Simplified Grid Implementation of Medical Image Processing Algorithms using a Workflow Management System"

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Medical Image Processing

Medical Image Processing is characterized by

- High storage capacity
  - Volume data, high resolution images, screening
- High computing power
  - large datasets, increase of accuracy
- High variety of applications
  - specialized processing steps
- Complex workflows
  - Image processing chains
- Often easily parallelizable
  - Image set level, Image level, tiles,...

Grid Computing

Grid Computing is the collaboration of distributed resources across institutional borders

- Scalable storage
- Scalable computing power
- Heterogeneous hardware
- Distributed administration
- Service oriented architecture

Grid Computing is a promising solution for increasing demands on medical image processing

D-Grid / MediGRID

- German D-Grid (since 2005)
  - National grid initiative for science (and economy)
  - Today: 19 Community grids and 1 integration project
- MediGRID (2005-2008):
  - Community grid for medicine and life sciences
  - Application modules and cross-sectional modules

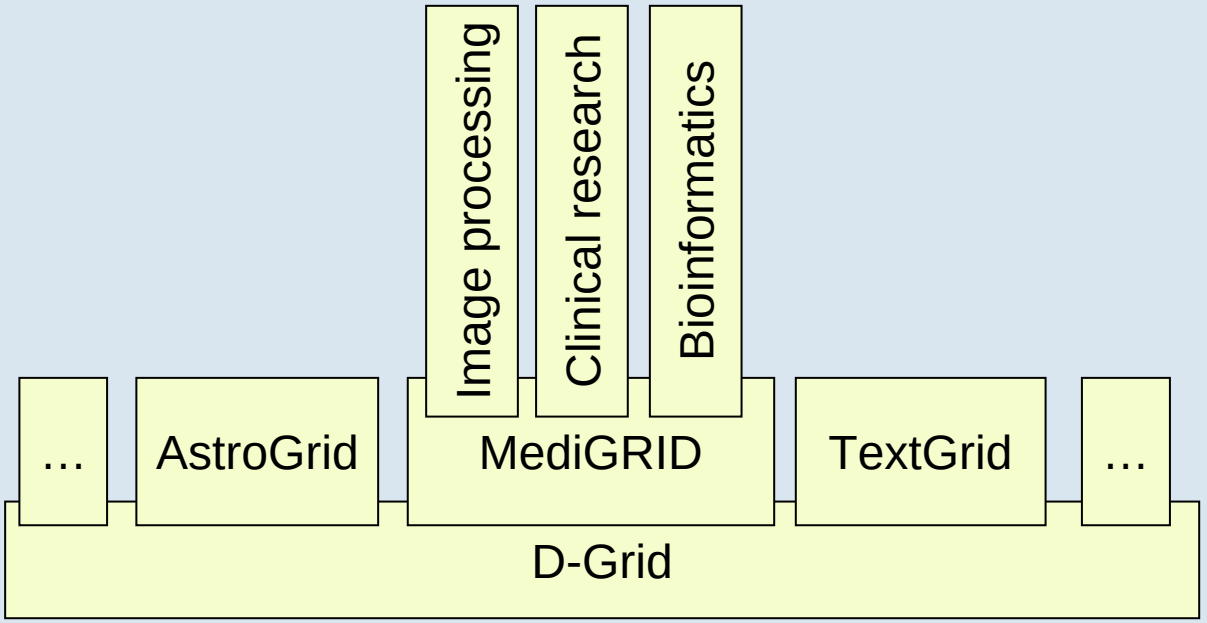


Image Processing Module

The image processing module implements representative applicaton scenarios in the MediGrid

Current research projects

- High benefit from grid, anonymized data

Main image processing components

- Preprocessing, registration, segmentation, classification, numerical simulations

Main tools and programming languages used in research

- Matlab, itk/vtk, c++, java, ...

Main standards and integration of external resources

- DICOM, PACS, Image Retrieval

Functional MRI Analysis

Functional MRI allows for localization of activated brain regions.

Statistical analysis over many repetitions of activation experiments

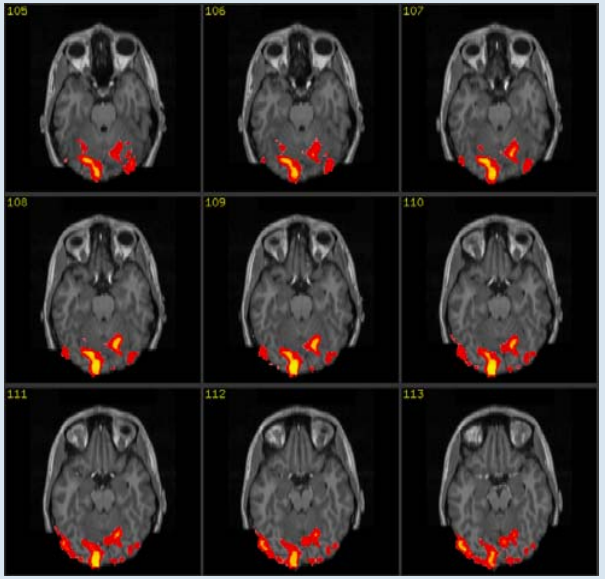
- high data volume

Preprocessing on single or few image level

- Smoothing of data
- Volume reconstruction
- Atlas-based registration

Standardsoftware SPM,

- based on Matlab



Virtual Vascular Surgery

Hemodynamic simulations based on a patient's vascular geometry allows for virtual surgery of cardiovascular deseases

Segmentation of vascular geometry from CT images

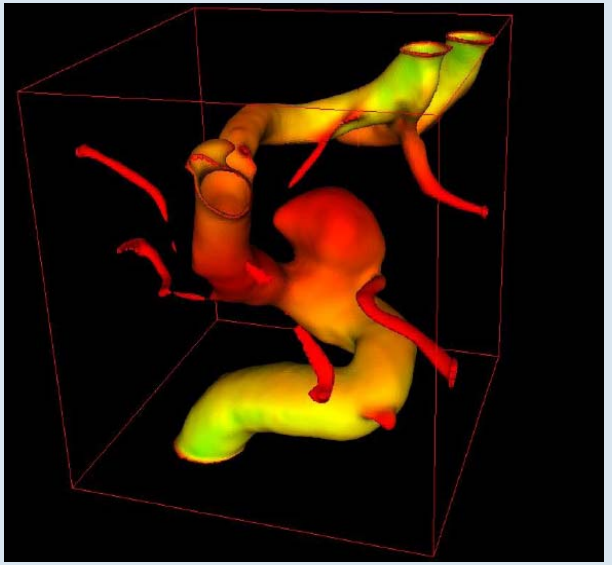
- interactive segmentation and virtual surgery

Numerical simulation of blood flow

- time consuming processing step
- initial parameters/geometry

Visualization of results

- Blood flow, pressure field



TRUS Prostate Imaging

Location of tissue probes within the prostate volume supports prostate cancer diagnosis and therapy planning

Location of biopsy needles in TRUS images

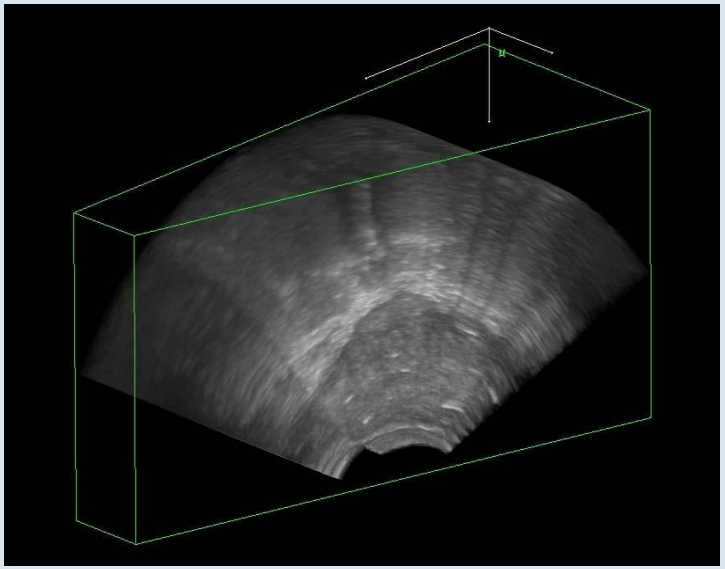
- Segmentation on 2D sequences

Location of 2D images within the prostate volume

- 2D-3D registration
- time vs. accuracy

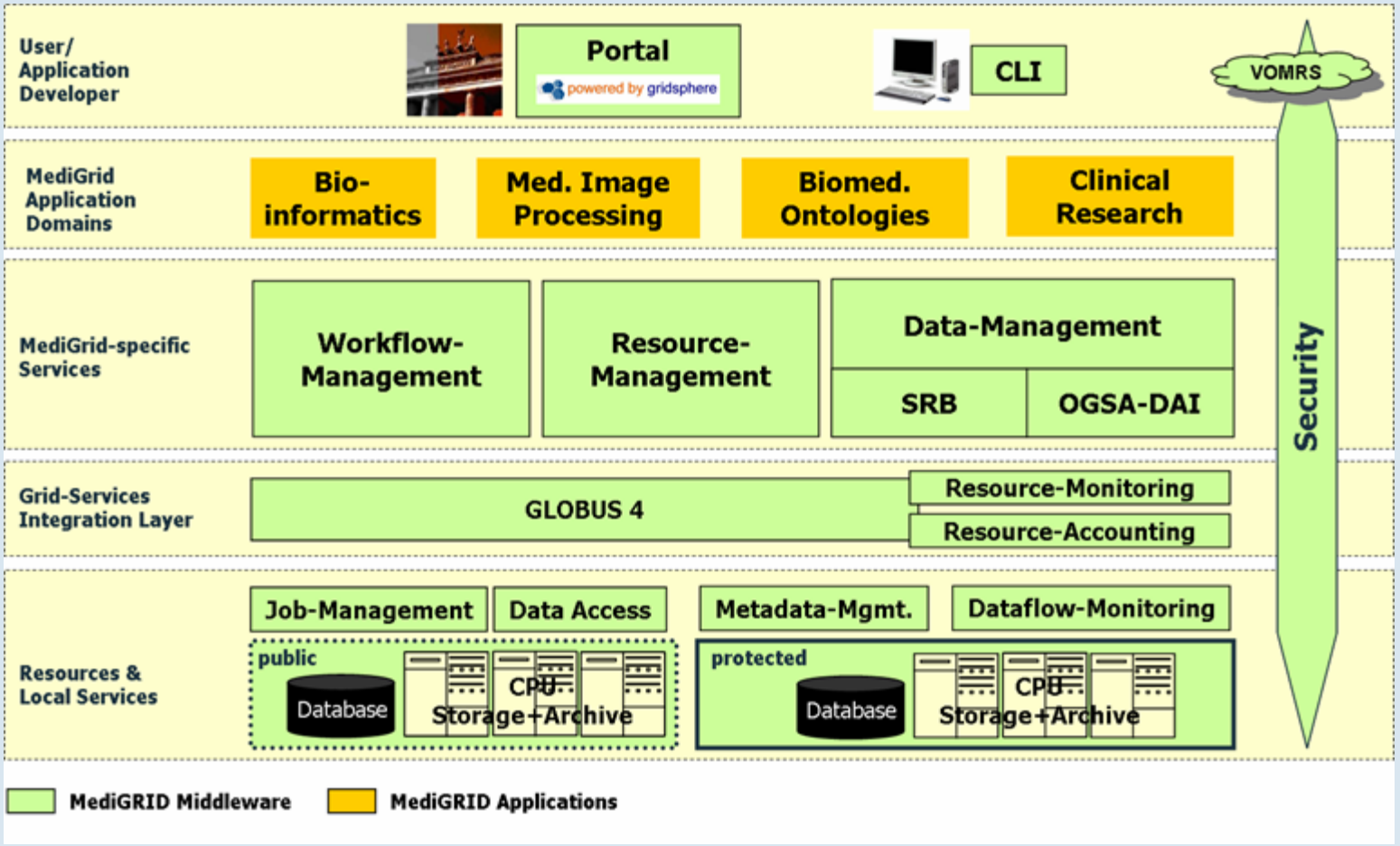
Complex workflow

- further processing steps
- image retrieval

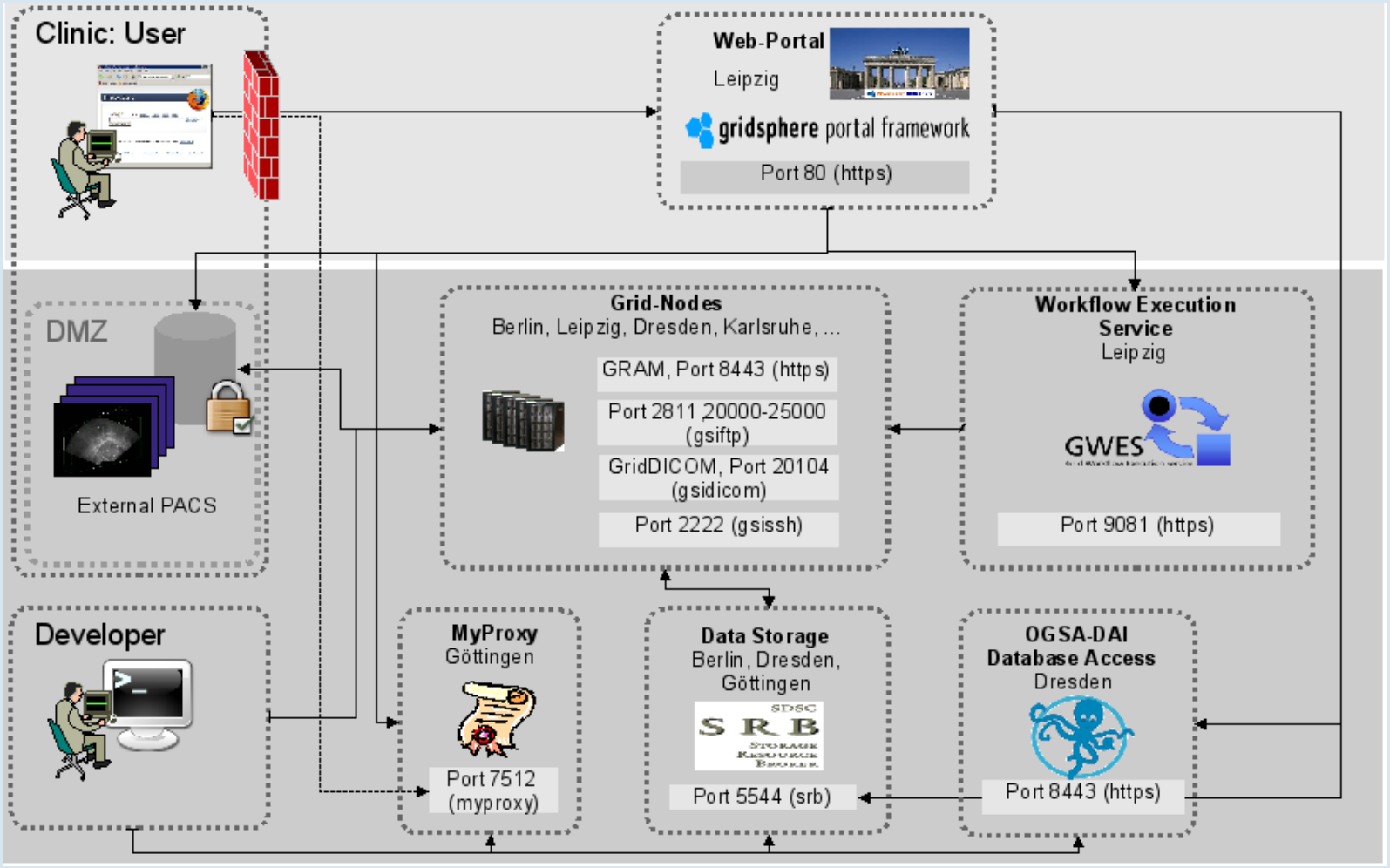


Middleware Solutions

Existing middleware is adapted and – where necessary – modified or extended. New components are developed.

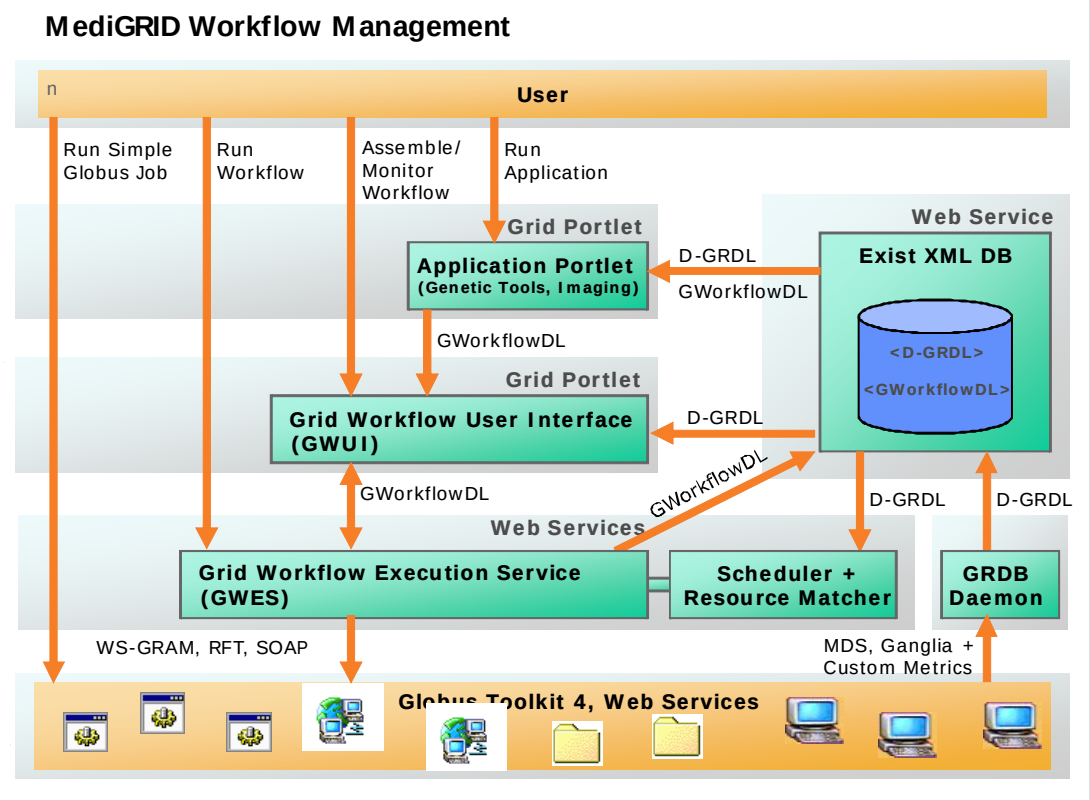


Current system architecture



Workflow Manager GWES

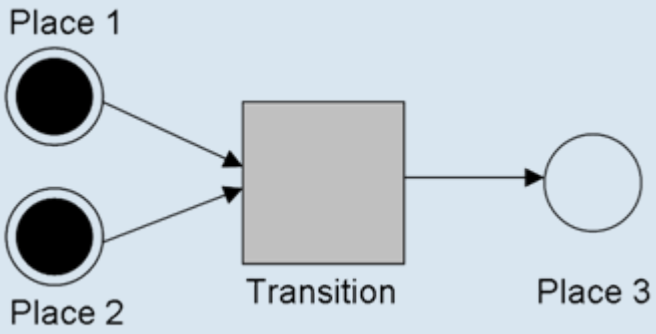
- Service-oriented, light-weight and open-source (for scientific and educational use)
- Implements Highlevel Petri nets using XML based workflow descriptions (GWorkflowDL)
  - Resource matching
  - Scheduling during runtime
  - Checkpointing
  - Persistence
  - Fault-tolerance
  - Web-based GUI for administration and control



Petri nets

Mathematical modeling language for distributed systems, consisting of

- Transitions (squares)
- Places (circles), that may hold n_p tokens (black dots)
- Flow relations (arrows between places and transitions)
  - Input place: arrow is pointing from place to transition
  - Output place: arrow is pointing from transition to place
- Marking: Distribution of tokens on places



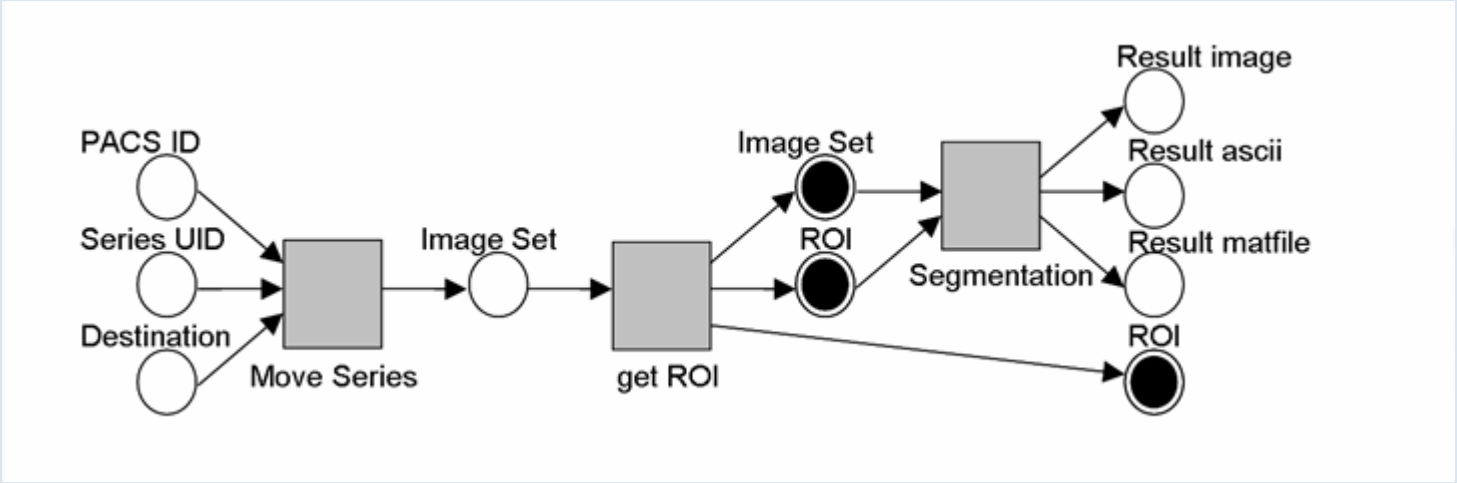
Petri nets

- Enabling of a transition:
  - All input places are occupied
  - All output places may receive further tokens
- Firing of a transition:
  - One token of each input place is consumed
  - One token is added to each output place
- Modeling of image processing workflows
  - Data -> token, executables -> transitions
  - Program execution -> firing

Petri nets

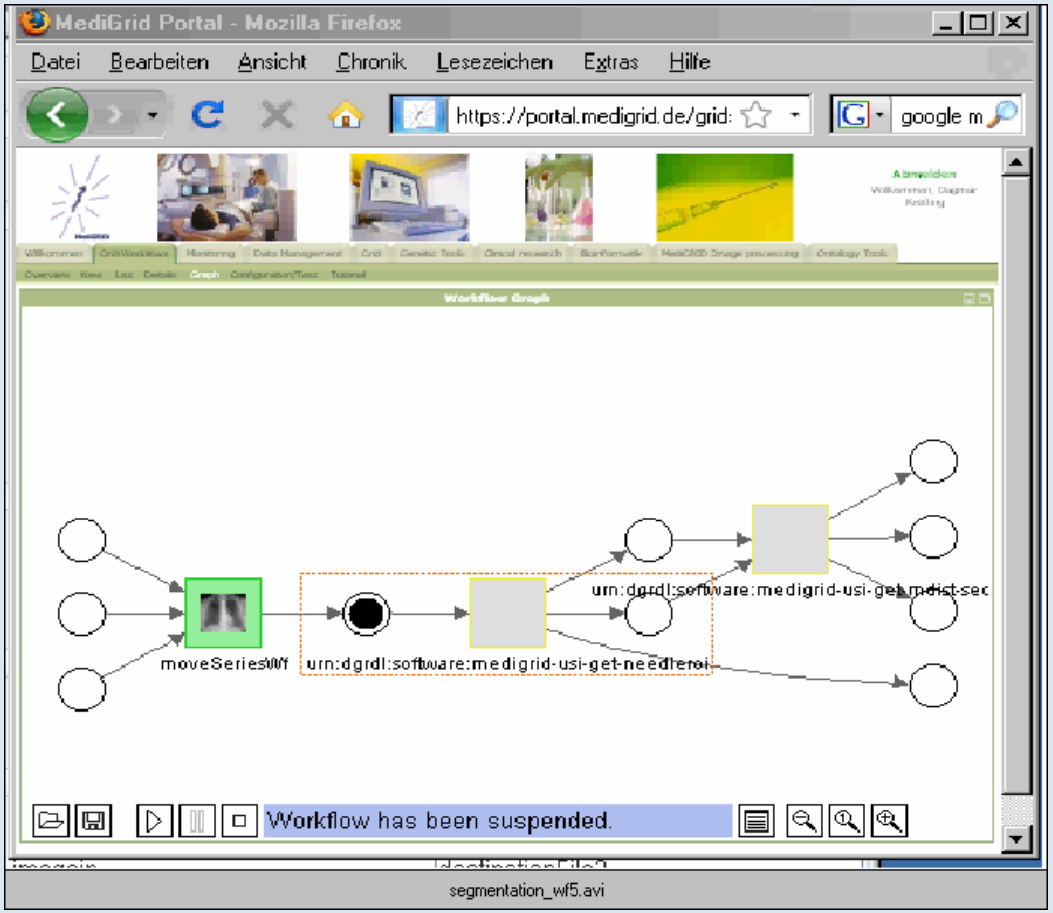
Modeling of Image processing chains

- Intuitive visualization
- Easy implementation of coarse grained parallelization



Coupling to the grid

Webbased control over the implemented workflow



Implementation steps

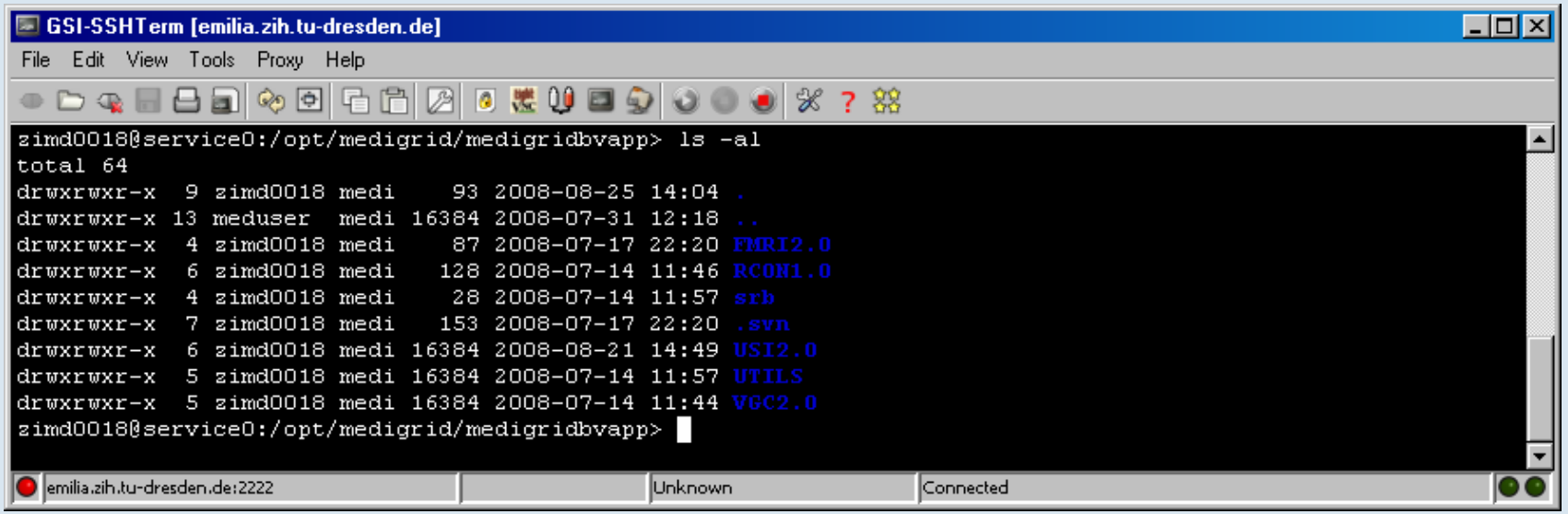
Implementation of command-line tools to the grid

1. Deployment of the software to the gridnodes
2. Generation of a wrapper script
3. Registration of the software
4. Creation of a workflow description
5. *Optional:* Integration of the workflow into the user portal

Deployment of software

Software has to be installed on the front-end of the sites

- Each application group has it‘s own remote directory
  - Copy application from a local directory to the remote installation directory with gsiscp (script)
  - Access to the gridnodes via gsissh and svn update



Wrapper script

A shell-script

- Sets environment (pathes, environment variables)
- Calls the program(s)
- Requirement: all parameters have to be passed as name/value pair
  - Program call:

    segmentation 51123_1100.png 51123_roi.mat
  - Script call:

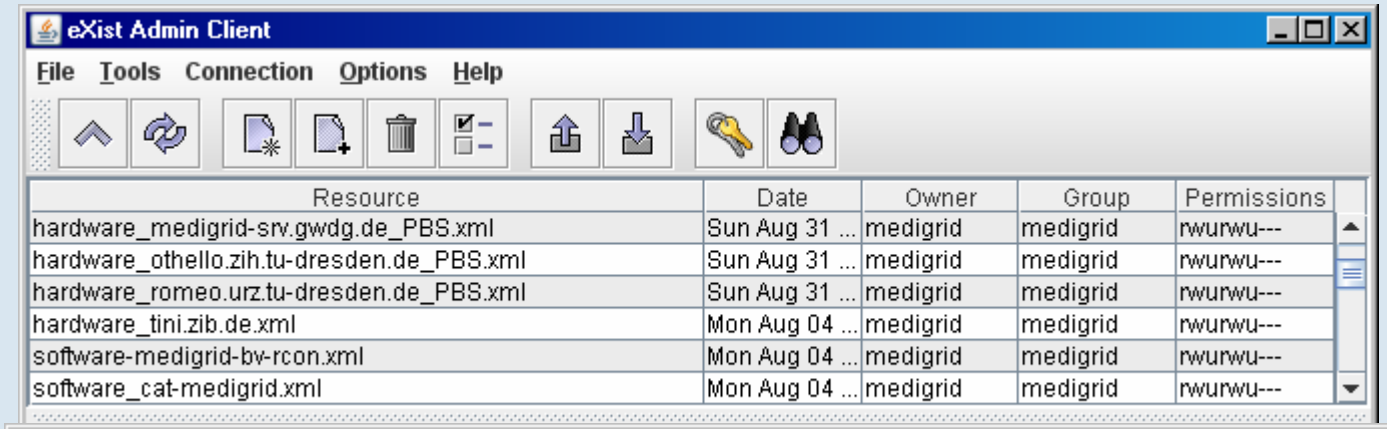
    gwes-segmentation-simple.sh

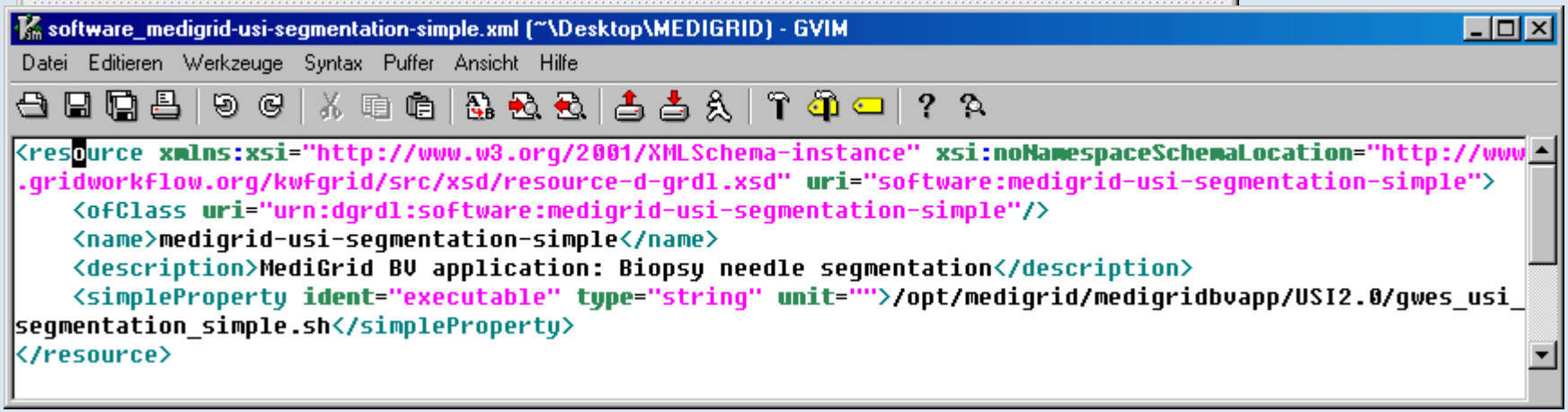
    –input_image 51123_1100.png *–roi* 51123_roi.mat

D-GRDL Registration

Database-entry (exIST-database, dgrdl):

- new software (path of the script)
- gridnodes where the software is available





Workflow Description

Xml-based GWorkflowDL

gwes-segmentation-simple.sh

–input_image 51123_1100.png *–roi* 51123_roi.mat

gwes-segmentation-simple-example.xml (~\Deskt...STRATION_WORKFLOWS\WORKFLOW_DESCRIPTION) - GVIM

Datei Editieren Werkzeuge Syntax Puffer Ansicht Hilfe

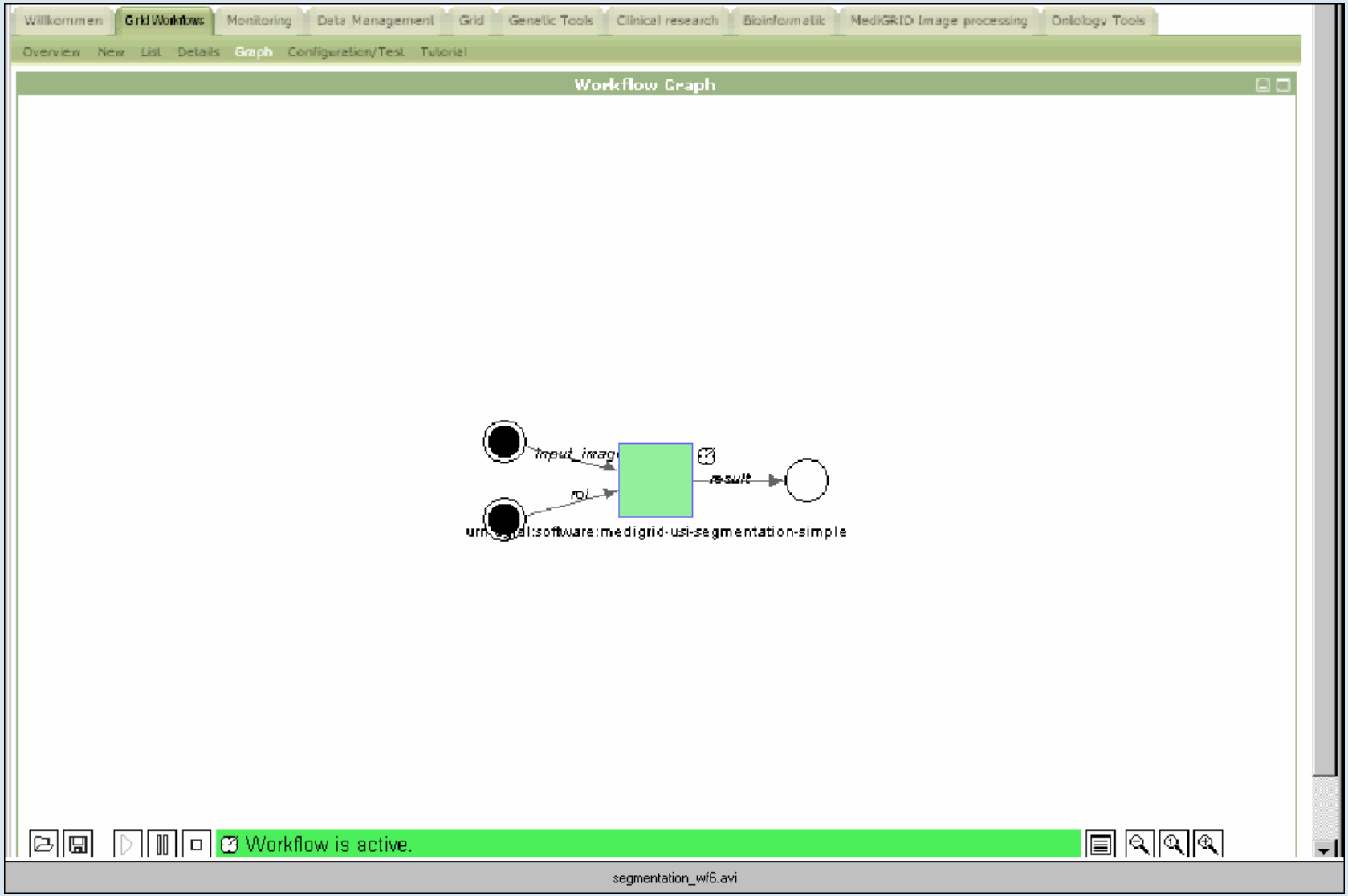
```
<workflow xmlns="http://www.gridworkflow.org/gworkflowdl" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xsd="http://www.w3.org/2001/XMLSchema" xsi:schemaLocation="http://www.gridworkflow.org/gworkflowdl http://
www.gridworkflow.org/kwfgrid/src/xsd/gworkflowdl_1_0.xsd" ID="No_ID">
    <description>Segmentation workflow</description>
    <property name="resource.repository.collection">/db/dgrdl</property>
    <place ID="input_image">
        <token><data xmlns=""><value xsi:type="xsd:string">51123_1100.png</value></data></token>
    </place>
    <place ID="roimat">
        <token><data xmlns=""><value xsi:type="xsd:string">51123_roi.mat</value></data></token>
    </place>
     <place ID="output"/>
   <transition ID="segmentation">
        <description>biopsy needle segmentation</description>
        <inputPlace placeID="input_image" edgeExpression="input_image"/>
        <inputPlace placeID="roimat" edgeExpression="roi"/>
        <outputPlace placeID="output" edgeExpression="result"/>
        <operation>
 <pe:programClassExecution xmlns:pe="http://www.gridworkflow.org/gworkflowdl/programclassexecution" softwareClas
s="urn:dgrdl:software:medigrid-usi-segmentation-simple"/>
        </operation>
    </transition>
</workflow>
                                                                              19,17         Alles
```

Using the workflow

Workflow upload to the workflow manager

- Webbased using the GUI
- Data has to be specified within the workflow
  - manually: error source
  - script: additional local tools
- Only reasonable for computer-affine researchers and users

Manual upload

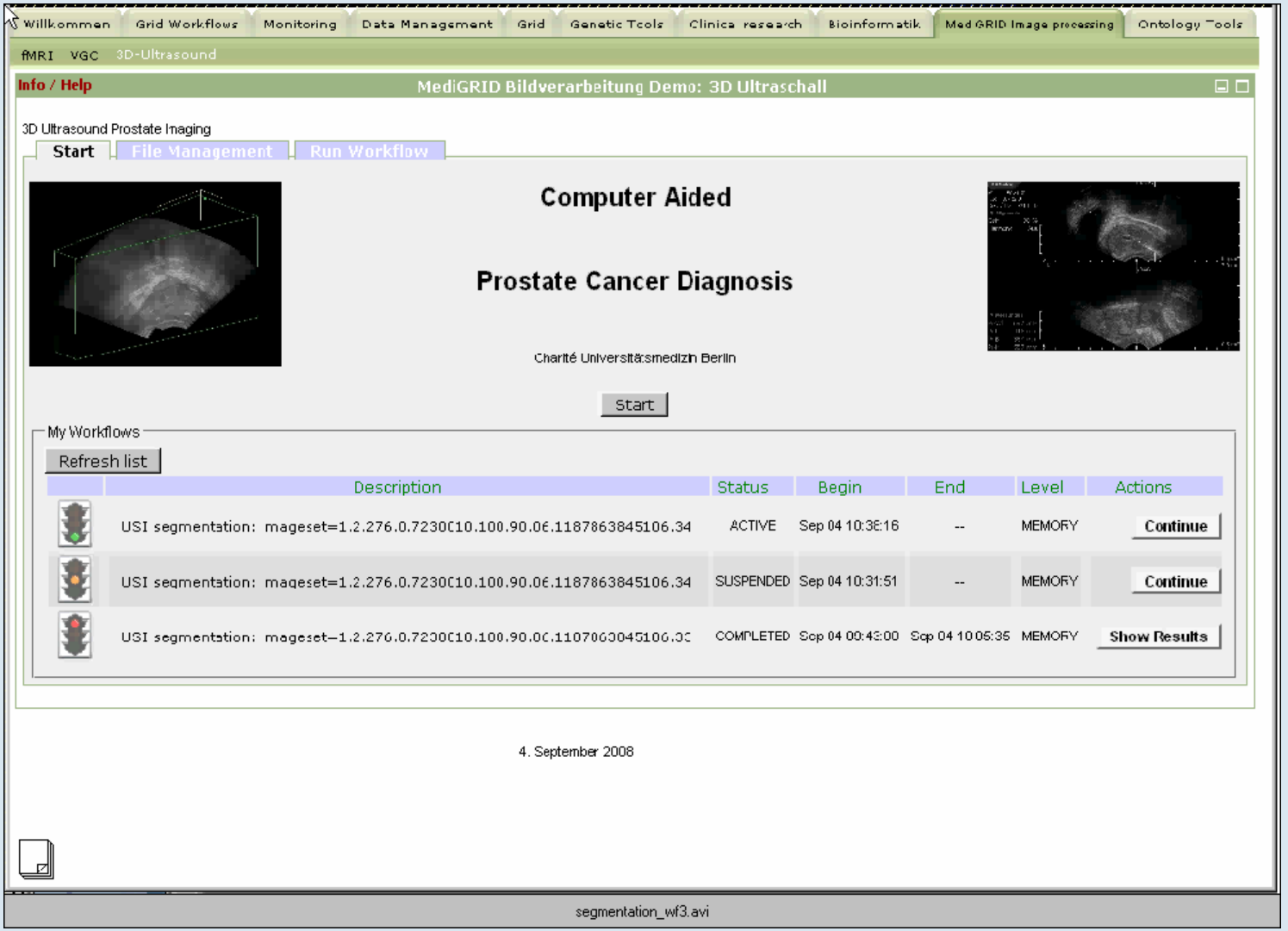


Portal integration

Integration of a workflow template in a GUI

- MediGRID: Integration into an applicationspecific portlet
- Further development time, but userfriendly

Portal Integration



Results

Willkommen | Grid Workflows | Monitoring | Data Management | Grid | Genetic Tools | Clinical research | Bioinformatik | MediGRID Image processing | Ontology Tools

fMRI | VGC | 3D-Ultrasound

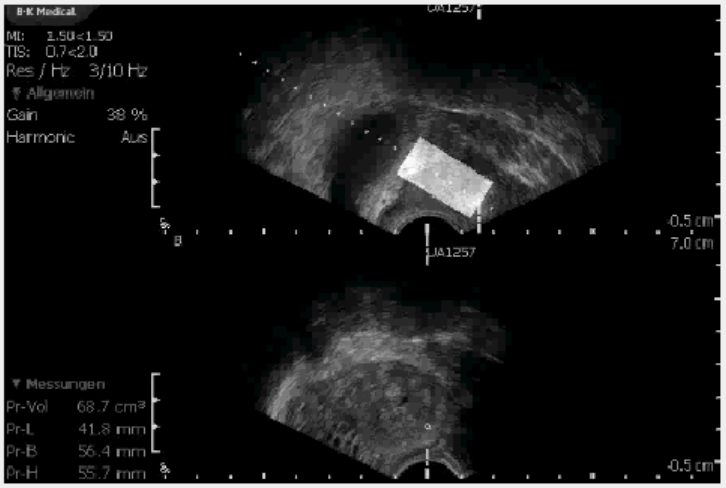
Info / Help

MediGRID Bildverarbeitung Demo: 3D Ultraschall

<< return to workflow list

The workflow produced the following results:

Segmented Needle | Needle ROI



4. September 2008

segmentation_wf4.avi

Results

Currently implemented:

- 5 image- and signalprocessing applications

- With application specific portlets:
  - Functional MRI: simple workflow (needs matlab)
  - Virtual vascular surgery: basic interactive visualization
  - Ultrasound imaging: 4 different workflows

- Without portlets:
  - Analysis of polysomnographic signals from a clinical study
  - Dynamical lung CT

- Recently started projects (Services@MediGRID, MedInfoGrid)

Discussion

-Use cases for quick implementation
  - Command-line code
  - Coarse-grained parallelization
  - Usage by the developer

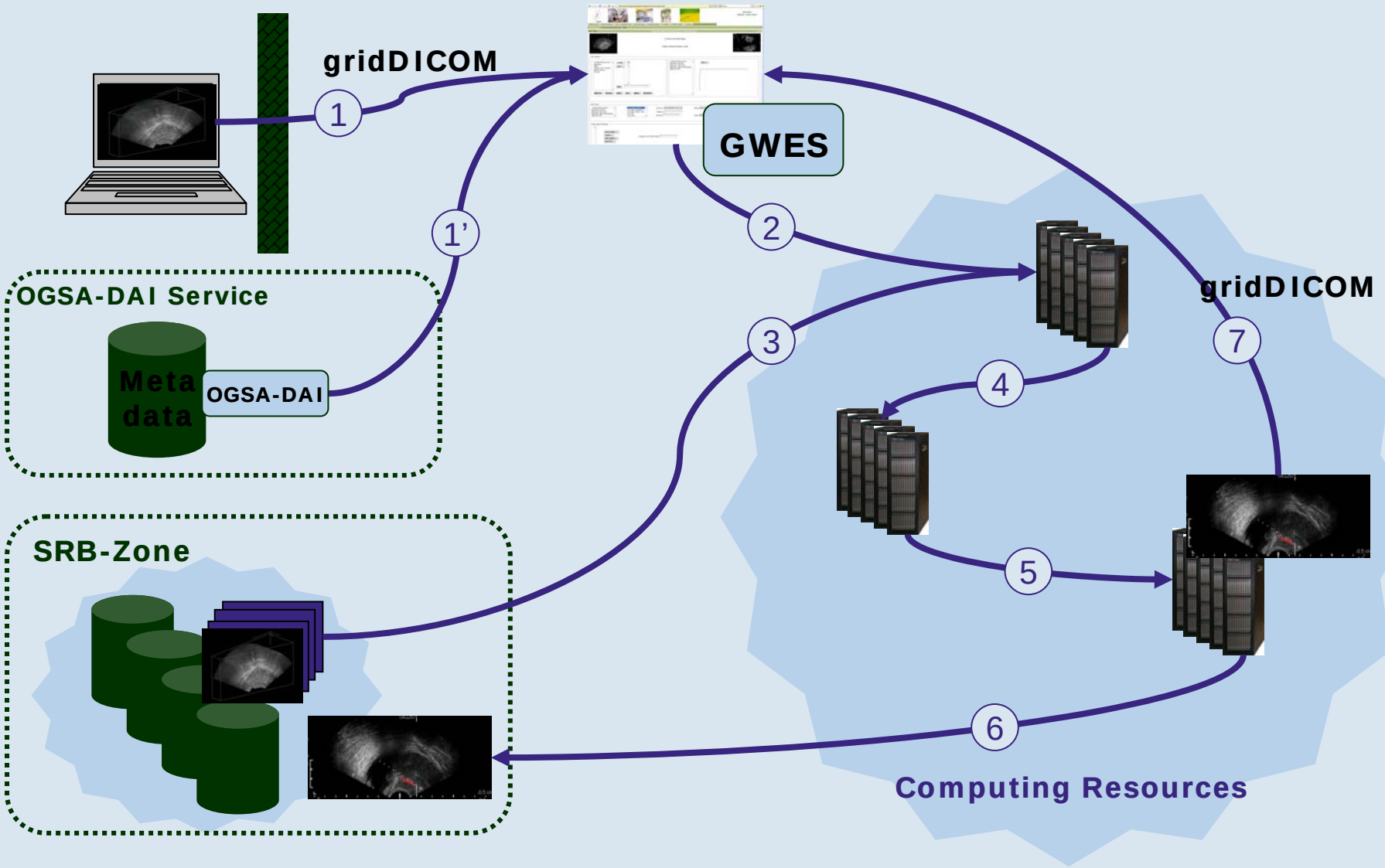
-Use cases for further portal implementation
  - Some interaction desired (e.g. image selection)
  - End-user application
  - Visualization of (intermediate) results

THANK YOU FOR YOUR ATTENTION

Further information: www.medigrid.de - dagmar.krefting@charite.de

Additional slides

Middleware solution



Web Portal

MediGRID User

MediGRID Developer

MediGRID Admin

Grid Certificate

MediGRID Portal

powered by gridsphere

Bioinformatics

Gensequenzanalyse

SNP Selection

Ontology Access

Ontologiezugriff

Medical Imaging

fMRI

TRUS

Hemodynamics

Standard Grid Portlets

Credential Management

File Browser

Developer-support

Workflow Management

D-GRDL Metadaten-Erstellung

Administration

Resource Monitoring

D-GRDL Metadaten-Management

Resource Management

Medical Grids

Medical Grids demand special requirements with respect to mere computing Grids

High security and safety

- Patient data, traceability of processing steps

User friendliness

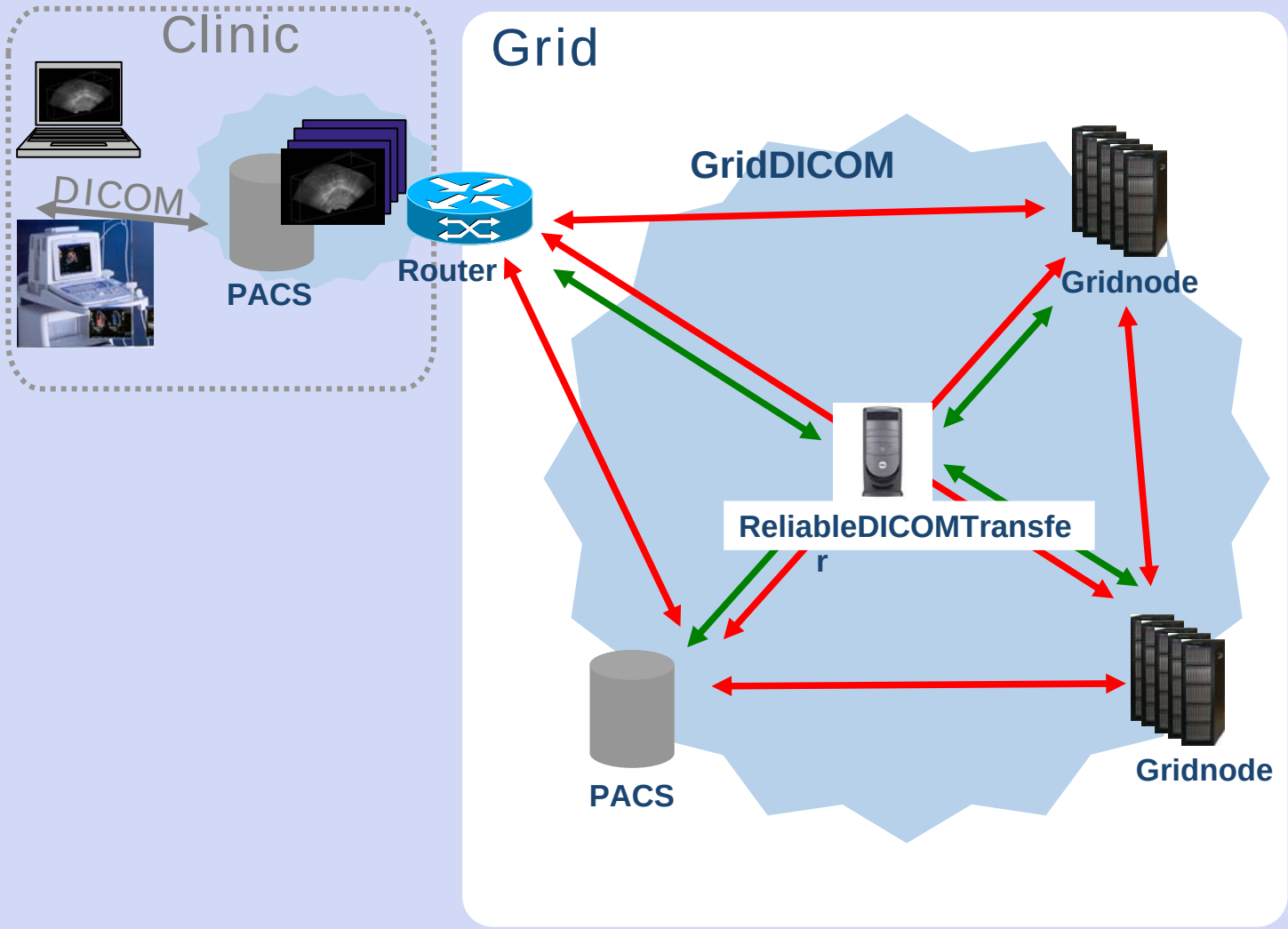
- User accustomed used to graphical user interfaces

Virtualization of grid resources

- Heterogeneous data and applications

Current research on modern Grids is working to overcome these barriers

gDICOM/RDT


Clinic
DICOM
PACS
Router
Grid
GridDICOM
Gridnode
ReliableDICOMTransfe
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PACS
Gridnode