms of tag nodes [Link2006]

Id	0	1	2	3	4	...
Per object rendering mode weights texture T_E						
R	1	0	0	1	0	...
G	0	0	1	1	0	...
B	0	.5	1	1	0	...
A	0	1	1	1	0	...
Node histogram S_n						
	0	1	0	0	0	...
Rendering mode histograms E						
R	1	0	0	1	0	...
G	0	0	1	1	0	...
B	0	1	1	1	0	...
A	0	1	1	1	0	...

```
shaderID = 0;
for (i = 0; i < 4; i++)
  if (S_n & E[i] != 0)
    shaderID += 1 << i;
```


Per Tag Shading



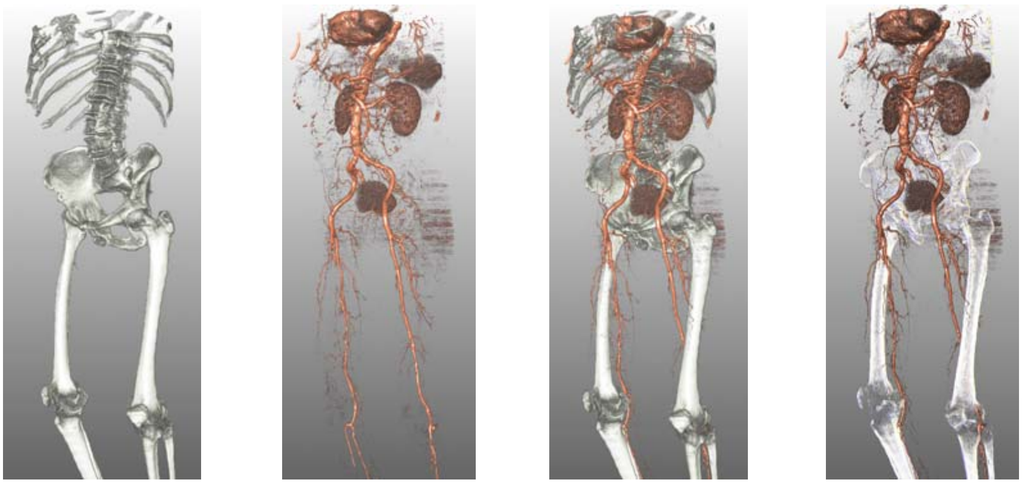
Mask Volume

- Defines an additional volume (no octree!)
- Binary inside/outside decision
- May be positioned/oriented anywhere in the volume
- Affects color and/or tag value
- Fast update, but size limited by texture memory, because it is loaded into one 3D Texture

Bone Removal with Mask Volume

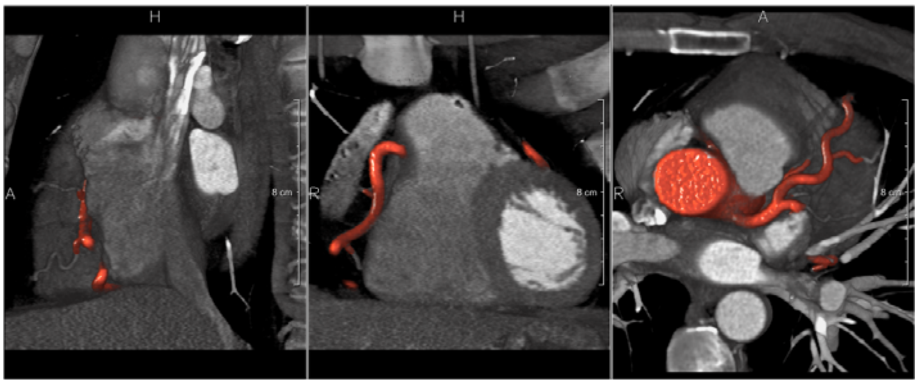
- Bone Removal outputs 256x256x256 mask volume when e.g. segmenting a 512x512x2000 slices dataset [Hahn2005]
- Mask volume is scaled to original volume while rendering
- Reduced mask resolution compared to original image creates artifacts, but allows for interactive segmentation updates

Bone Removal Example



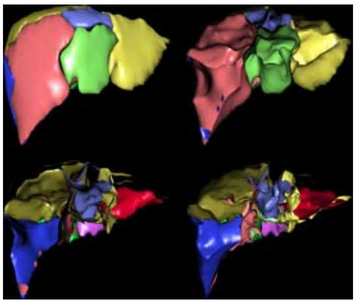
Slab Rendering

- Extends 2D Viewers to show Volume Rendering
- Render slab of slices with orthogonal projection
- All presented render modes are applicable

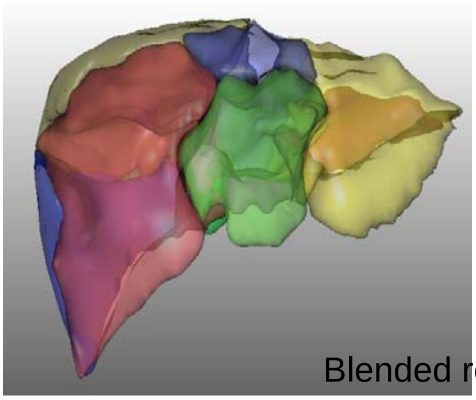


Depth Peeling

- Order Independent Transparency [Everitt2001]
- Image space algorith on GPU
- Emulates dual depth buffer tests
- Replaces traditional triangle sorting on CPU
- Multipass rendering of scene



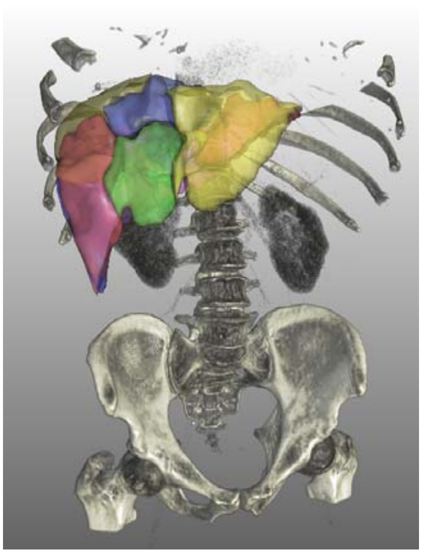
Layers



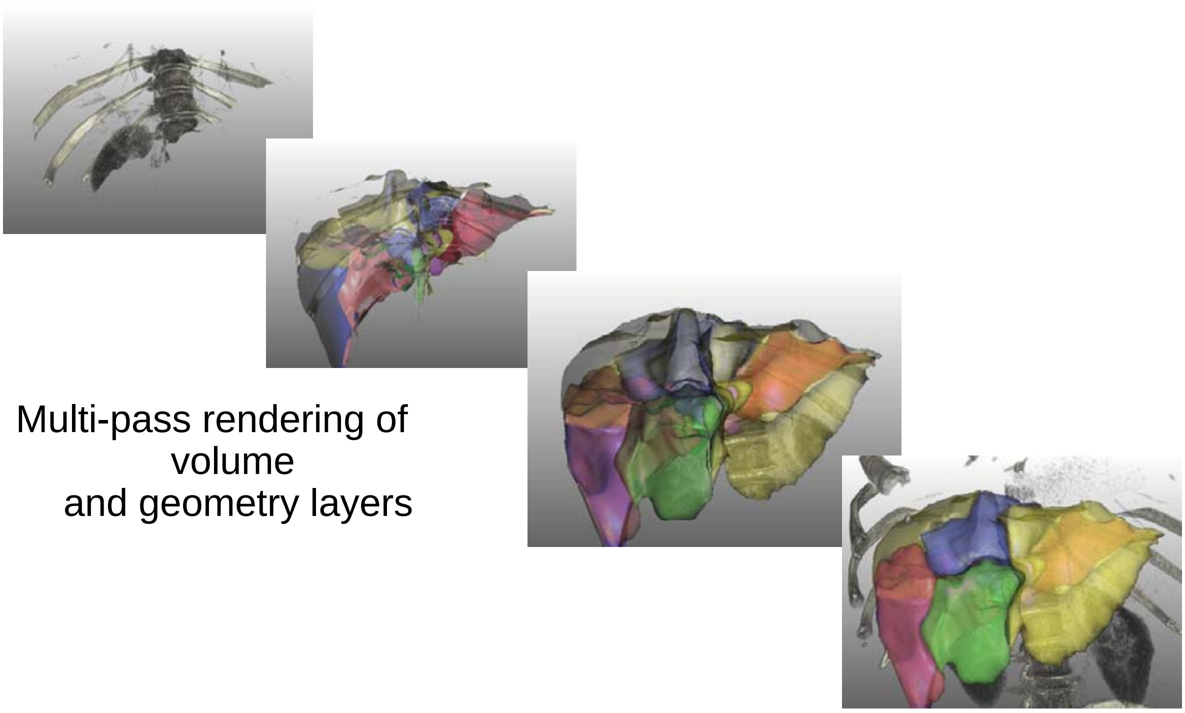
Blended result image

Transparent geometry and Volume Rendering

- Do depth peeling on geometry and keep color and depth layers as textures
- Mixes peeled color layers and volume rendering
- Multipass volume rendering for depth layers
- Can also use depth layers to do depth clipping or modify color/tag values [WEE02] [WEE03]



Transparent geometry and Volume Rendering



Multi-pass rendering of volume
and geometry layers

Summary

- Modern graphics hardware allows advanced shading at interactive frame rates
- Presenting segmented objects becomes more important
- Mixing Volume Rendering with semi-transparent geometry allows to nicely integrate triangle and voxel based representations in the same view

MeVisLab

- Most presented rendering modes are integrated in the **SoGVRVolRen** module and it's extensions, which is part of **MeVisLab Basic**
- Download MeVisLab at www.mevislab.de and check the examples of **SoGVRVolRen**

Acknowledgements

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