

Voreen – Volume Rendering Engine

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Version 5.0

Outline

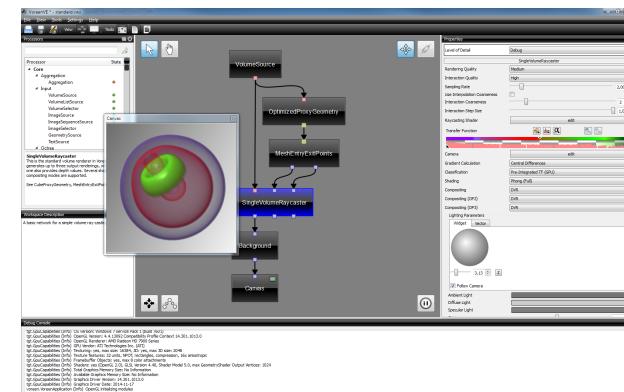
1. About Voreen
2. Obtaining Voreen
3. Project Structure
4. Property Linking
5. Extending Voreen
6. Additional Features

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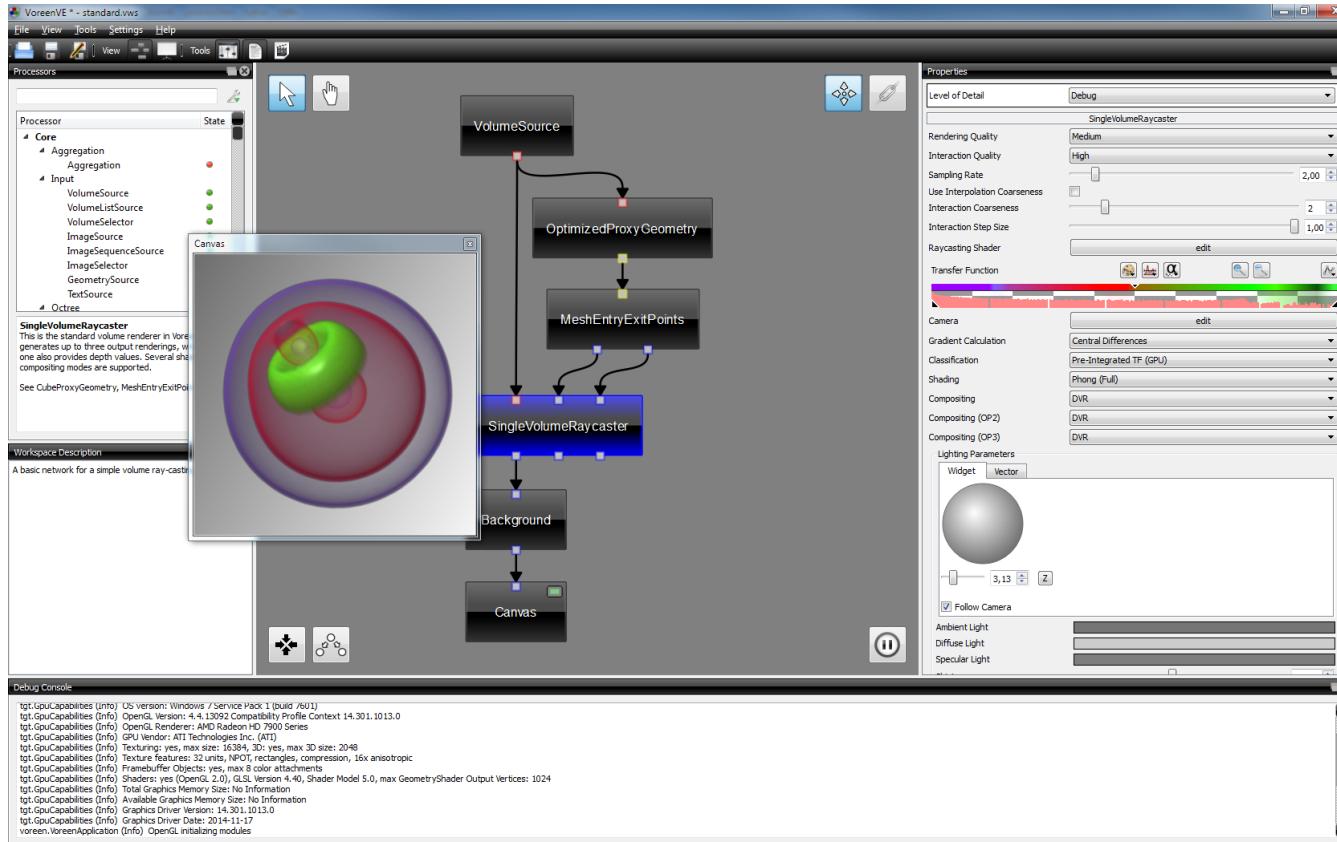
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About Voreen

- 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**)

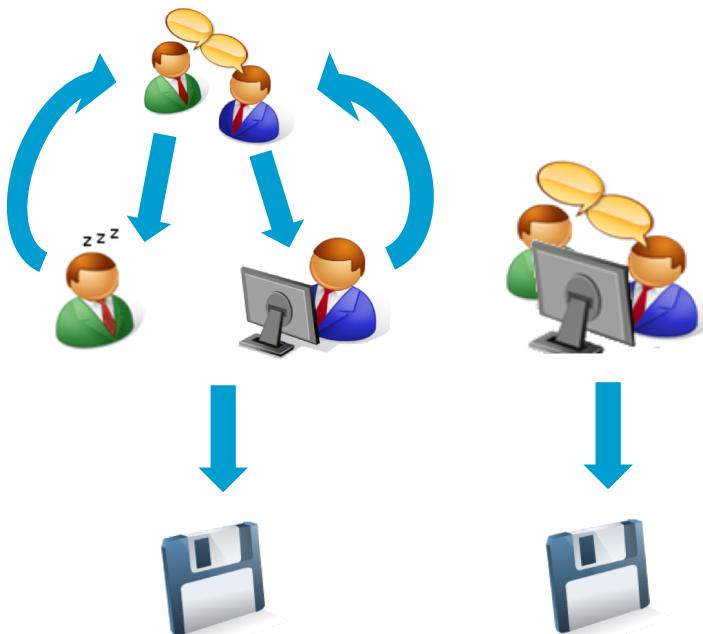
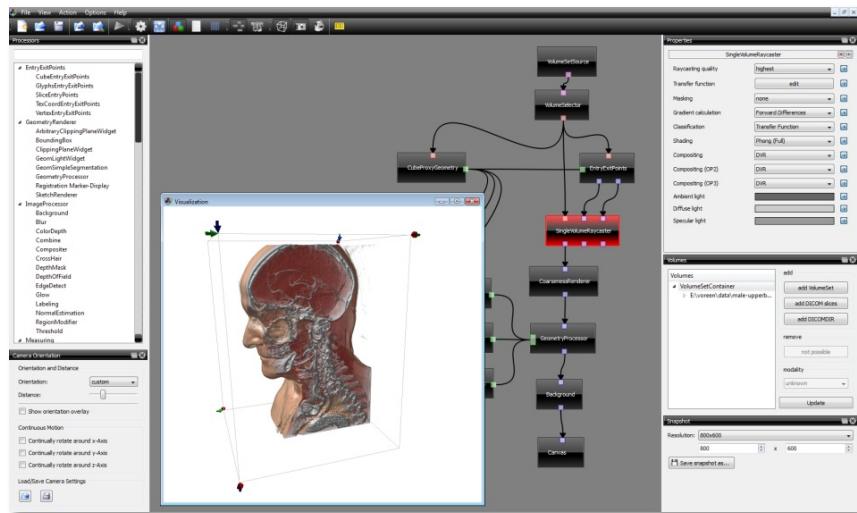


About Voreen



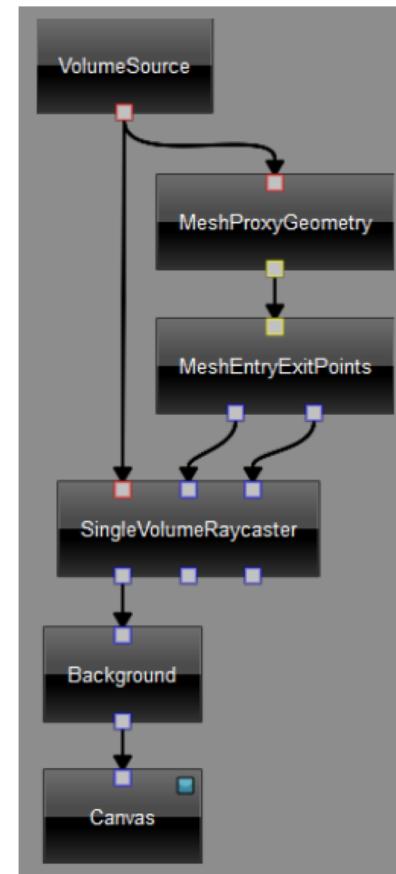
Collaborating with Domain Experts

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



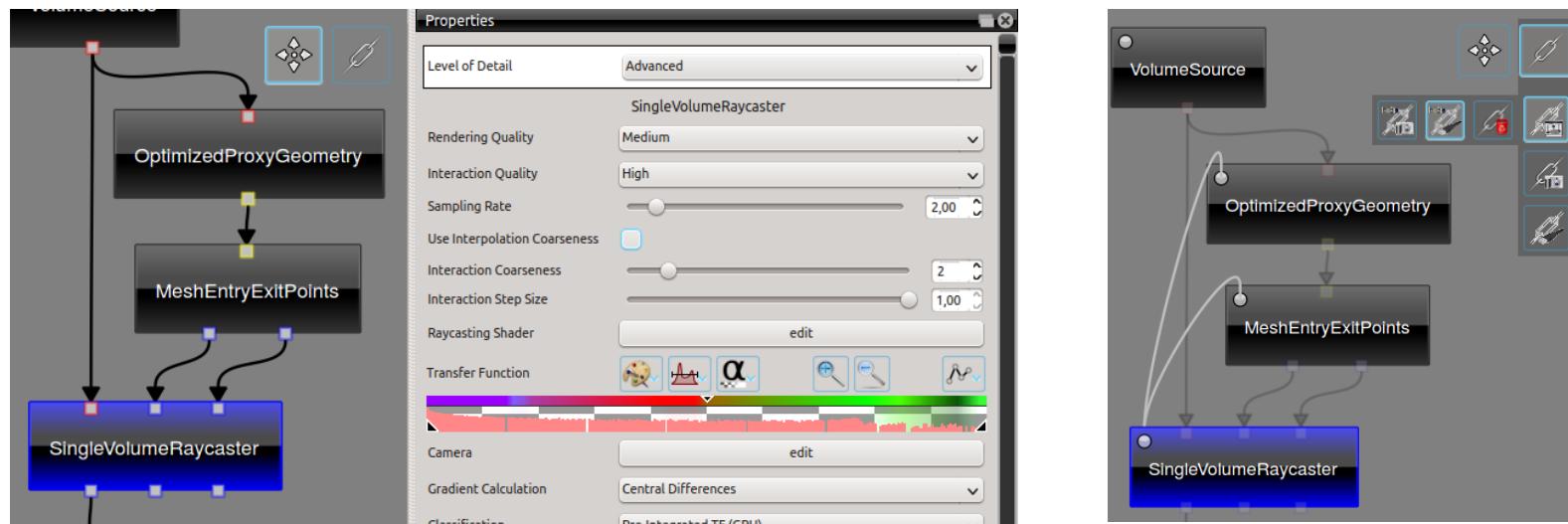
Data Flow Concept

- 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



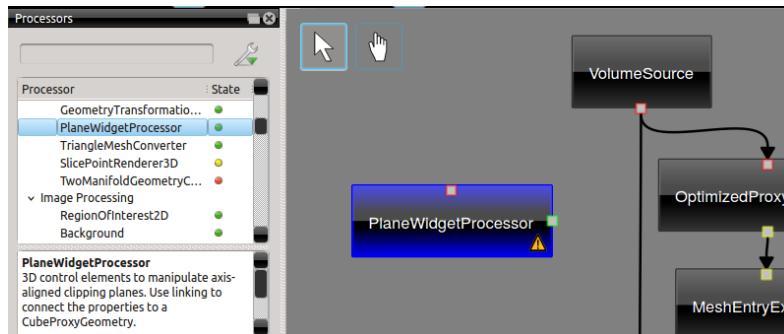
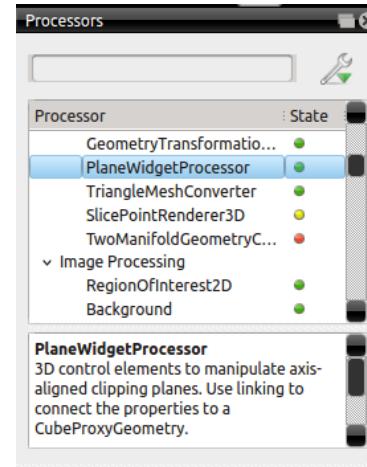
Data Flow Concept

- 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



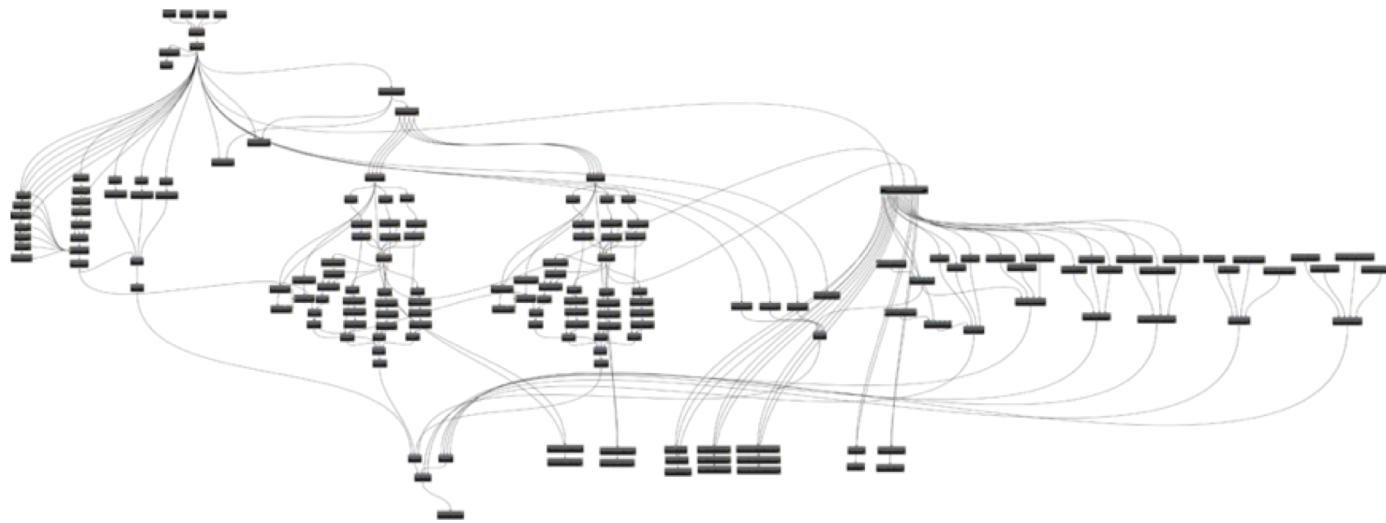
Data Flow Concept

- 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



Data Flow Concept

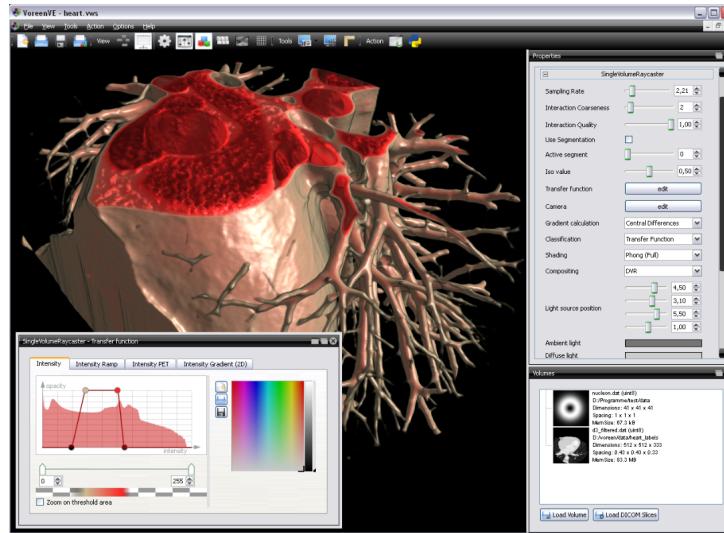
- Drawbacks: networks may become large and confusing for domain experts
- Large number of components and properties, settings, ...



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

Application Mode

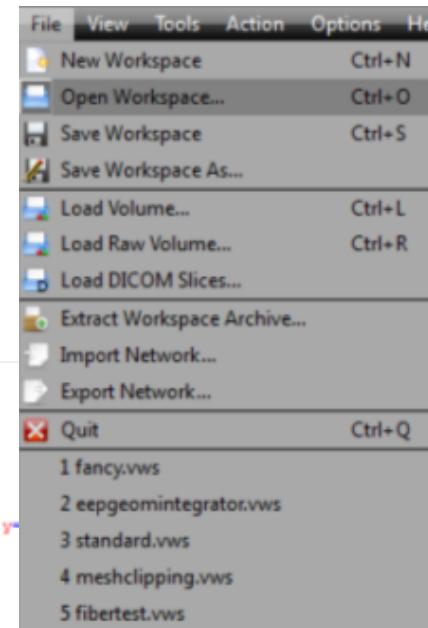
- As an addition to the network mode there exists an application mode.
- Revised and extended in Voreen 5.0
- Visibility of single properties can be configured
- Provides a user interface for the actual application domain as an abstraction from the underlying network



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="174" />
            </MetaData>
            <position x="-3.16516089" y="1.88449895" z="2.34805959" />
            <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="useFloatRenderTarget" value="false" />
    </Properties>
</Processor>
```



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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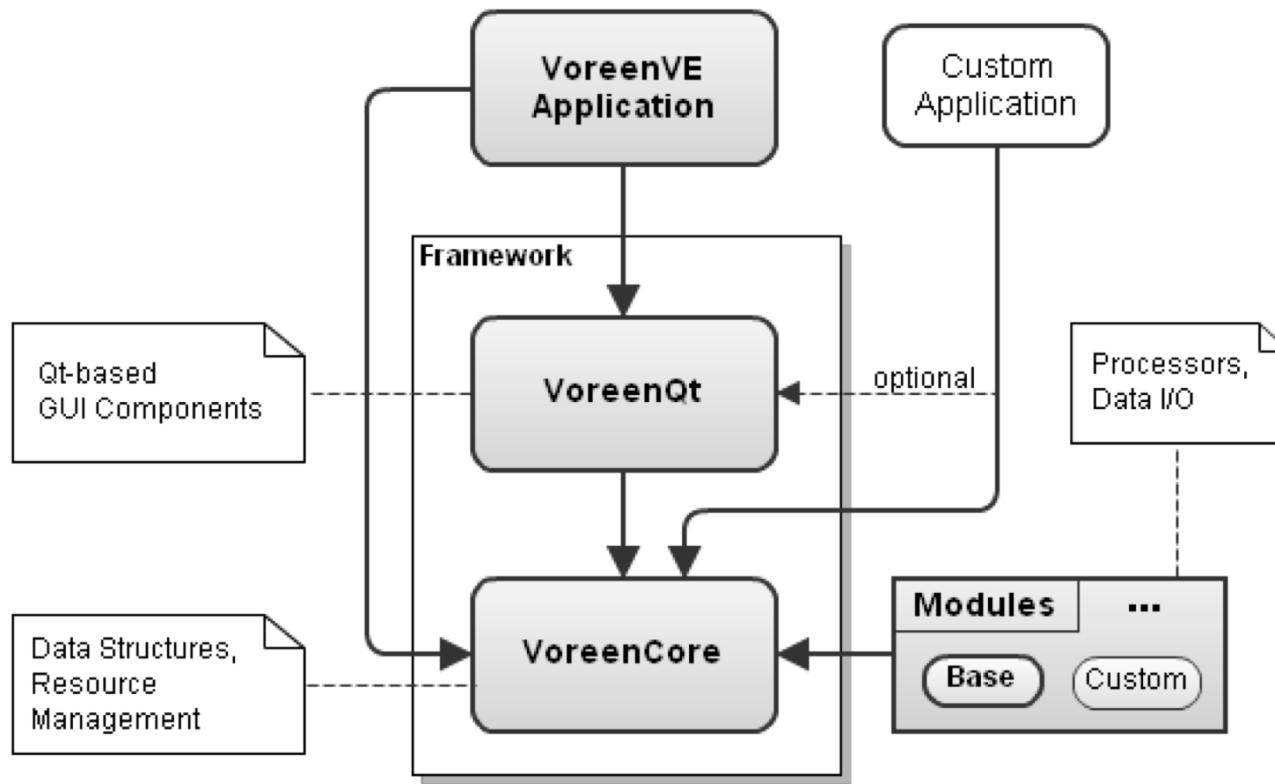
Obtaining Voreen

- 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



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)



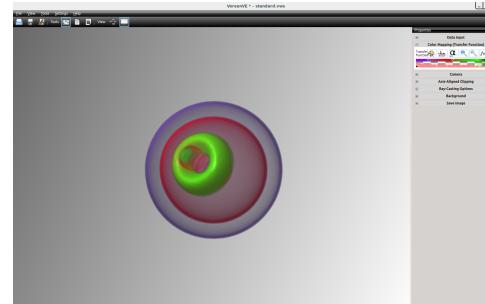
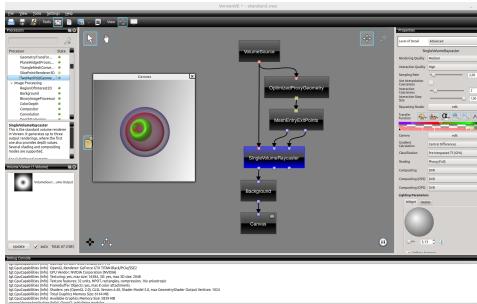
- Voreen **Qt library**

- Property widgets
- Processor widgets
- Graphical network editor



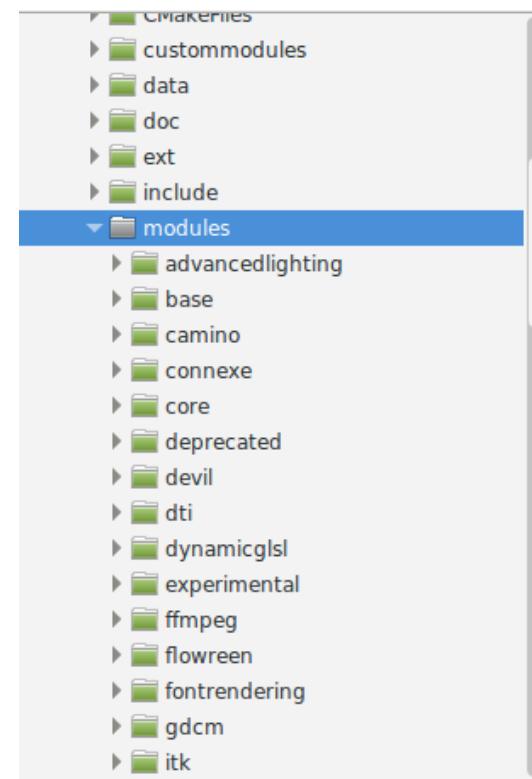
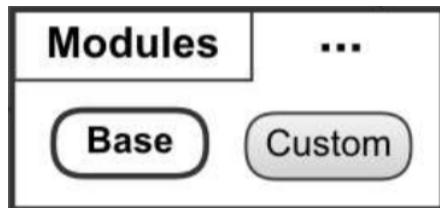
VoreenVE

- 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



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**

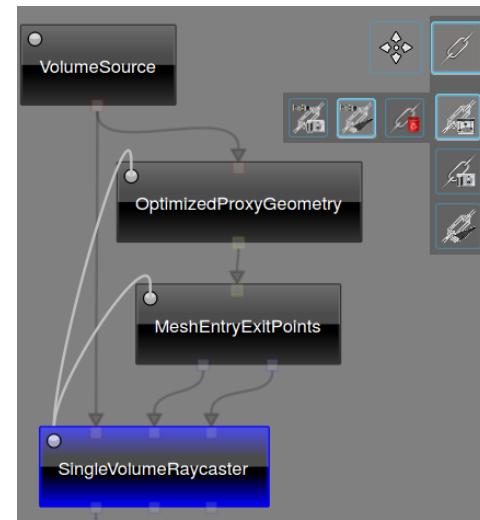


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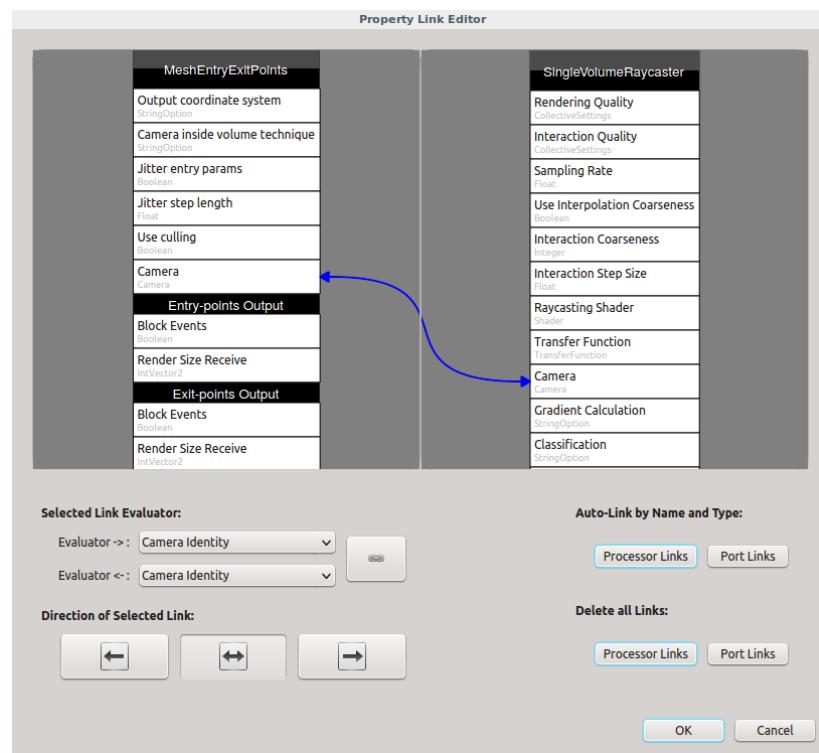
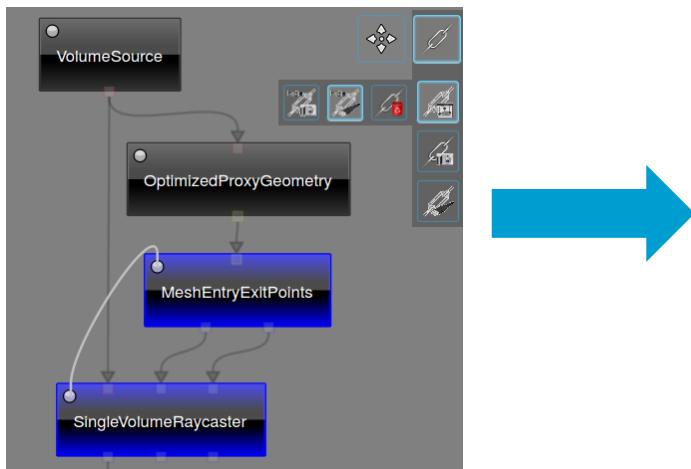
Property Linking

- 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 \leftrightarrow Integer \leftrightarrow Boolean
- Linking of more complex properties (e.g., transfer functions)
- (Optional) auto-linking of camera properties



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

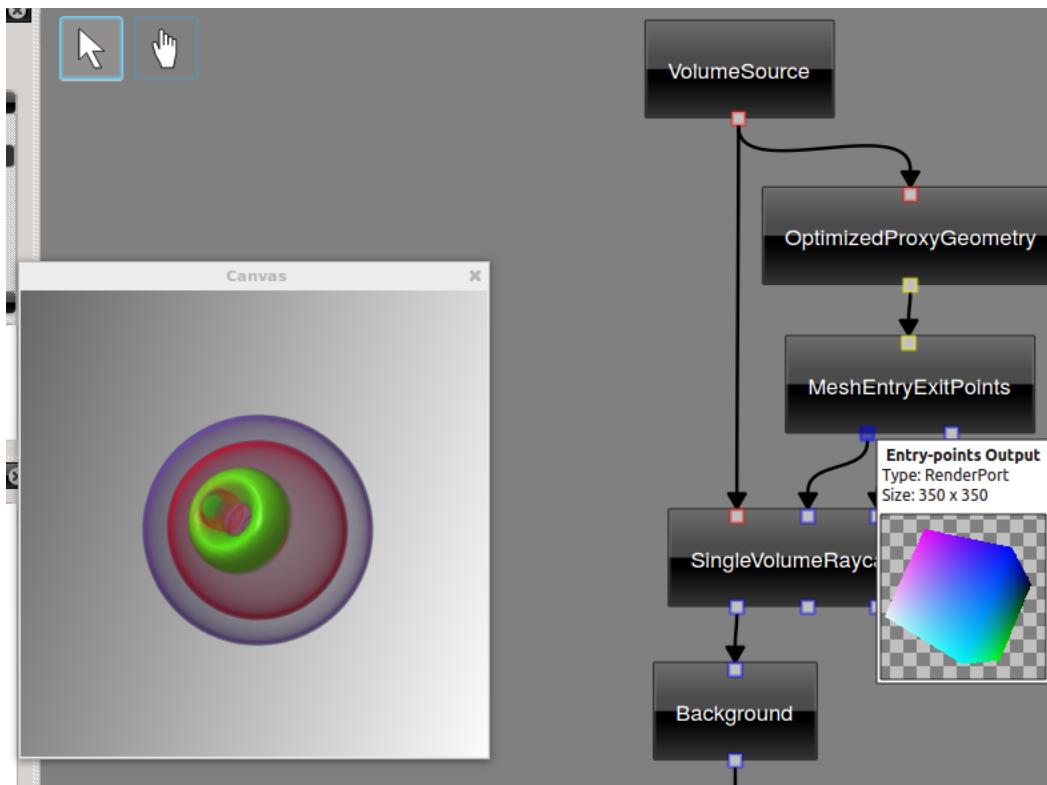
- Tutorials on the website (more to come)
 - Adding a module
 - Adding a processor
- Sample-module *voreen/modules/sample* can be used as a starting point
 - Documentation in the source code should be helpful
- Use existing processors as templates
 - *process()*-method does (almost) all the work, is 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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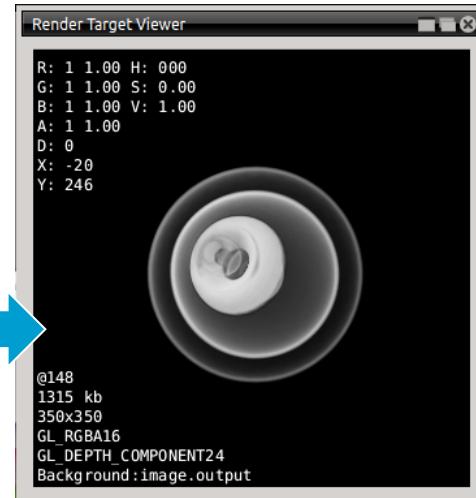
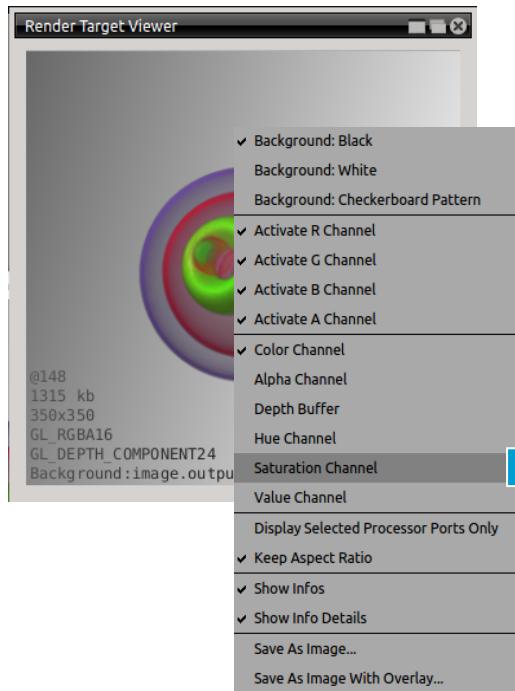
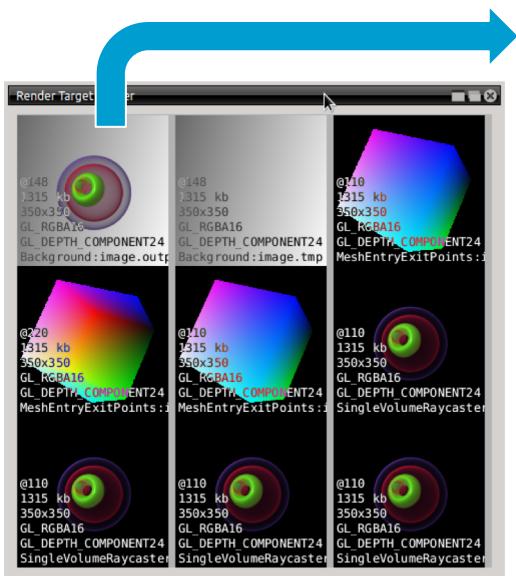
Visual Debugging

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



Visual Debugging

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



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

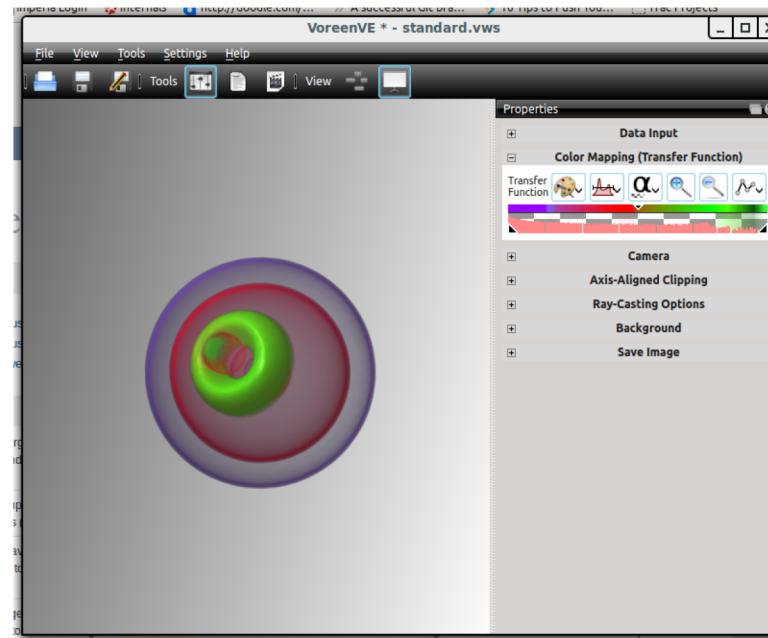
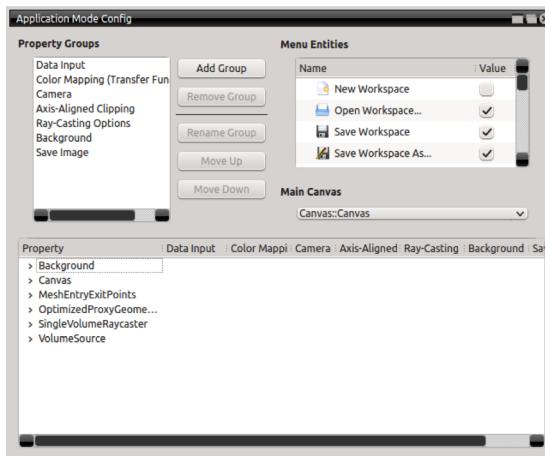
```
    std::vector< std::pair<float, tgt::vec3> > myData_;
```

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

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

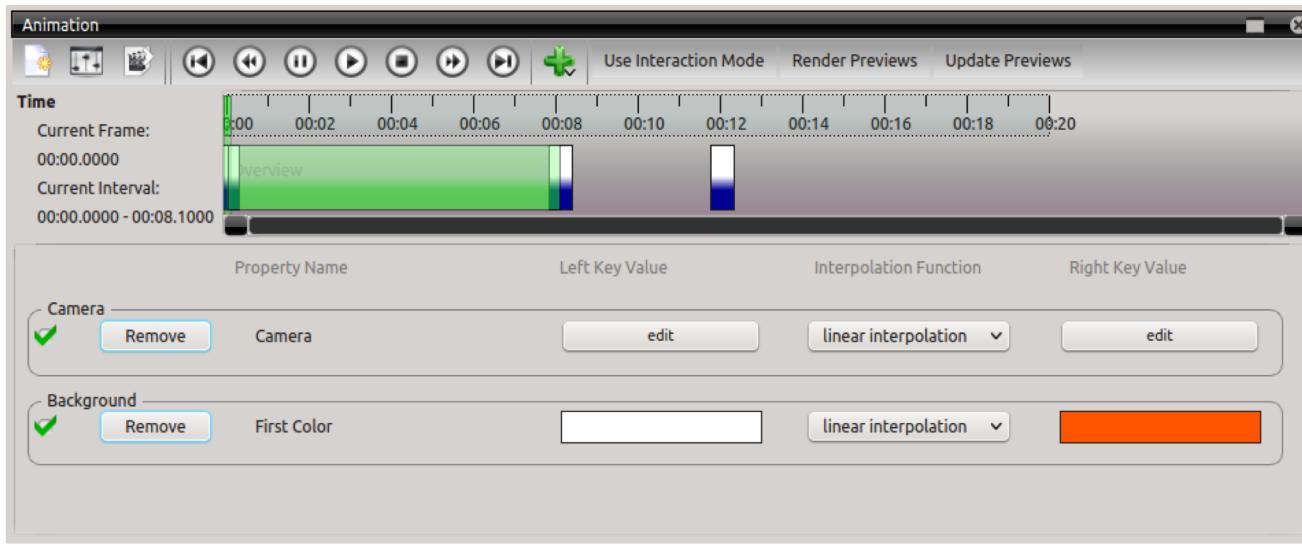
Application Mode Configuration

- 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



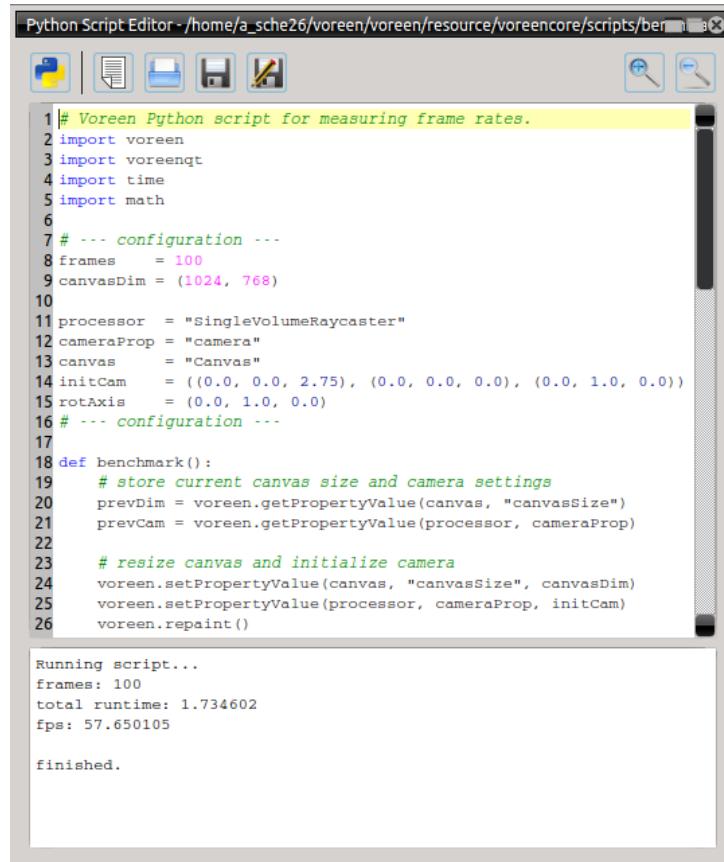
Animation

- 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



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)



The screenshot shows the Voreen Python Script Editor interface. The script window contains the following code:

```
# Voreen Python script for measuring frame rates.
import voreen
import voreengt
import time
import math

# --- configuration ---
frames = 100
canvasDim = (1024, 768)

processor = "SingleVolumeRaycaster"
cameraProp = "camera"
canvas = "Canvas"
initCam = ((0.0, 0.0, 2.75), (0.0, 0.0, 0.0), (0.0, 1.0, 0.0))
rotAxis = (0.0, 1.0, 0.0)
# --- configuration ---

def benchmark():
    # store current canvas size and camera settings
    prevDim = voreen.getPropertyValue(canvas, "canvasSize")
    prevCam = voreen.getPropertyValue(processor, cameraProp)

    # resize canvas and initialize camera
    voreen.setPropertyValue(canvas, "canvasSize", canvasDim)
    voreen.setPropertyValue(processor, cameraProp, initCam)
    voreen.repaint()

Running script...
frames: 100
total runtime: 1.734602
fps: 57.650105

finished.
```

Selected Modules

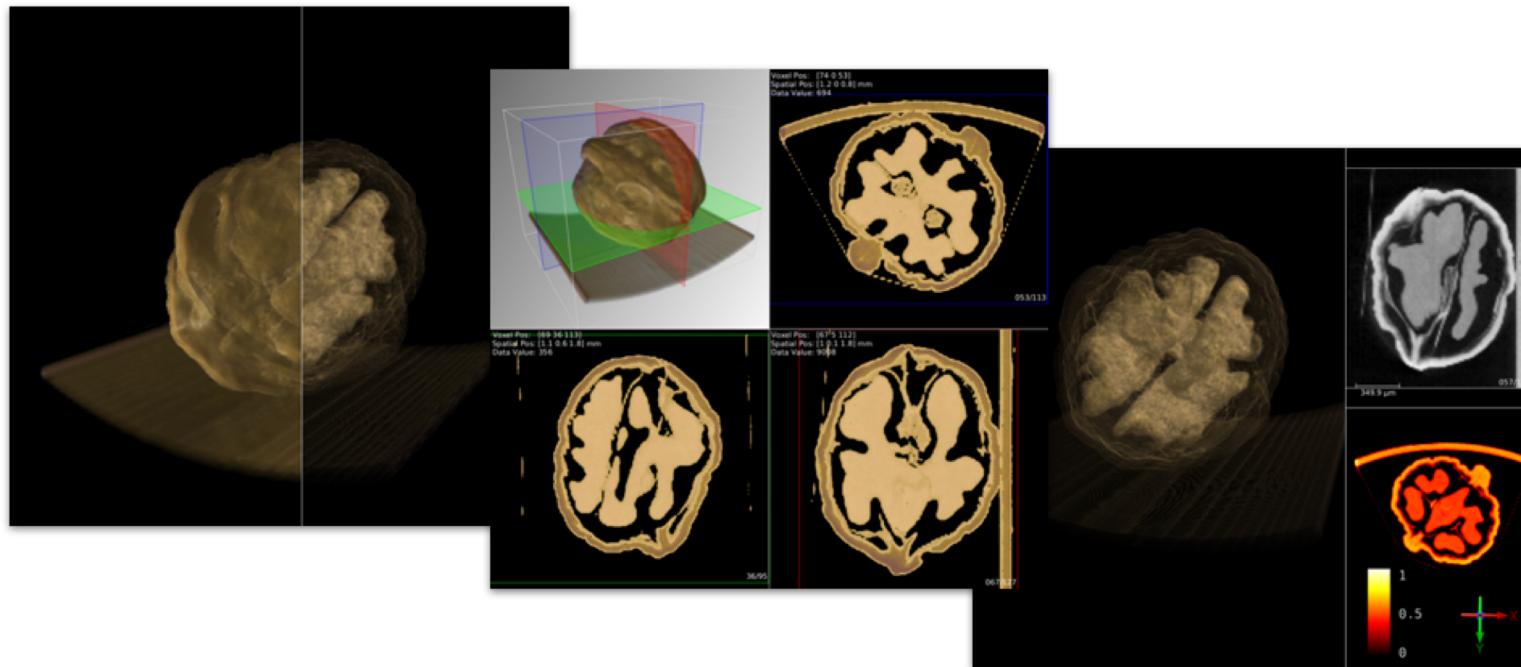
- *Base*
 - Base functionality, standard rendering processors (2D and 3D)
 - Volume and geometry processors
 - Clipping
 - Bounding boxes
 - Image processors (post processing etc.)
 - Volume I/O
- *Ffmpeg*
 - Video export
- *OpenCL*
 - Rendering of large data sets (≥ 30 GB)
- *OpenMP*
 - Parallel code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

Selected Modules

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

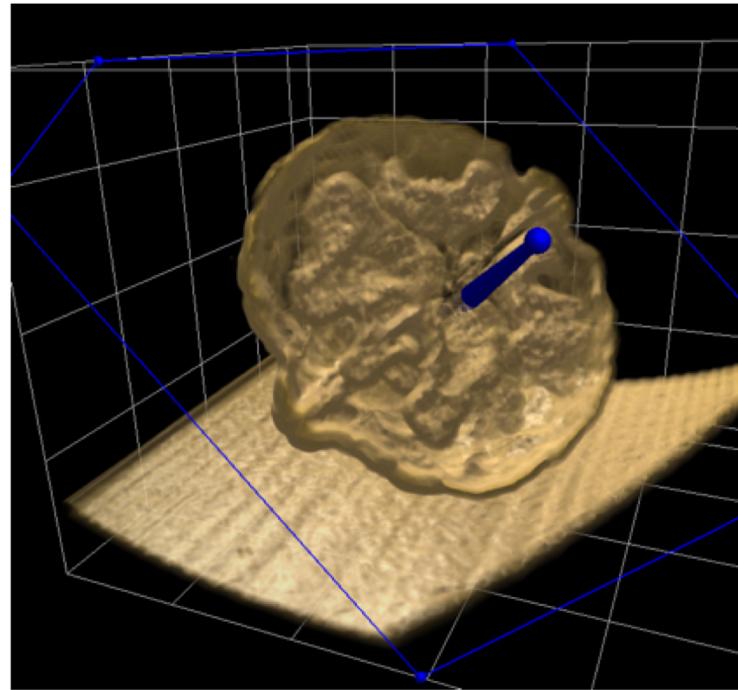
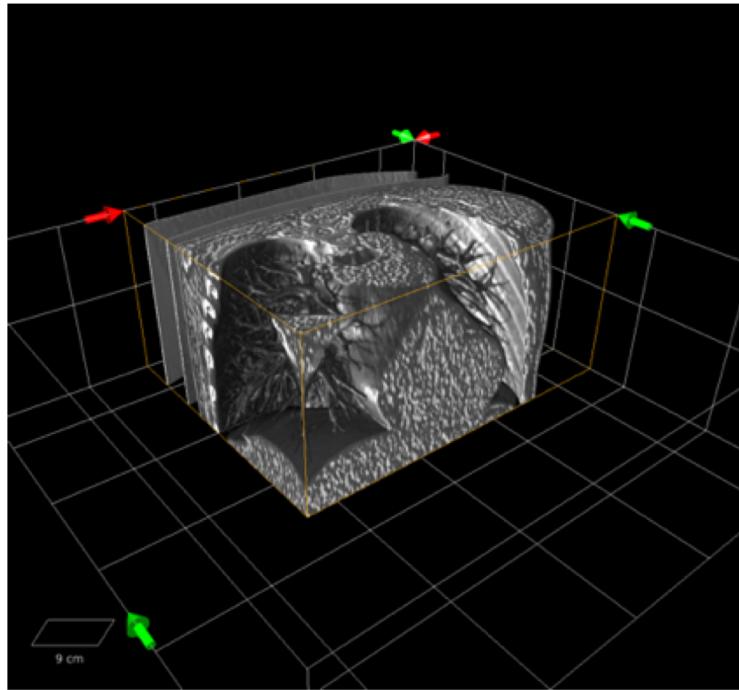
Selected Functionality Examples

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



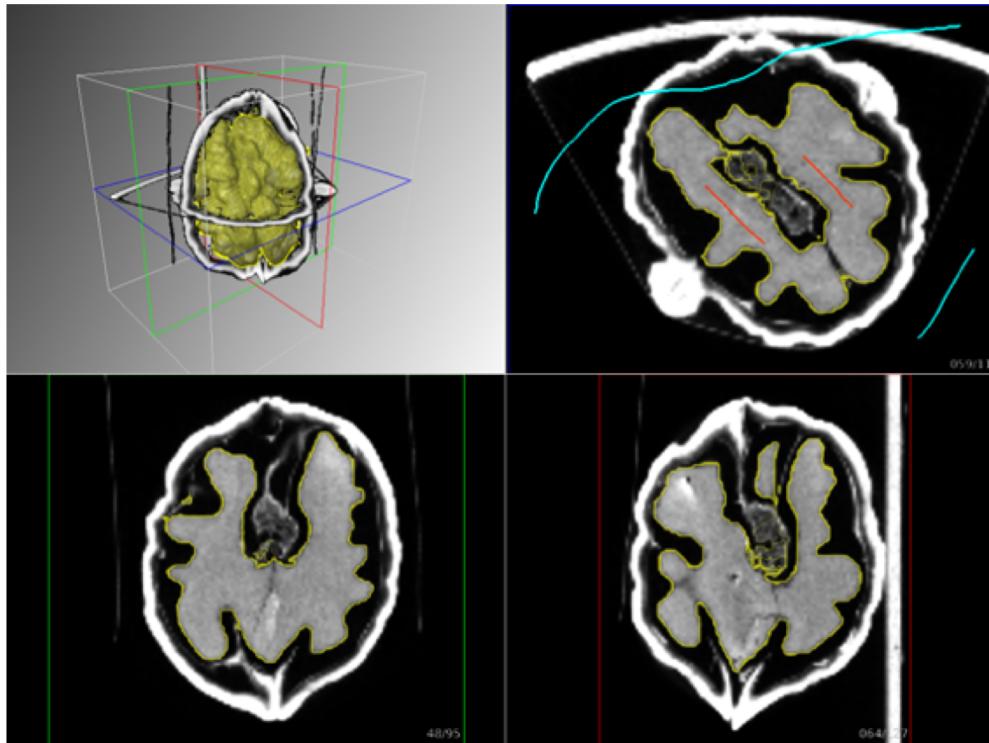
Selected Functionality Examples

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



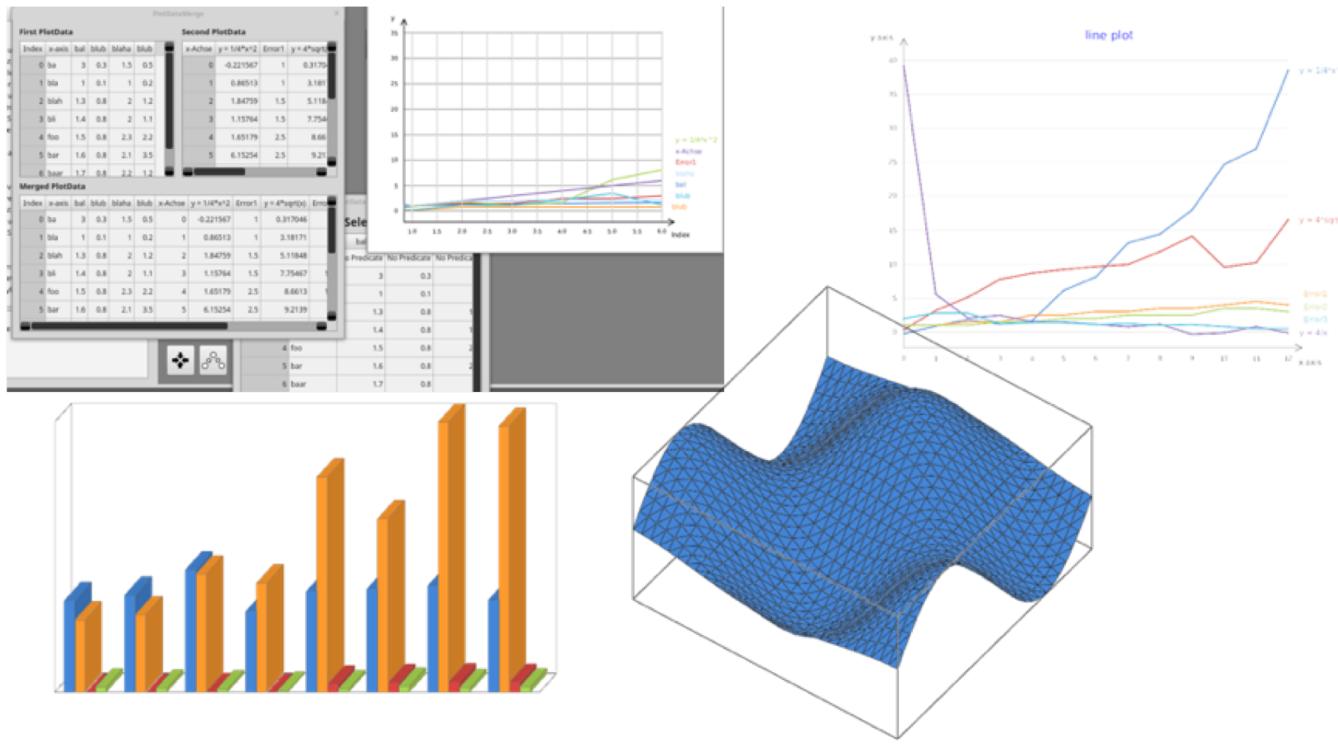
Selected Functionality Examples

- Random walker: semi-automated volume segmentation



Selected Functionality Examples

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

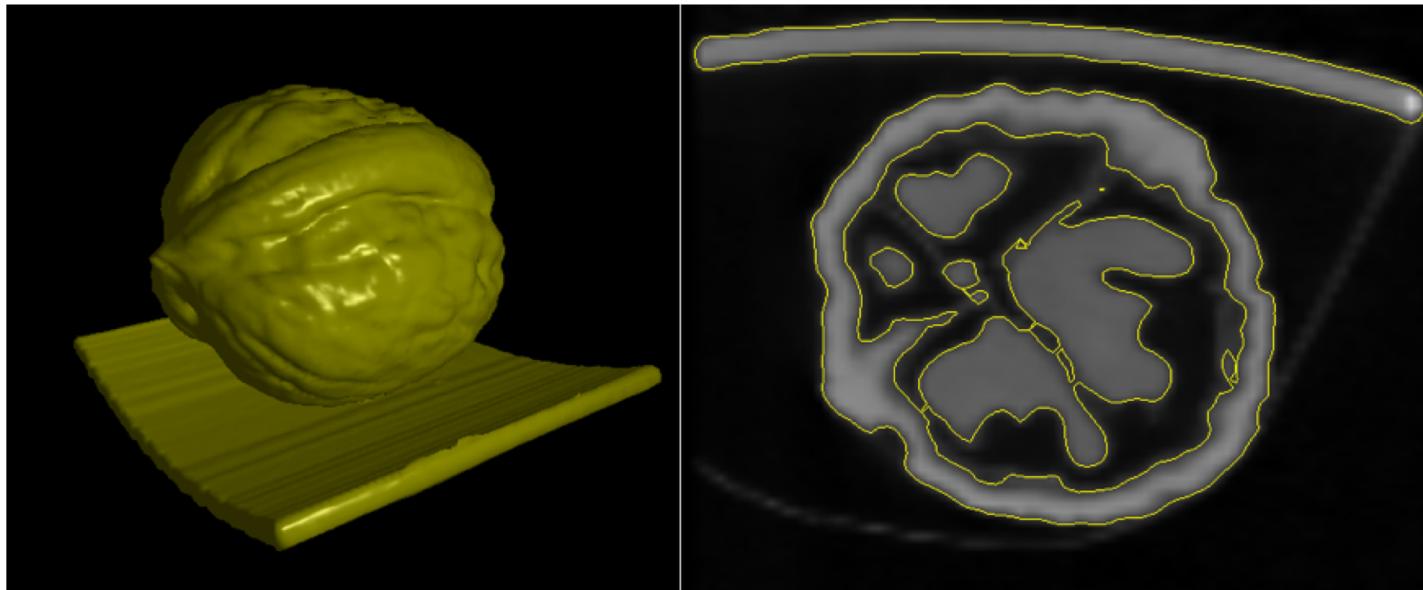


Selected Functionality Examples

- 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)

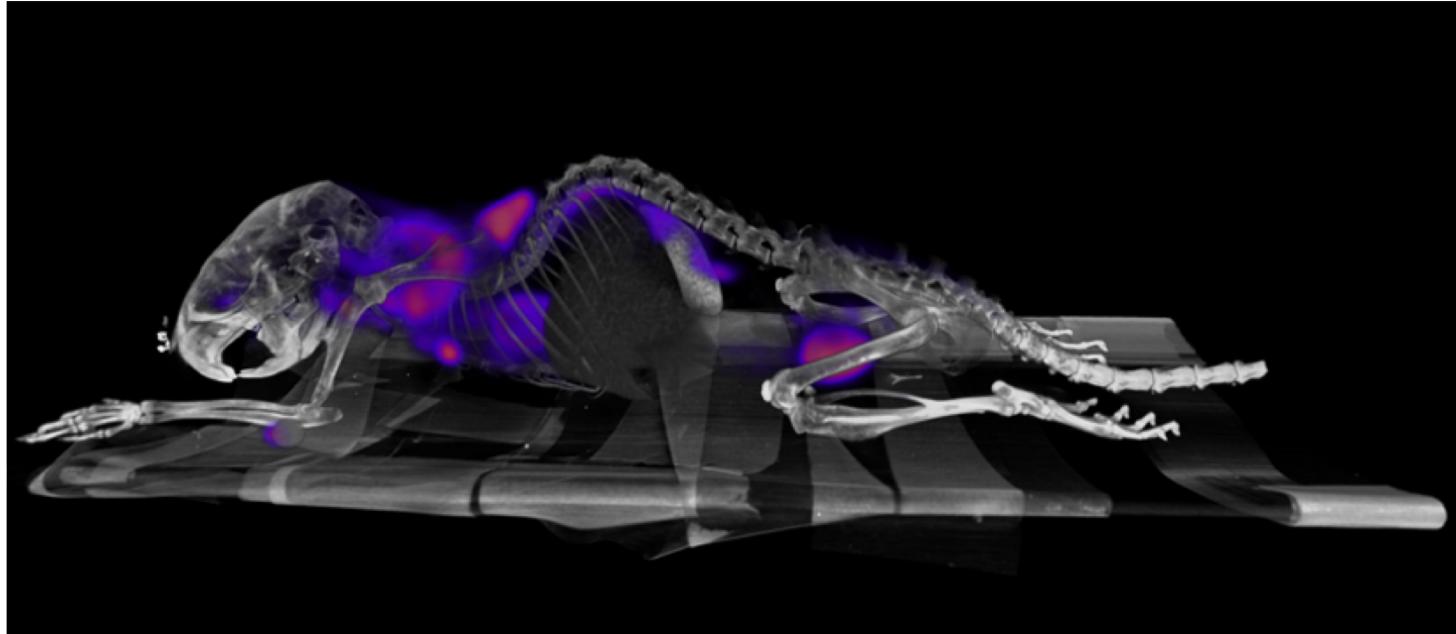
Selected Functionality Examples

- Surface Extraction based on iso values



Selected Functionality Examples

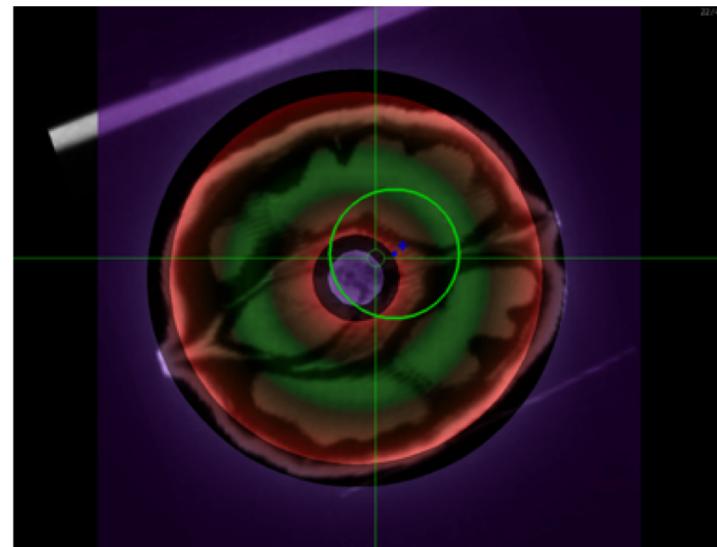
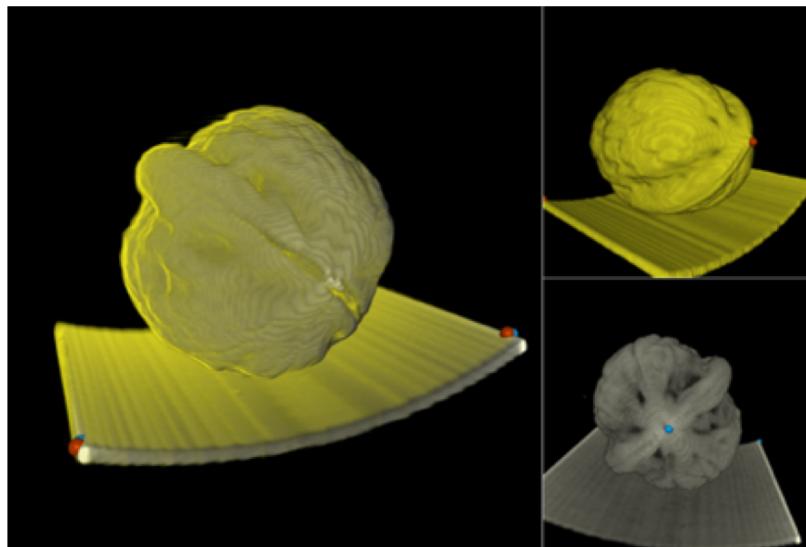
- Multivolume Raycasting: Simultaneous 3D visualization of multi-modal datasets



living.knowledge
WWU Münster

Selected Functionality Examples

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



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