Westfälische
Wilhelms-Universität
Münster

Voreen – Volume Rendering Engine

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Version 5.0.1

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Outline

1. About Voreen
2. Obtaining Voreen
3. Project Structure
4. Property Linking
5. Extending Voreen
6. Additional Features

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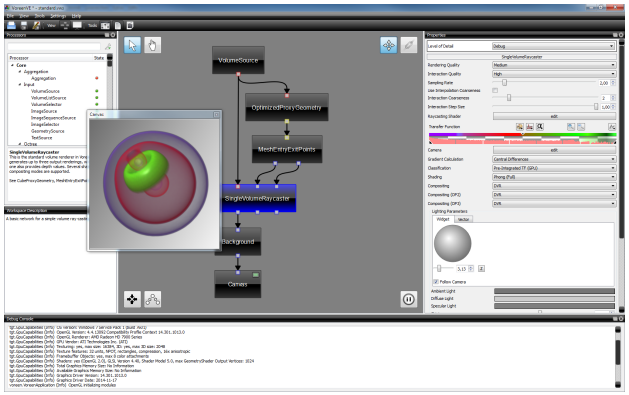
About Voreen

- Framework for interactive visualization of volumetric data
  - Originally initiated and maintained by the Visualization & Computer Graphics Research Group at the University of Münster in the Collaborative Research Centre 656 'Molecular Cardiovascular Imaging'
  - Now maintained and developed collaboratively by the Pattern Recognition and Image Analysis Group (https://uni-muenster.de/PRIA) and the VISualization and graphIX (VISIX) research group (https://uni-muenster.de/VISIX)
- Open source (GPL) research platform with a focus on rendering / visualization, some preprocessing capabilities and analysis tools
- Functional entities can be reused by exploiting the data-flow metaphor
- Integrates not only volume data (e.g., geometry, flow data, ...)
- Platform independent (Windows, Linux; Mac OS currently not supported)



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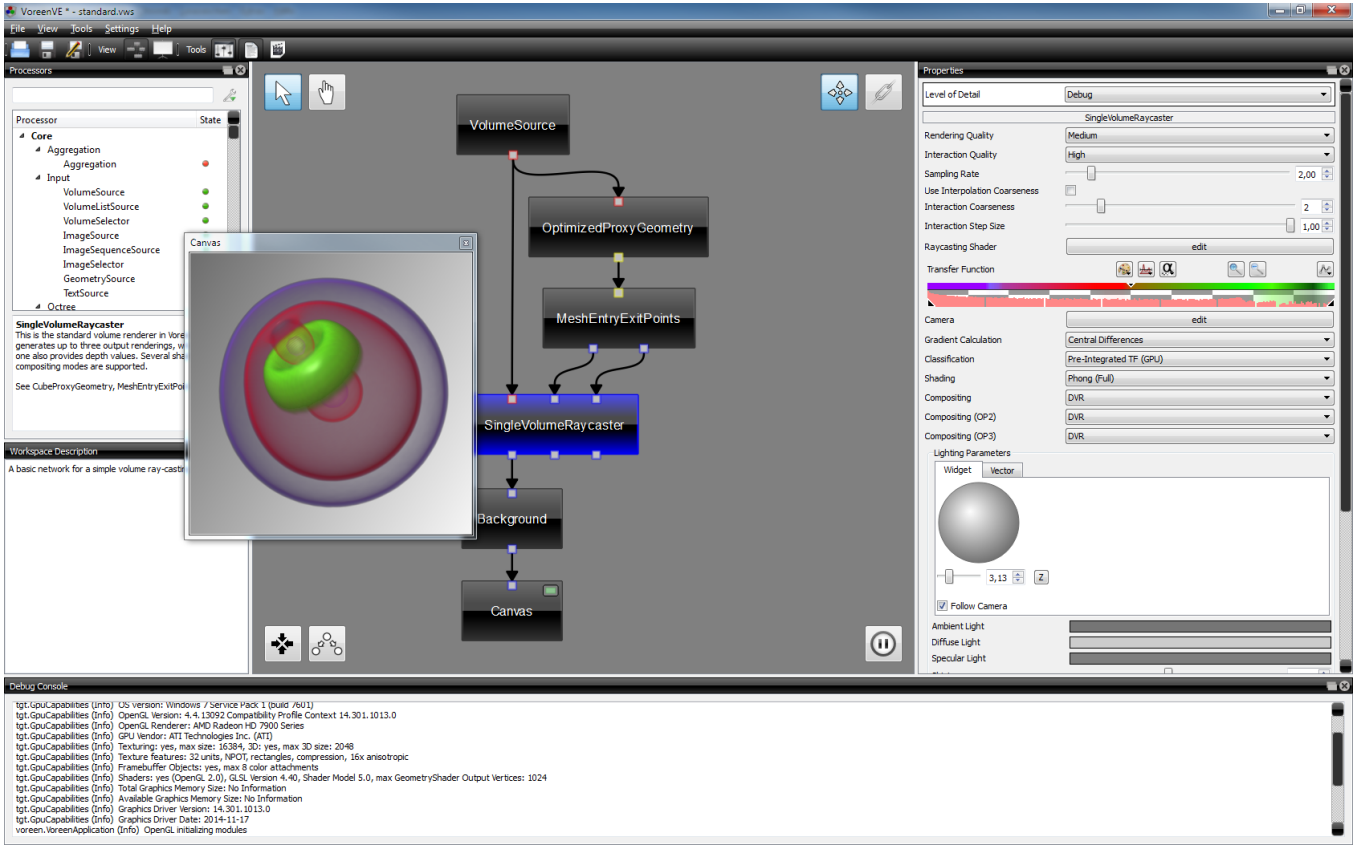
About Voreen



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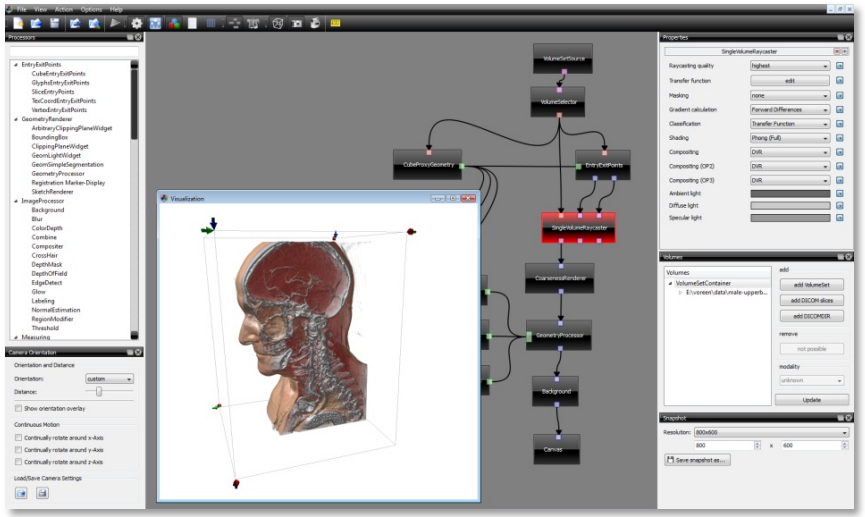
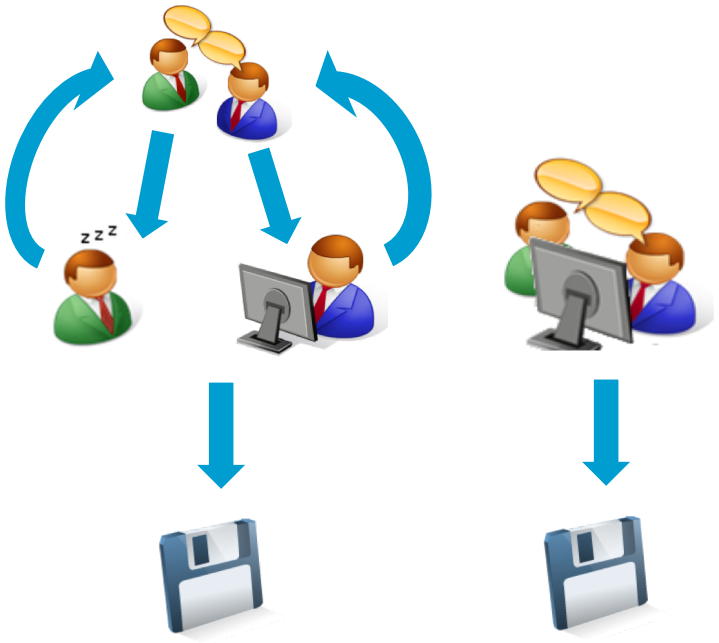
Collaborating with Domain Experts

- Insightful visualizations can only be generated collaboratively
- Challenging for domain experts and computer scientist





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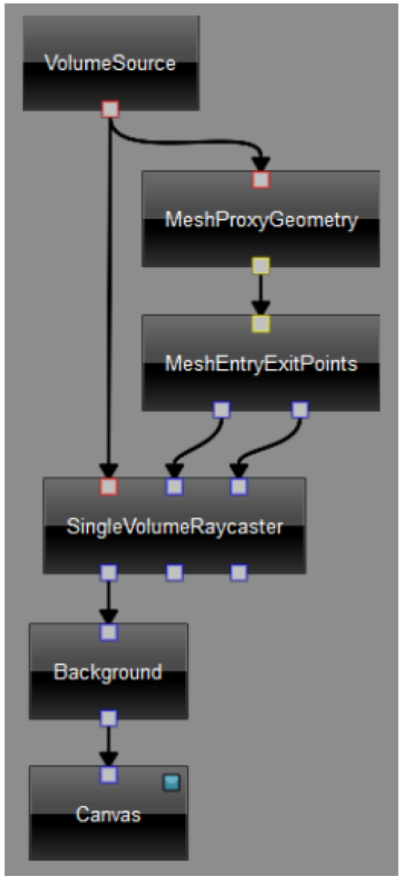
Data Flow Concept

- Data flow network for visual rapid prototyping
  - Modular concept, reusability
- Data (e.g., volume data, geometry, images, …) is transmitted through the network

- *Processors*: Entities that perform computations (e.g., rendering, geometry processing, data import)
- Connected by *ports*
  - Different types, e.g., *ImagePort*, *GeometryPort*, …

- Central *network evaluator*
  - Determines evaluation order
  - Manages resources



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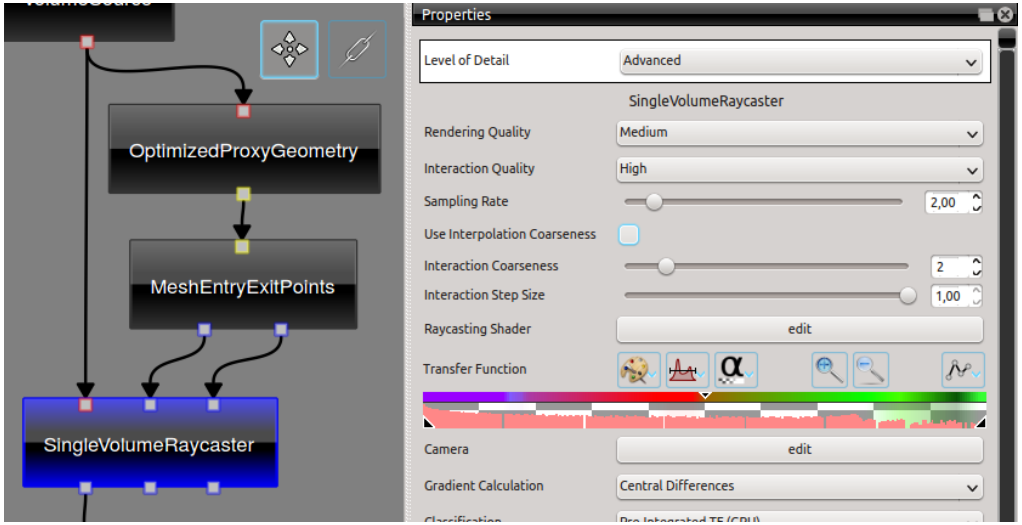
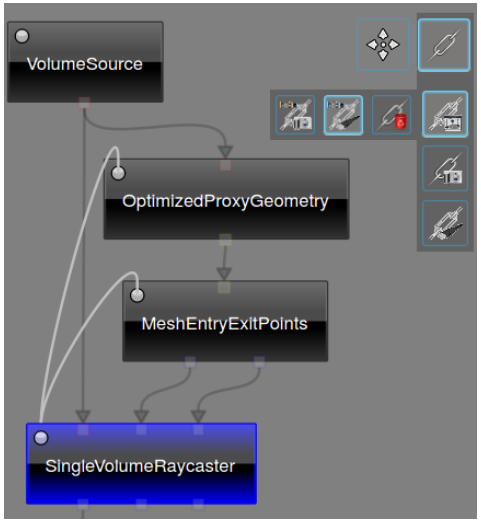
Data Flow Concept

- Configuration of processors through *properties*
  - e.g., lighting, camera, transfer function
- Specify processor behavior
- Interactive manipulation of network behavior through interaction with properties
- *Linking* of properties for synchronization between processors





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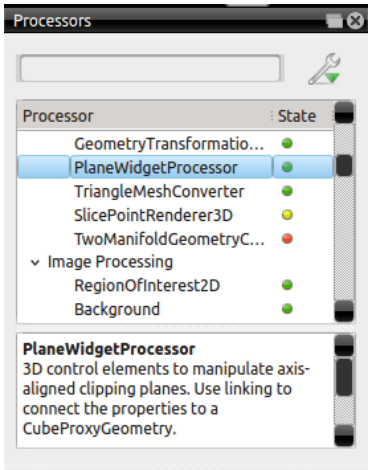
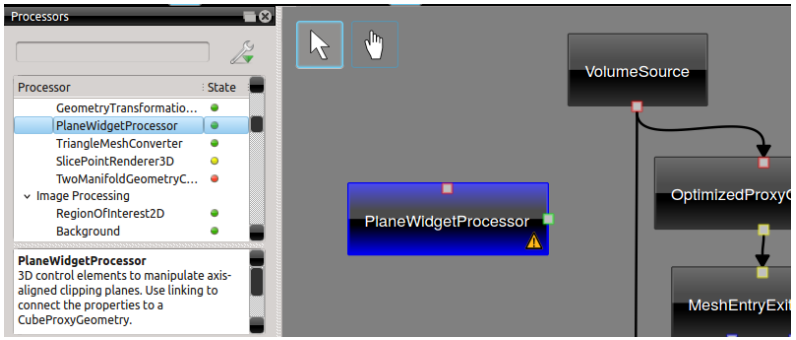
Data Flow Concept

- Reusability of processors
  - Processors are organized in processor list
  - List can be searched and sorted by type, module, name, ...
  - State flags depict the processor's stability
    (= experimental, = testing, = stable)



- Processors can be dragged into the network to create a new network or extend an already existing network



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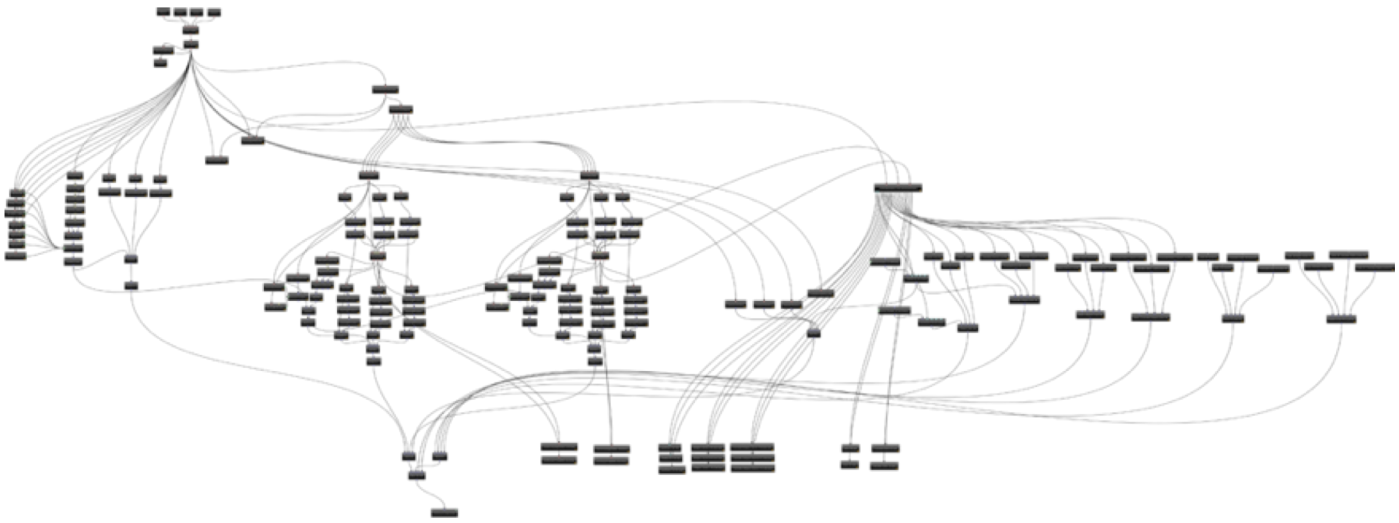
Data Flow Concept

- Drawbacks: networks may become large and confusing for domain experts
- Large number of components and properties, settings, ...



- Solution: provide a more streamlined application user interface for a created workspace

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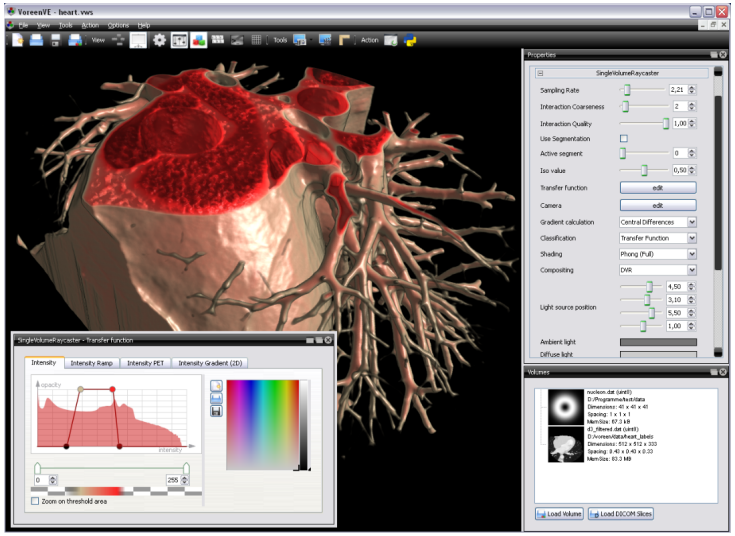
Application Mode

- As an addition to the network mode there exists an application mode.
- Revised and extended in Voreen 5.0
- Visibility of single properties can be configured
- Provides a user interface for the actual application domain as an abstraction from the underlying network



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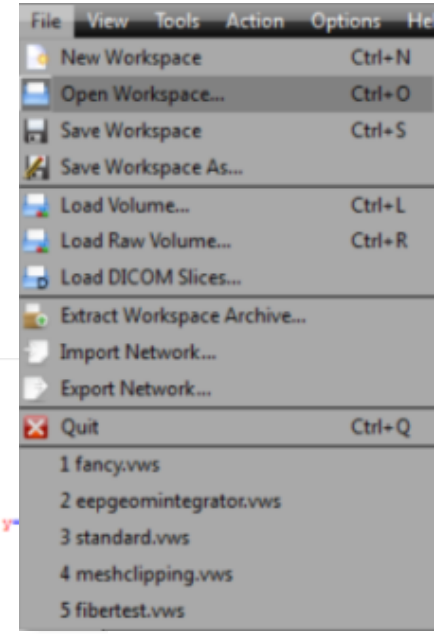
Workspaces

- The current session is serialized within the XML- based Voreen workspace format *.vws*
  - Network topology
  - Property states
  - Processor layout
  - Loaded volumes
  - …




```
<Processor type="MeshEntryExitPoints" name="MeshEntryExitPoints" id="ref8">
    <MetaData>
        <MetaItem name="ProcessorGraphicsItem" type="PositionMetaData" x="-205" y="-174" />
    </MetaData>
    <Properties>
        <Property name="camera" adjustProjectionToViewport="true" id="ref16">
            <MetaData>
                <MetaItem name="EditorWindow" type="WindowStateMetaData" visible="false" x="-955" y=
            </MetaData>
            <position x="-3.16516089" y="1.88449895" z="2.34805989" />
            <focus x="-0.14060999" y="-0.205892" z="0.00218" />
            <upVector x="0.3551189" y="0.87701076" z="-0.3236399" />
        </Property>
        <Property name="filterJitterTexture" value="true" />
        <Property name="jitterEntryPoints" value="false" />
        <Property name="jitterStepLength" value="0.005" />
        <Property name="supportCameraInsideVolume" value="true" />
        <Property name="useFloatRenderTargets" value="false" />
    </Properties>
</Processor>
```

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Technical Aspects

- Written in C++
- Exploits OpenGL / GLSL and (optionally) OpenCL, OpenMP
- GUI optional (Qt 5)

- Support for several volume file formats (e.g., RAW, DICOM, HDF5, TIFF-Stacks, ...)

- Main renderer: OpenGL / GLSL volume ray-casting

- Support for out-of-core data sets using an octree data structure and an OpenCL volume ray-casting approach

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Obtaining Voreen

- Download of pre-built version or source code from http://voreen.uni-muenster.de
- Current public version 5.0

- Configuration via the CMake build system
- Instructions for building Voreen from source can be found on the website

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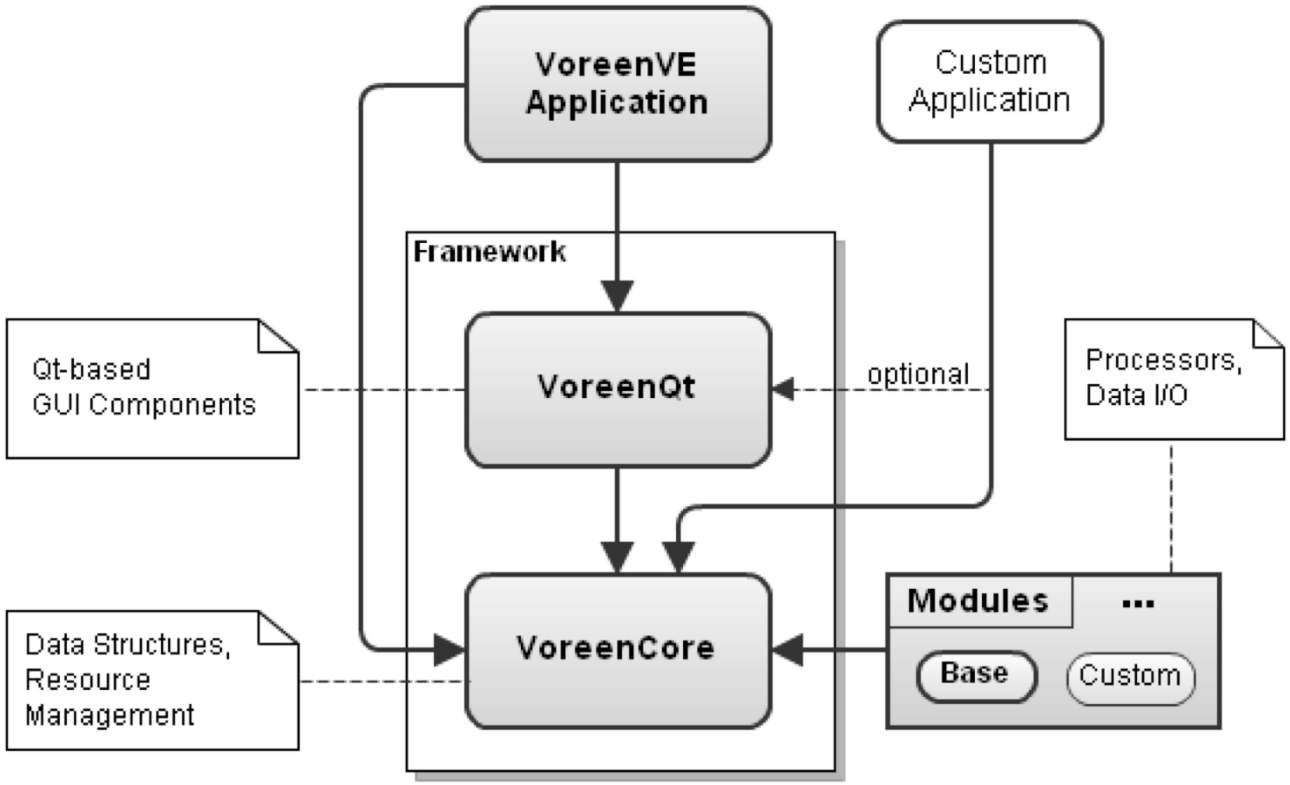
Voreen Architecture



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Framework

- Voreen core library
  - Ports, Properties
  - Processor base classes
    - *Processor, VolumeProcessor, RenderProcessor, ImageProcessor, …*
  - Data structures
    - Data flow network, volumes, geometries, …
  - Network handling
  - Minimal external dependencies (OpenGL, GLEW, Boost, TinyXML)

- Voreen Qt library
  - Property widgets
  - Processor widgets
  - Graphical network editor

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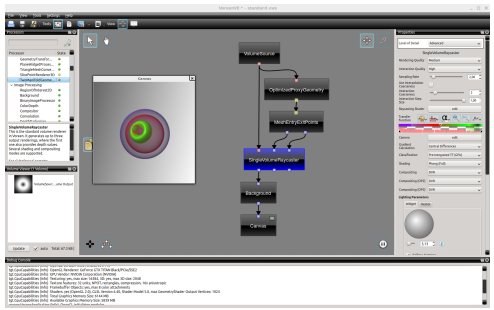
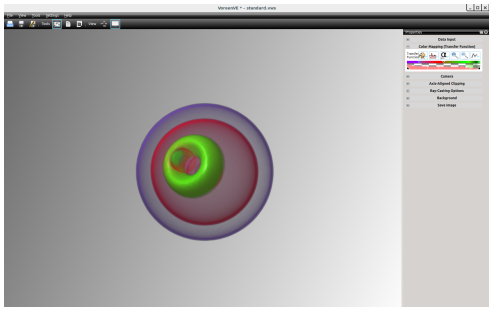
VoreenVE

- Visualization environment for rapid prototyping
  - Auto-generated property widgets (Voreen Qt Library)
  - Visual debugging
    - Inspection of intermediate rendering results
  - Runtime shader editing
- Application mode for domain experts
  - Hides the underlying network
  - Visibility of single properties can be configured





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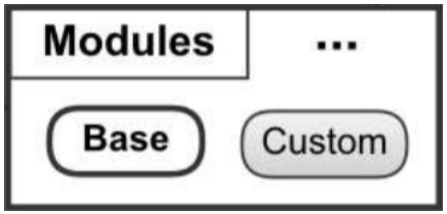
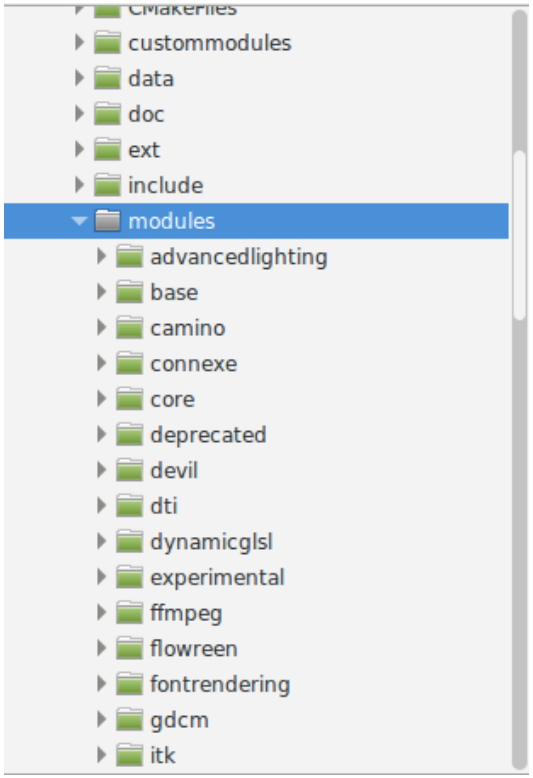
Modules

- Recommended way to extend Voreen
- Encapsulate rendering and data processing functionality
  - Processors
  - Data reader and writers
- Are included / excluded from the build process using CMake configuration options
- May contain external libraries
- Dedicated directory for custom modules





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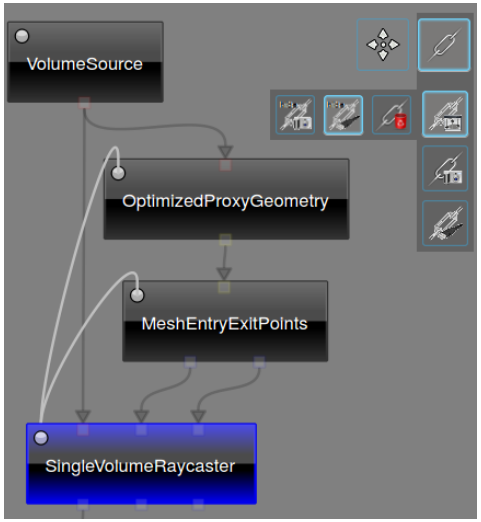
Property Linking

- Properties of the same type can be linked (value synchronization)
  - Within or across processors
  - Uni- or bidirectional
  - Cycle prevention
- Linking of differing, but compatible property types is also possible
  - Float ⟷ Integer ⟷ Boolean
- Linking of more complex properties (e.g., transfer functions)
- (Optional) auto-linking of camera properties



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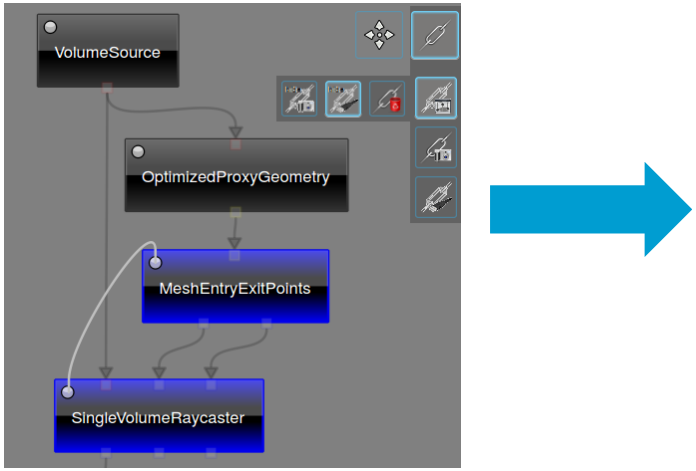
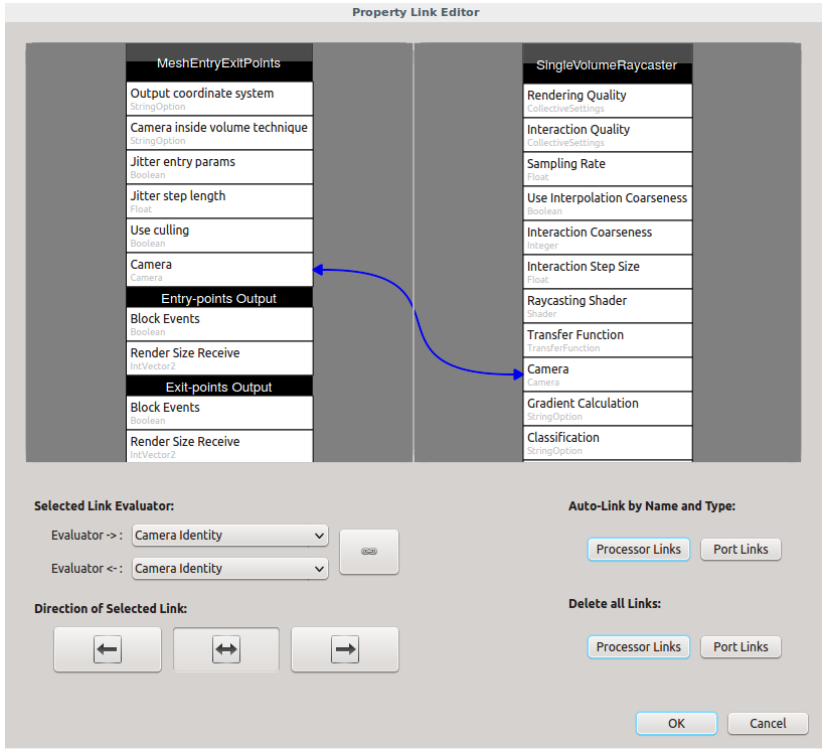
Managing Links in VoreenVE

- Network editor provides *linking layer*
  - Links are represented by arrows
  - Port connections are faded out
  - Dragging a line between processors opens *linking dialog*





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Extending Voreen

- Tutorials on the website (more to come)
  - Adding a module
  - Adding a processor
- Sample-module *voreen/modules/sample* can be used as a starting point
  - Documentation in the source code should be helpful
- Use existing processors as templates
  - *process()*-method does (almost) all the work, is called during network evaluation
  - Adding ports / properties using *addPort()* and *addProperty()* in constructor
  - Callback-functions for performing actions on property changes can be realized using *MemberFunctionCallback* or *LambdaFunctionCallback*
- ...

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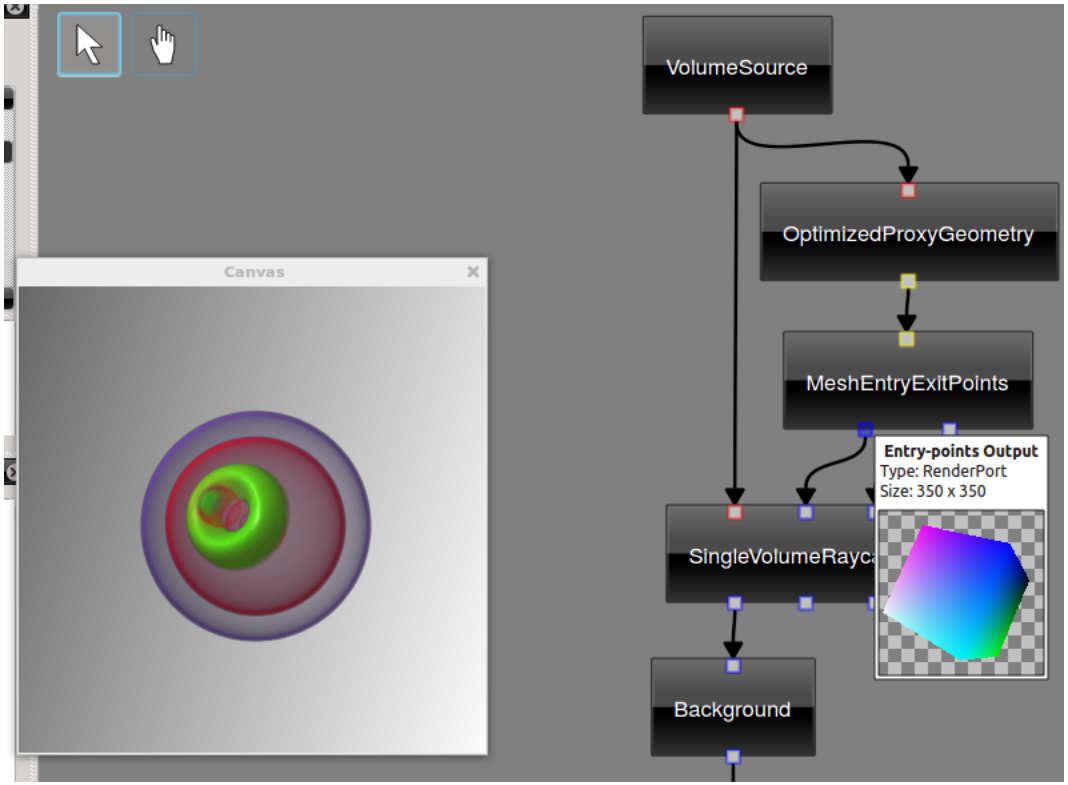
Visual Debugging

- By hovering over render ports, their content can be inspected



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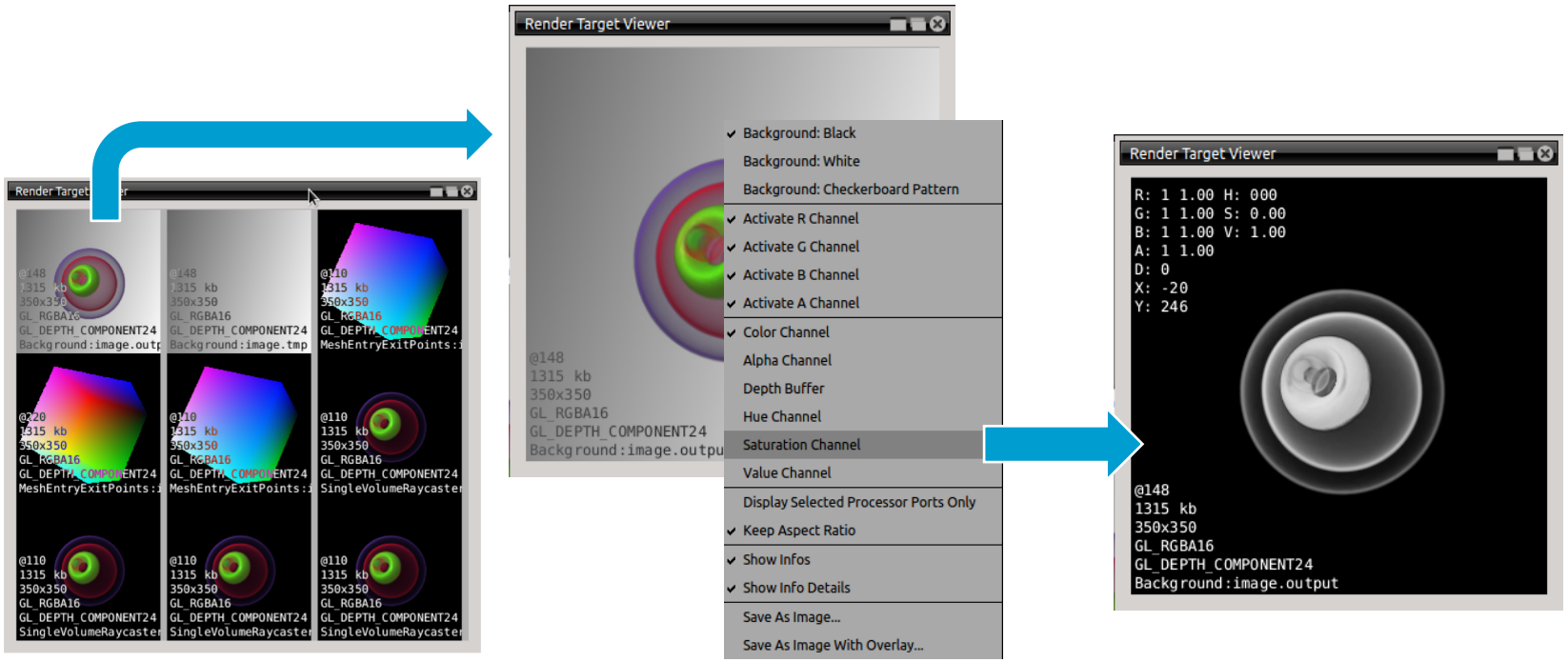
Visual Debugging

- Render target viewer allows to inspect the color, alpha, depth layer , ...
- For all render targets (e.g., *RenderPort* objects)



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Serialization

- Workspace serializes network topology and property states to XML
- Custom data can be serialized by implementing the *Serializable* interface and overwriting the *serialize*- and *deserialize*-methods
- Serializer supports primitive data types, *tgt* data types (e.g., vectors, matrices, ...), and STL containers
- Voreen 5.0 also added a binary JSON serializer that can optionally be used instead of the XML serialization

```
std::vector< std::pair<float, tgt::vec3> > myData_;

void TestProcessor::serialize(Serializer& s) const {
    s.serialize("MyData", myData_);
}

void TestProcessor::deserialize(Deserializer& d) {
    d.deserialize("MyData", myData_);
}
```

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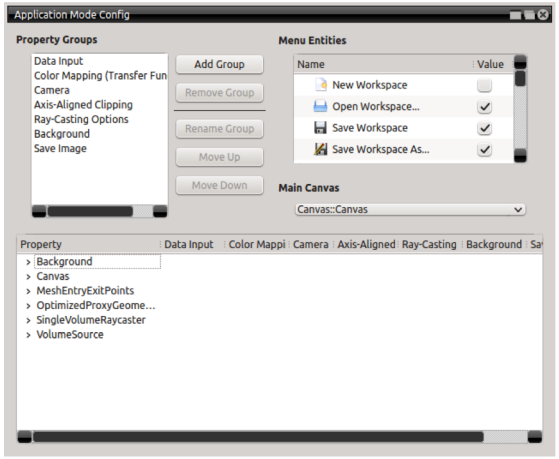
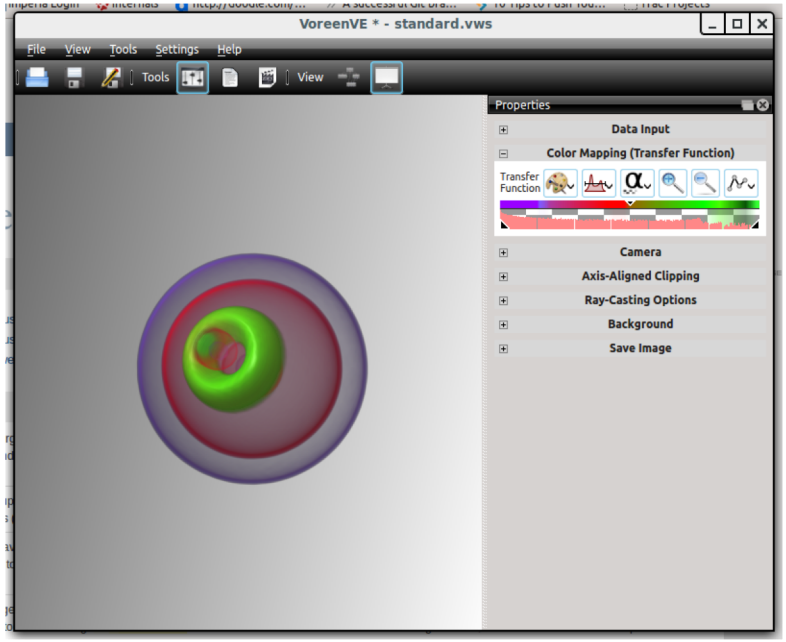
Application Mode Configuration

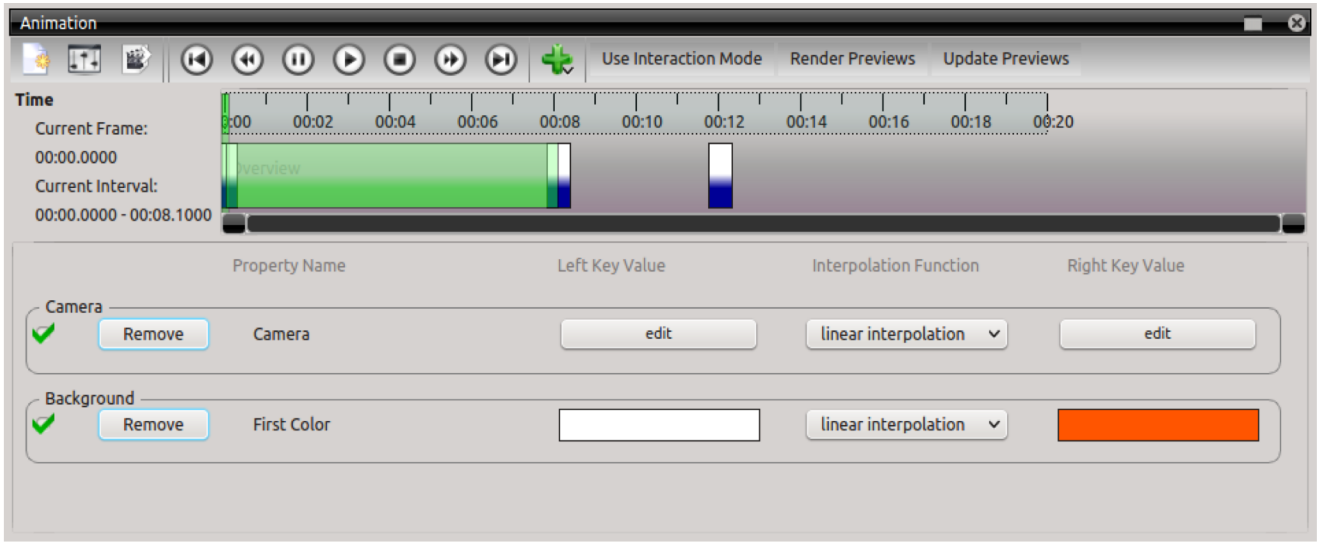
- Configures the application mode by creating property groups and adding selected properties to a specific group
- Properties of multiple processors can be grouped by functionality in the interface
- Independent from network topology





Animation

- Allows to animate (almost) all properties that have been added to the application mode configuration
- User specifies key frames for which the property value is stored
- Automatic interpolation of values in intervals between key frames
- Video export



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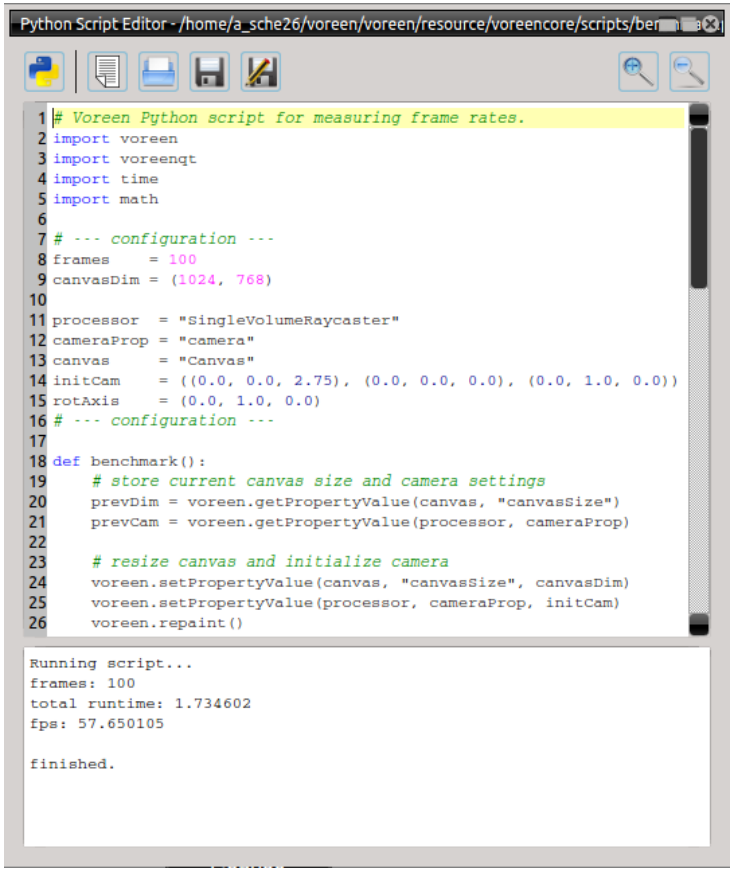
Python Scripting

- Generic read / write access to almost all types of properties, including cameras
- Volume and transfer function loading
- Canvas snapshots
- Integrated Python editor
- Since Voreen 5.0: Python 3
  (earlier versions of Voreen: Python 2.7)



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Selected Modules

- *Base*
  - Base functionality, standard rendering processors (2D and 3D)
  - Volume and geometry processors
  - Clipping
  - Bounding boxes
  - Image processors (post processing etc.)
  - Volume I/O
- *Ffmpeg*
  - Video export
- *OpenCL*
  - Rendering of large data sets (≥ 30 GB)
- *OpenMP*
  - Parallel code execution for various processors

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Selected Modules

- *Plotting*
  - Multiple plotting functions (2D / 3D)
- *RandomWalker*
  - Semi-automatic 3D segmentation of volume data sets

- ... and many more.

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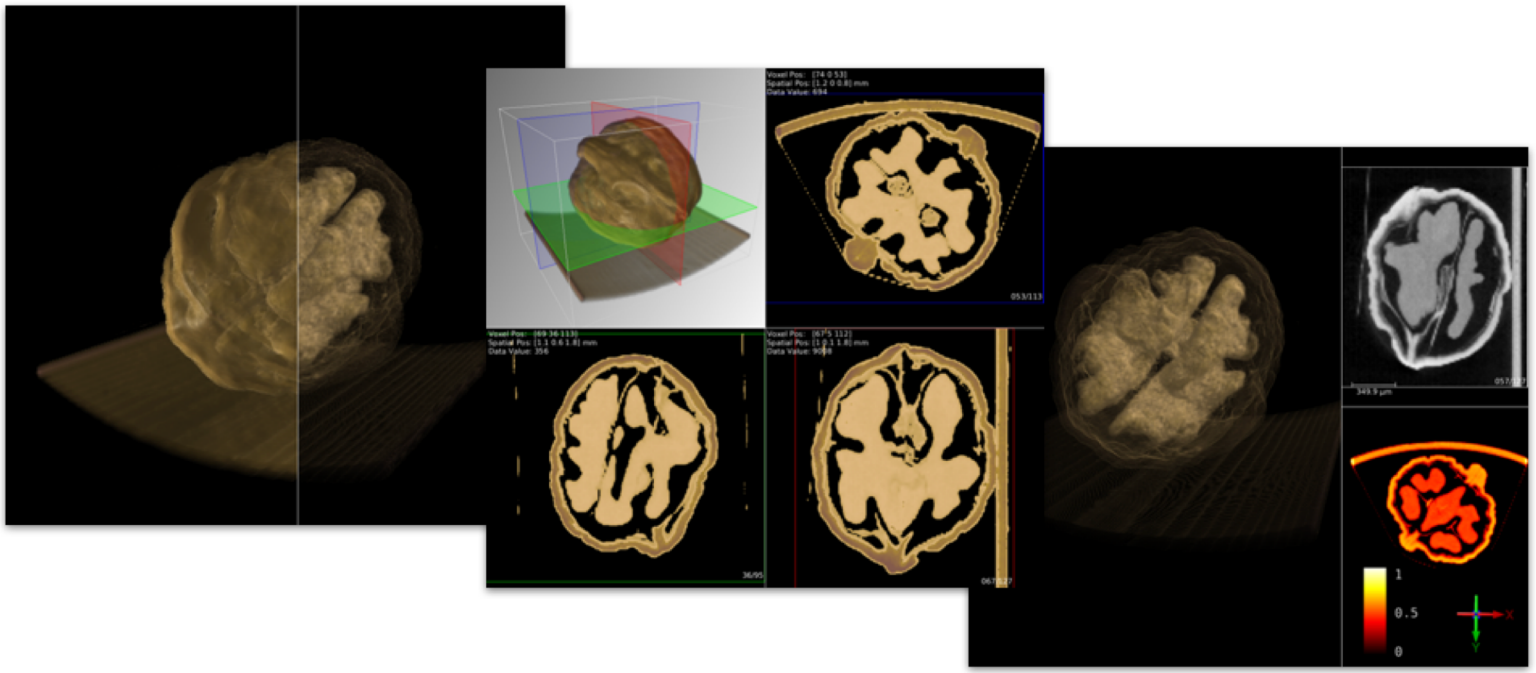
Selected Functionality Examples

- Configurable views: Splitter, triple view, quad view, tabs, ...



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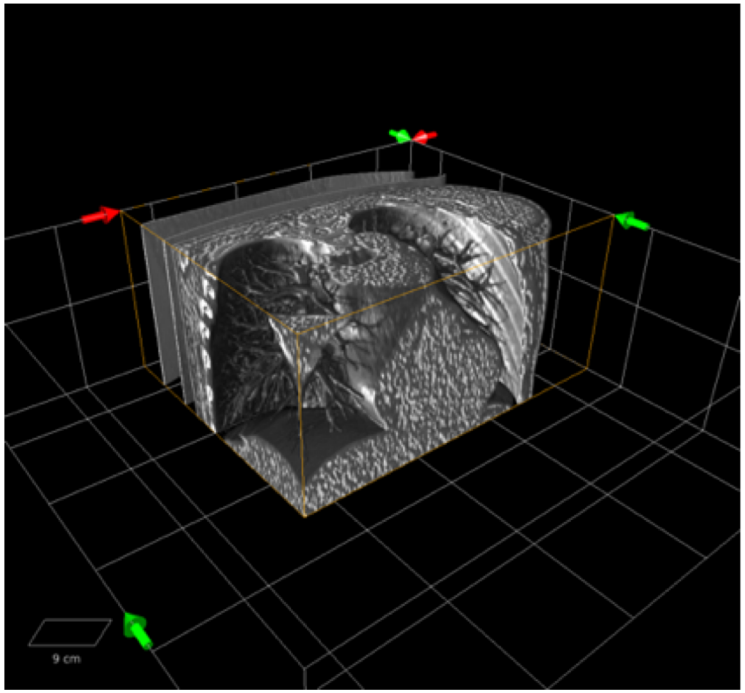
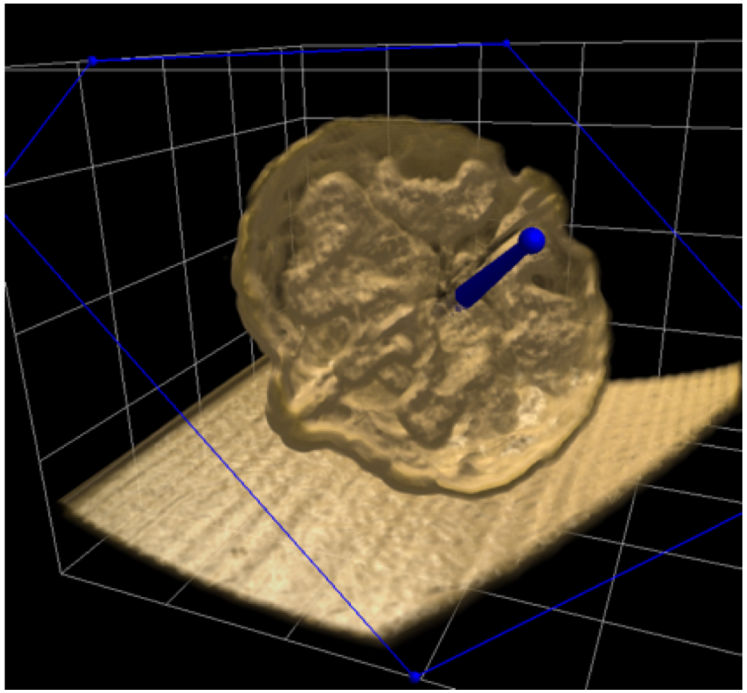
Selected Functionality Examples

- Interactive clipping: Axis-aligned clipping, arbitrary clipping, on-screen handles





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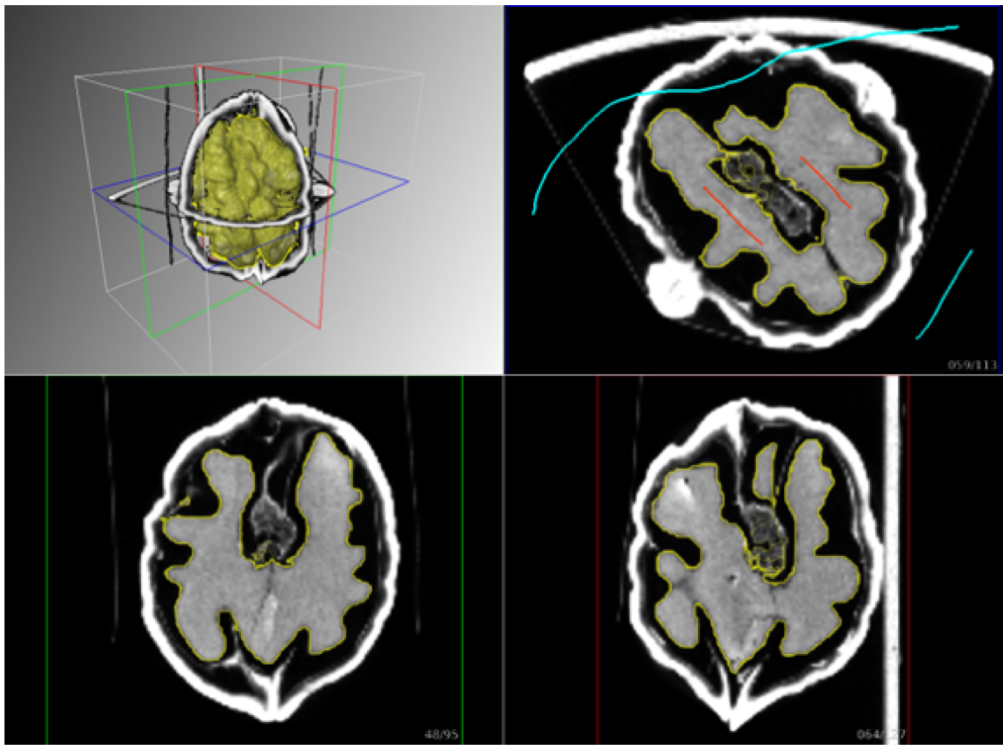
Selected Functionality Examples

- Random walker: semi-automated volume segmentation



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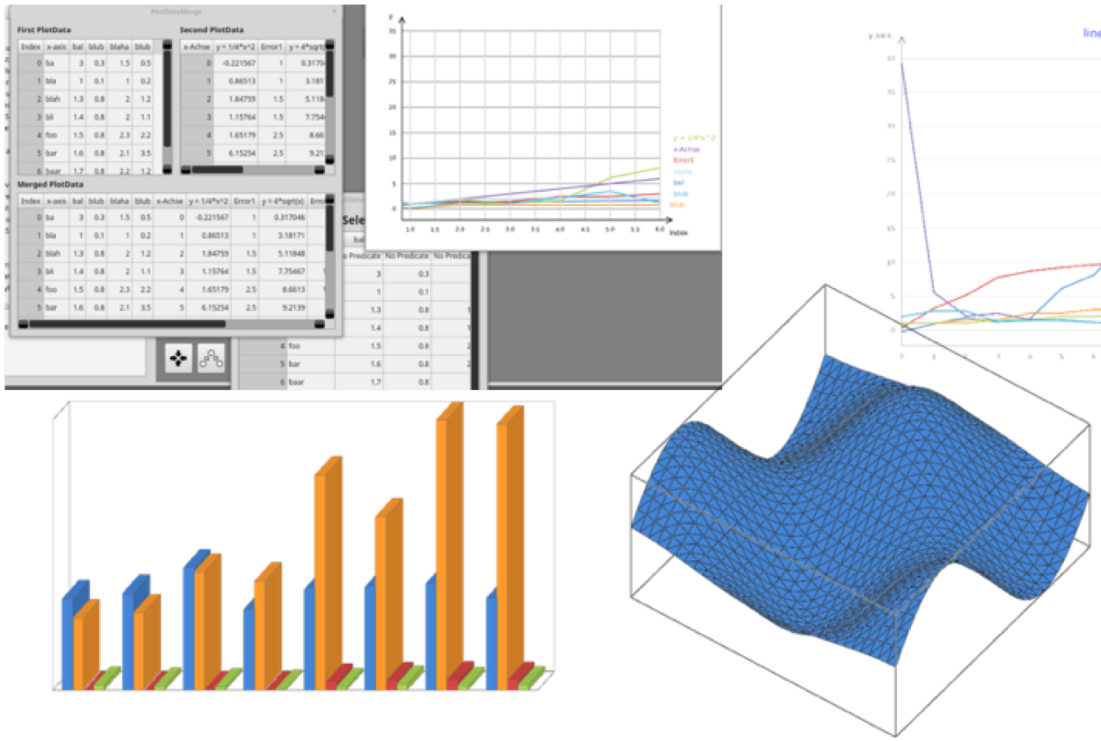
Selected Functionality Examples

- Plotting: Support for CSV files, line plots, bar plots, 3D surface plots, ...



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Selected Functionality Examples

- Large Volume Visualization:
  - Interactive 3D and 2D visualization of multi-channel volume data (e.g., lightsheet microscopy image stacks)
  - Support for TIFF / OME TIFF image stacks
  - HDF5 file support (incl. compression)
  - Rendering of large data sets (100 GB and more)

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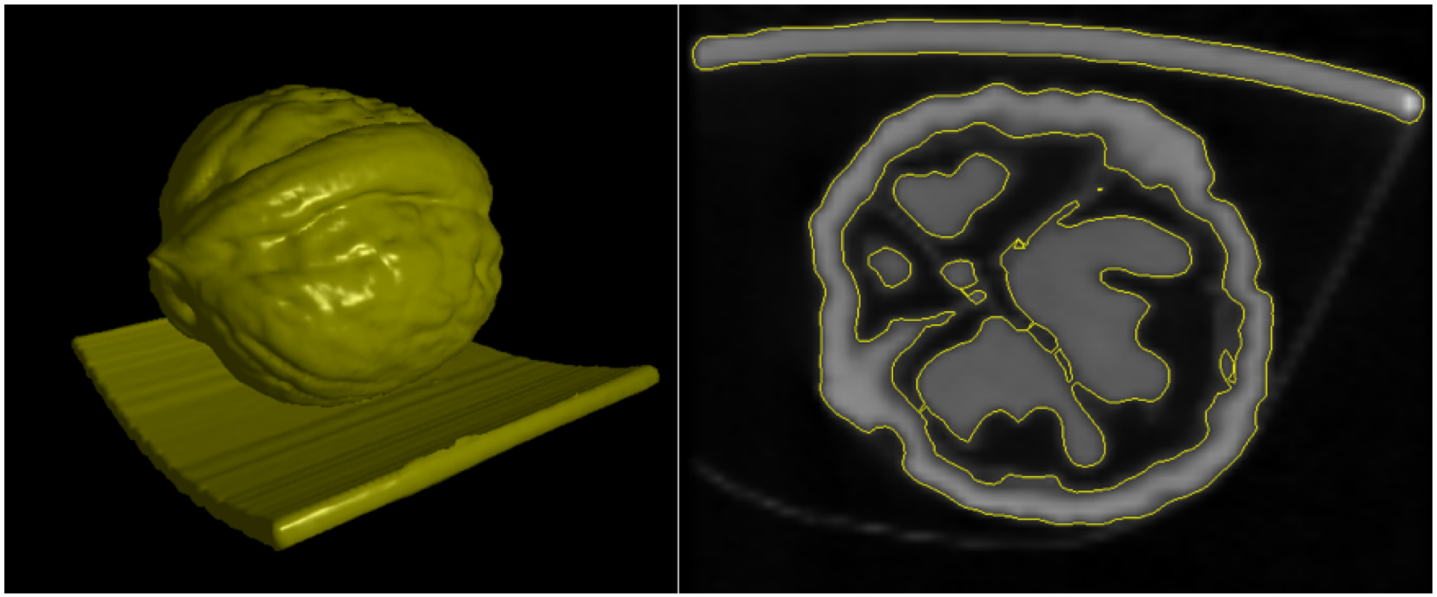
Selected Functionality Examples

- Surface Extraction based on iso values



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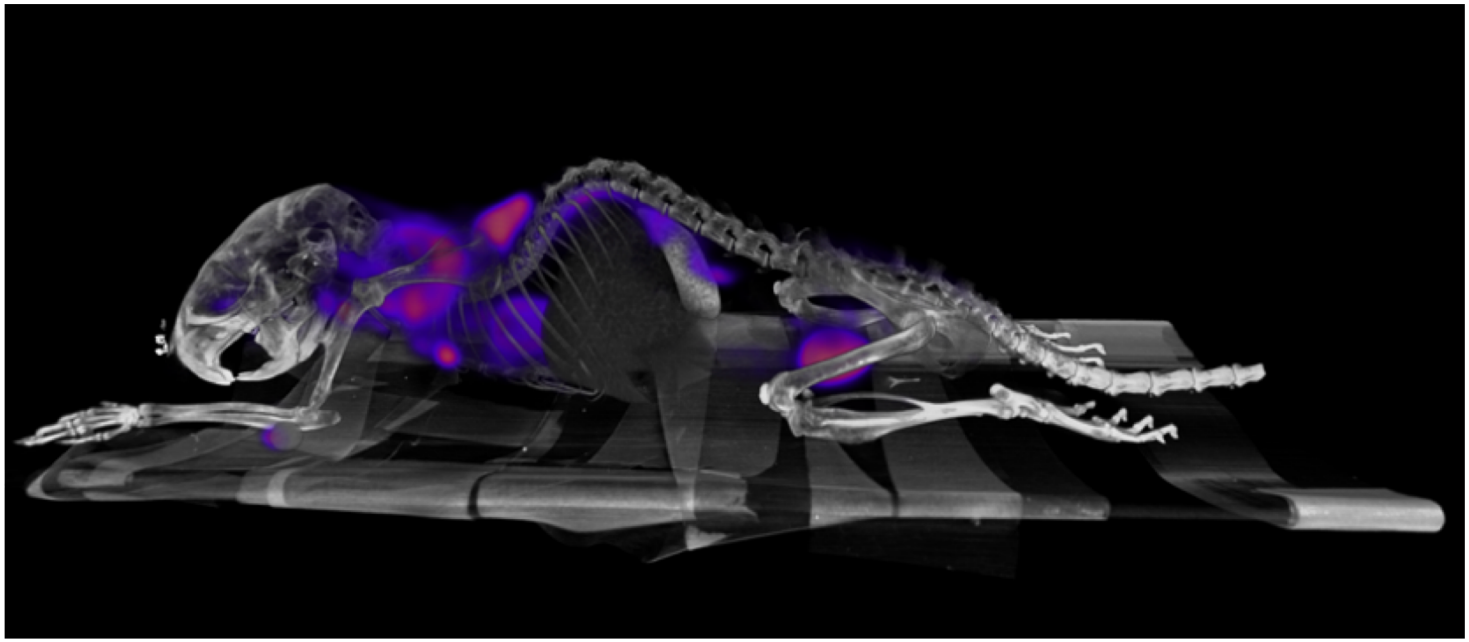
Selected Functionality Examples

- Multivolume Raycasting: Simultaneous 3D visualization of multi-modal datasets



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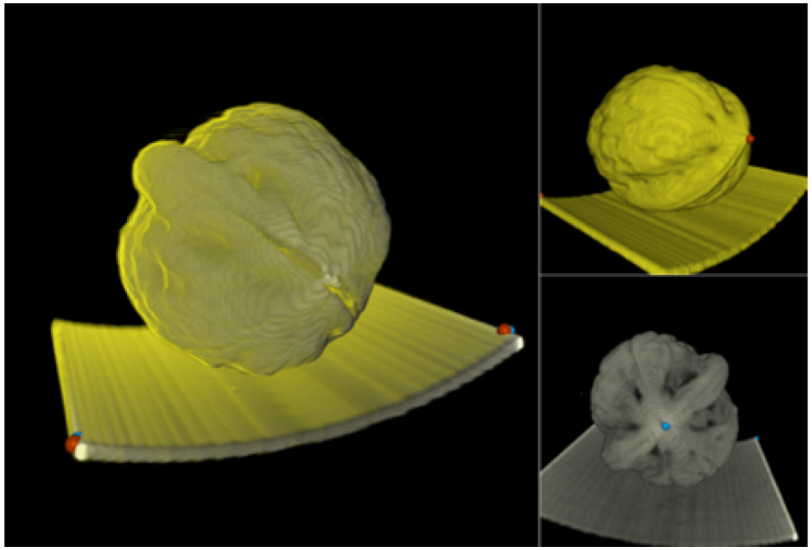
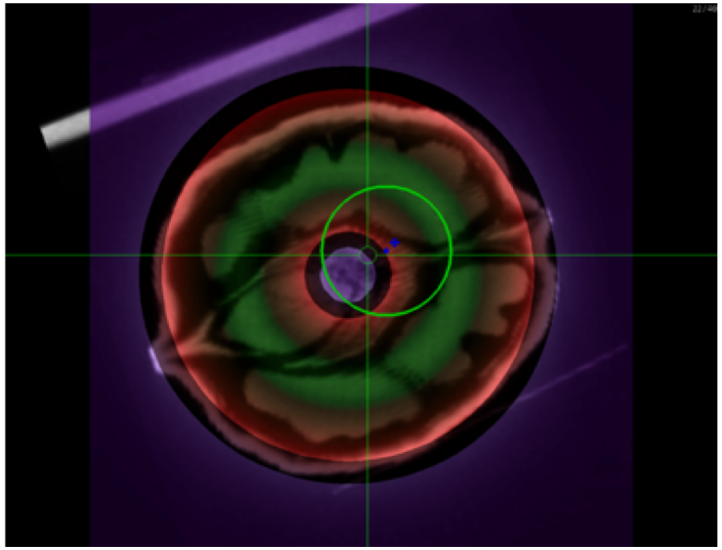
Selected Functionality Examples

- Volume Registration: Landmark registration, interactive (manual) registration





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