BAM
Bundesanstalt für Materialforschung und -prüfung

Sicherheit in Technik und Chemie

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aRTist - An Industrial-Radiology Simulator Using Tcl/Tk And VTK

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www.bam.de

Outline

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Introduction

The aRTist Simulator

- Radiography Model
- Software Implementation

Application Scenarios

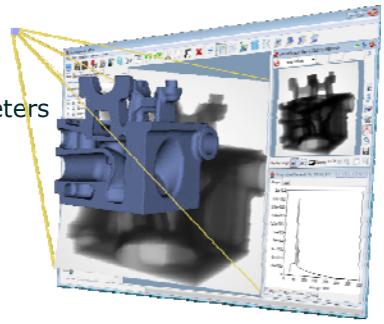
- Radiographic Testing Considering Scattered Radiation
- Computed Tomography
- Backscatter Techniques

Live Demo

Introduction

Goal of modeling in NDT

- Feasibility analysis
- Optimization of radiographic parameters
- Qualification of NDT systems
- Model-based data interpretation
- Training of NDT/NDE personnel



Design objectives for aRTist

- Providing RT modeling software for practitioners
- Easy to use user interface
- Containing models for all relevant RT components
- Handling complex multi-material part geometries

The aRTist Simulator

- Radiography Models
- Software Implementation

Elements Needed for Modeling RT

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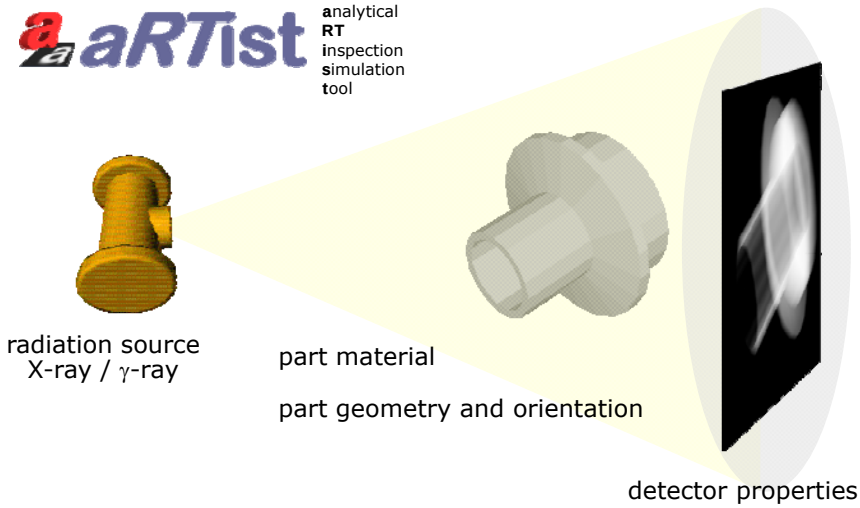
aRTist — **a**nalytical **RT** **i**nspection **s**imulation **t**ool



Geometry Representation

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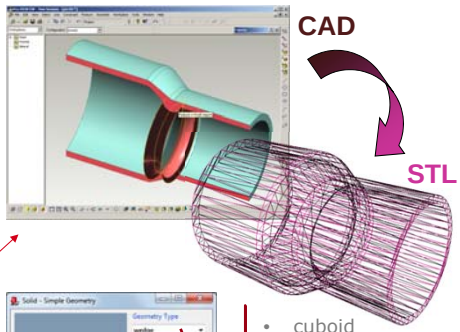
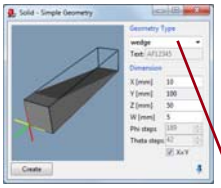
- Separation of homogeneous regions
- Surface description with plane polygons (triangles)
- Simple mathematical treatment of single facets (ray tracing)
- Approximation of curved surfaces
- STL as standard exchange format
- Sources:
  - CAD
  - CT
  - internal solids





- cuboid
- ellipsoid
- cylinder
- tube
- cone
- text
- wedge
- step wedge

Elements of RT Modelling: Radiation Source

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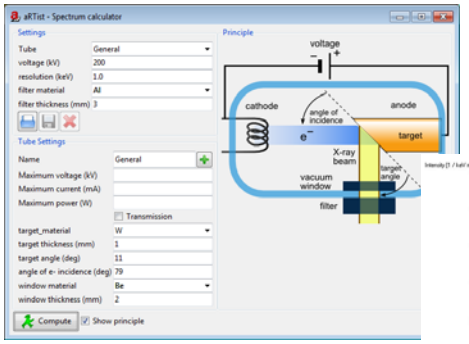
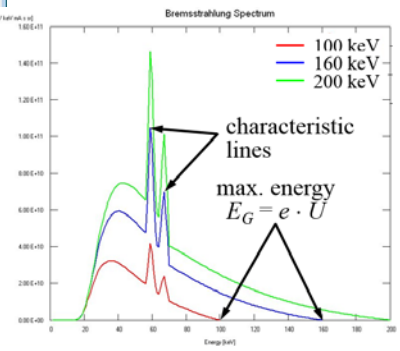
Bremsstrahlung Model





Spectrum Simulation

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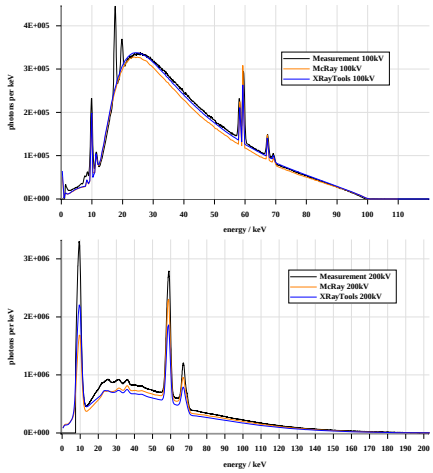

transmission tube at 100 kV
5 µm tungsten thin target
250 µm beryllium substrate

Comparison of:

- **Developed model**
- **Monte Carlo model McRay**
- **Measurement**

direct radiation tube at 200 kV
tungsten thick target

Attenuation Mechanisms

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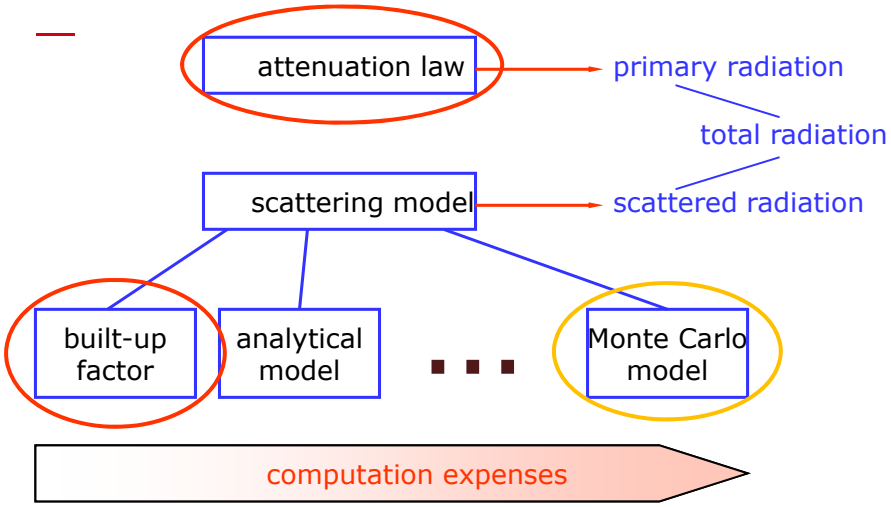

Analytical Model

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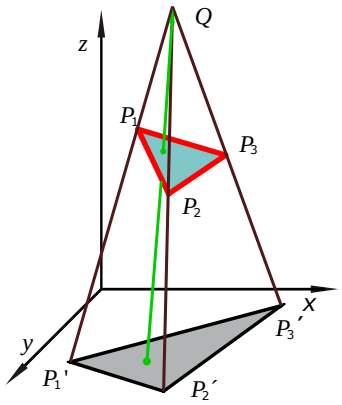
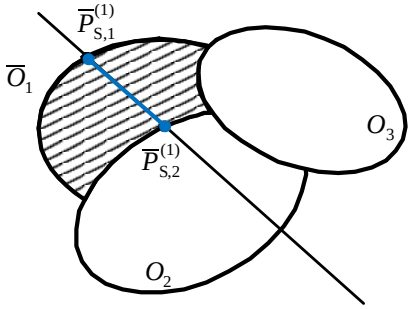


Optimized ray tracing algorithm



Effective contribution of overlapping objects

Monte Carlo Model
McRay module of aRTist

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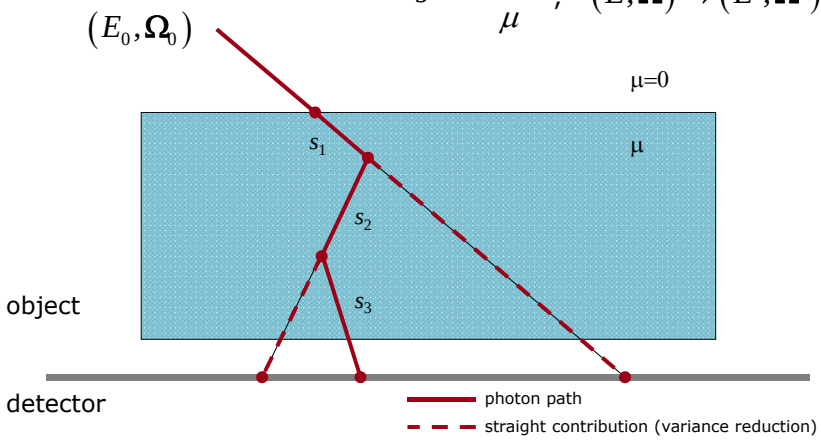
$$s = -\frac{\ln \xi}{\mu} \quad ; \quad (E, \Omega) \rightarrow (E', \Omega')$$



The aRTist Simulator

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- Simple selection and handling of IQIs on objects
- Cursor based positioning of objects, detectors and artificial flaws
- Cursor based viewing of the scenes
- Selection of test samples for different industrial sectors
- Selection of kV and spot for tube
- Monte-Carlo scatter model
- Selection of detector brand

aRTist — **a**nalytical **RT** **i**nspection **s**imulation **t**ool

Implementation

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- Tcl/Tk
  - Open source
  - Platform independent
  - GUI, 3D graphics, scripting, …
- Compiled core (C++), ray-tracer engine added to VTK

```
proc LoadVtk {} {

    package require vtkhybrid
    package require vtkrendering
    package require vtkinteraction
    package require vtkwidgets


if { [catch { package require vtkRaycast }] } {
```


The Visualization Toolkit (VTK)

Features

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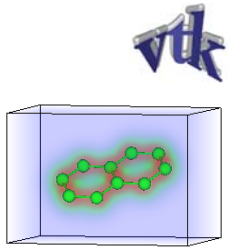
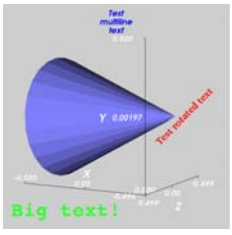
- Open Source
- Platform Agnostic
- Language Agnostic
- Data Model
- Visualization
- Modeling
- Imaging
- 3D Graphics
- 2D Plots and Charts
- Interaction and GUI Support
- InfoVis
- Parallel Processing





The Visualization Toolkit (VTK)

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Language Agnostic

Cxx

```
vtkPolyDataMapper *cylinderMapper = vtkPolyDataMapper::New();
cylinderMapper->SetInputConnection( cylinder->GetOutputPort() );
```

Java

```
vtkPolyDataMapper cylinderMapper = new vtkPolyDataMapper();
cylinderMapper.SetInputConnection( cylinder.GetOutputPort() );
```

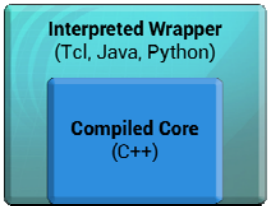
Python

```
cylinderMapper = vtk.vtkPolyDataMapper()
cylinderMapper.SetInputConnection( cylinder.GetOutputPort() )
```

Tcl

```
vtkPolyDataMapper cylinderMapper
cylinderMapper SetInputConnection [ cylinder GetOutputPort ]
```

Interpreted layer generated automatically by VTK wrapping process



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Application Scenarios

- Radiographic Testing Considering Scattered Radiation
- Computerized Tomography
- Backscatter Techniques

Radiographic Testing Considering Scattered Radiation

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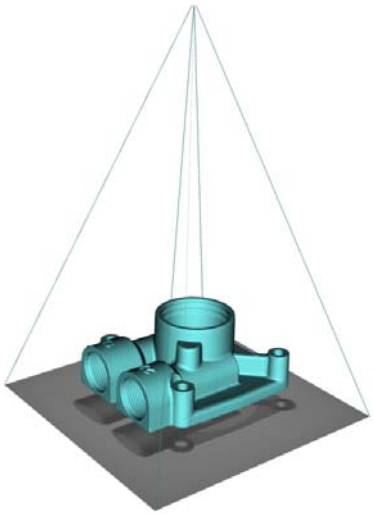
Simulation setup:

- Casting, 84x96x42 mm³
  - Geometry generated from CT
  - > 90.000 triangles
  - 3-38 mm Al in this projection
- RT parameters
  - 120 kV
  - SDD 220 mm
  - Ideal detector 1500x1500 pixels
- Calculation time (Core™ i7, 3.4 GHz, quad core)
  - Primary image: **1.5 s**
  - Scatter image ($2x10^8$): **81 s**



Radiographic Testing Considering Scattered Radiation

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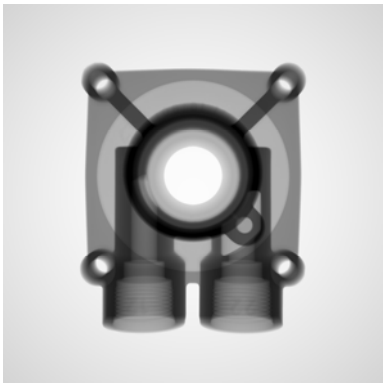
Simulation Steps Including Monte Carlo Scatter Model

1. Source model
   - Bremsstrahlung production and characteristic radiation
2. Analytical primary image
   - Ray tracing with attenuation law
3. Separate primary and scatter image by McRay
4. Smoothing of scatter image
5. Scaling of scatter image based on primary image values from McRay and analytical calculation
6. Summation of analytic primary and McRay scatter image
7. Detector model

Radiographic Testing Considering Scattered Radiation

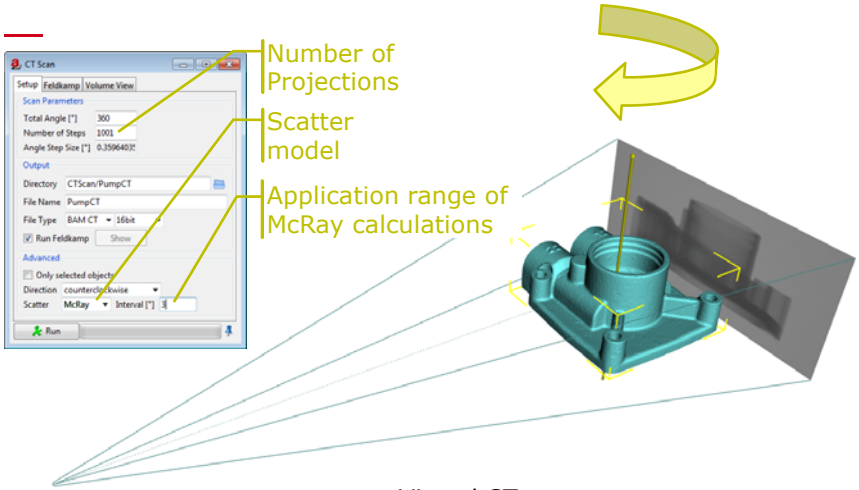


Primary image

Scatter image

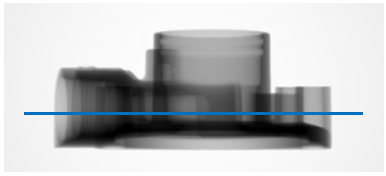
Calculation time (Core™ i7, 3.4 GHz, quad core)
Primary image: **1.5 s** Scatter image ($2x10^8$): **81 s**

Virtual Computed Tomography
CtScan module

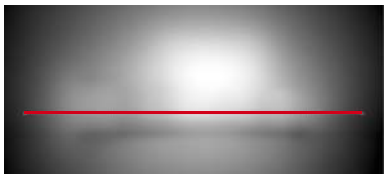


Virtual CT setup

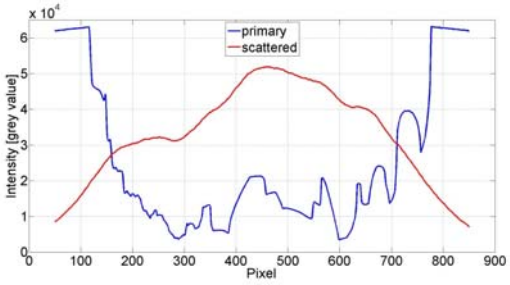
Virtual Computed Tomography
Projection Data



Primary image

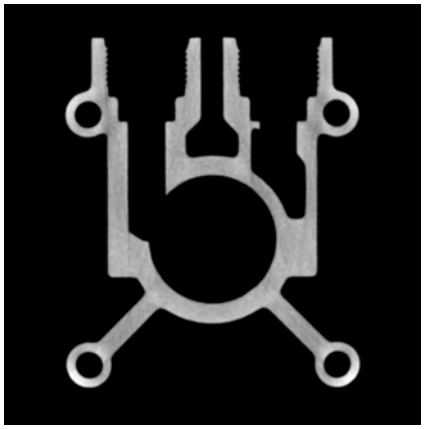


Scatter image



Profile plot

Virtual Computed Tomography
Reconstruction Results



Without scatter contribution

With scatter contribution

Virtual Computed Tomography
Study of Influential Parameters

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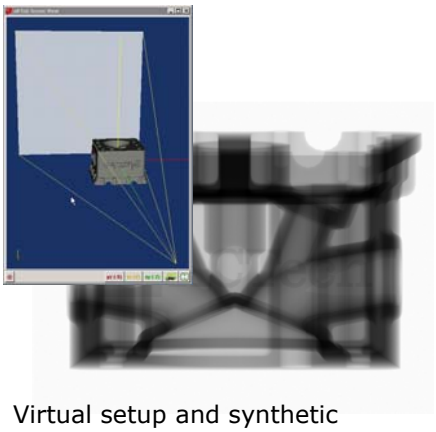
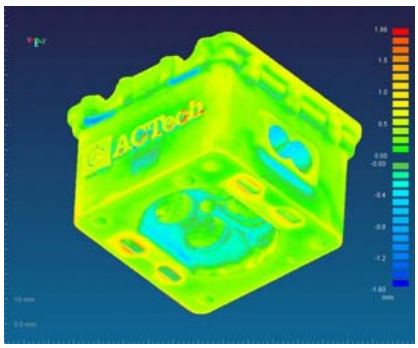


Virtual setup and synthetic radiography



Comparison of coordinates from virtual CT to real measurement

Backscatter Techniques

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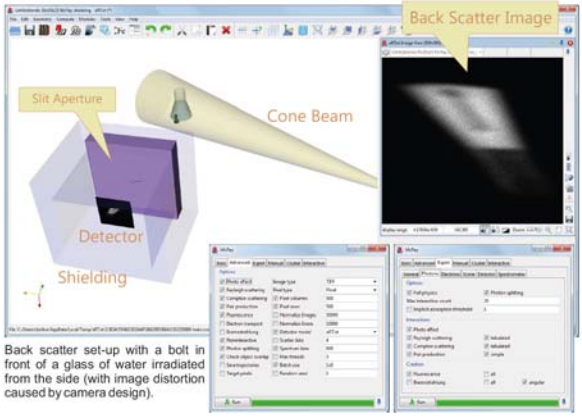
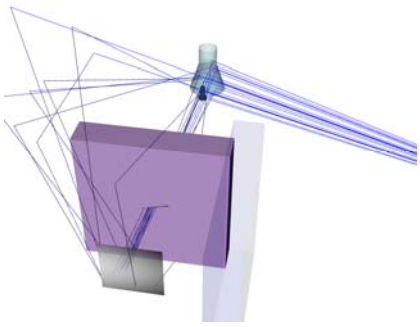
Simulation with Monte Carlo Scatter Model (McRay)

- aRTist utilized as graphical interface for McRay
- Optional remote execution of McRay
  - e.g. HPC cluster

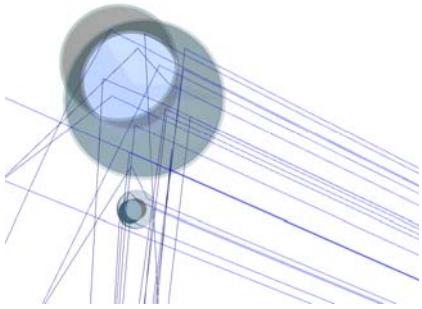


Back scatter set-up with a bolt in front of a glass of water irradiated from the side (with image distortion caused by camera design).

Backscatter Techniques



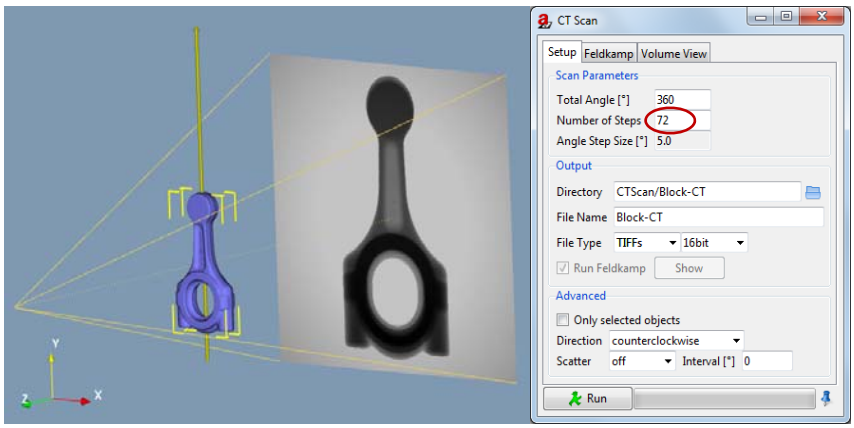
Visualization of selected traces: Overview image
(inadequate shielding ➔ contributions from scattering in air)



Visualization of selected traces: Detailed view

Live Demo

Virtual CT with aRTist



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Conclusions

Further Information

www.aRTist.bam.de

Conclusions

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Simulation with aRTist and McRay

- Combination of analytical and Monte Carlo model
- Effective simulation including scatter contribution
- Applicability for radiation techniques shown
  - **Radiography** – full integration of McRay
  - **Computed Tomography** – virtual CT
  - **Backscatter** techniques – aRTist as GUI for McRay

aRTist

RT modeling software for science and industry

- Tcl/Tk: GUI, scripting
- VTK: compiled core engine