Interfaces development for medical imaging Applications in the framework of the Multiple Scleoris disease

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INRIA

http://www.inria.fr

- Institut National de Recherche en Informatique et en automatique.
- Goals:
  - Dedicated to fundamental and applied research.
  - Play a major role in technology transfer.

Asclepios

http://www-sop.inria.fr/asclepios/

- In medical image processing domain.
- Goals:
  - Analysis of medical and biomedical images with advanced geometrical, statistical, physical and functional models.
  - Provides optimized tools to clinicians

NeuroLOG *http://neurolog.polytech.unice.fr*

- A three years ANR scientific project (2007-2009)
- Goal: Federate medical data and algorithms, and sharing computing resources on grid infrastructure.
- On three different pathologies:
  - Multiple Sclerosis
  - Brain Stroke
  - Tumours
- Partners from different disciplines:
  - Software technologies
  - Databases and knowledge
  - Medical imaging

My work

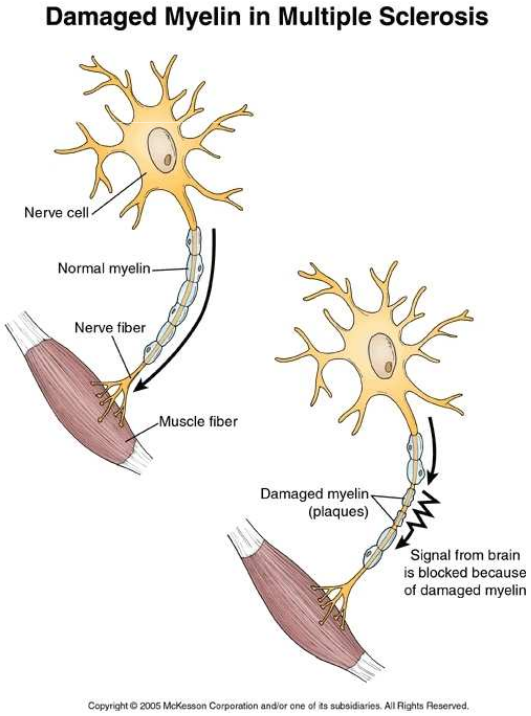
- To understand an application of brain MRI segmentation by implementing tools in the software SepINRIA.
- To deploy this application on the EGEE computational grid

Plan

- Brain MRI segmentation pipeline
- SepINRIA software
- Workflow deployment on the EGEE grid
- Time performance and study of a method's parameter influence
- Conclusion

Multiple Sclerosis (MS) brain MRI segmentation

- Segmentation of lesions on brain MRI is required for diagnosis or follow-up purpose in MS.



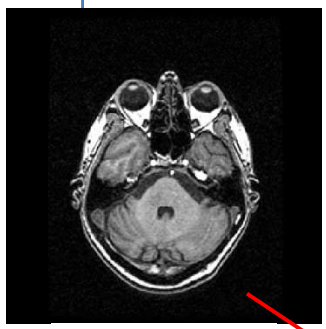
Improved EM-based tissue segmentation and partial volume effect quantification in multi-sequence brain MRI.
G. Dugas-Phocion, M. Angel G. Ballester, G. Malandain, C. Lebrun, and N. Ayache. MICCAI'04.

The pipeline

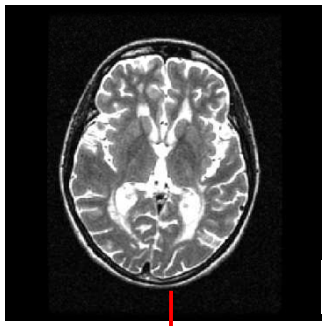
Brain MRI segmentation pipeline: Five main steps

Spatial normalization

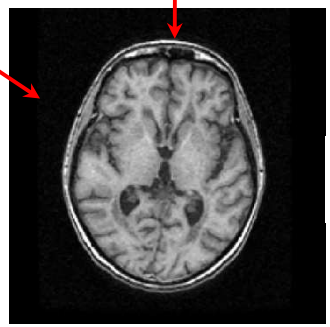
A rigid registration of the T1 on the T2 sequence is performed.



T1 sequence



T2 sequence



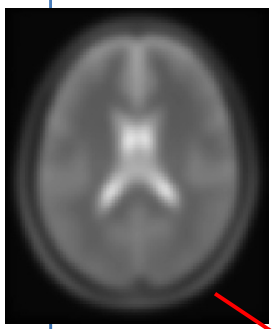
T1 sequence registered

Block matching: A general framework to improve robustness of rigid registration of medical images.
S. Ourselin, A. Roche, S. Prima, and N. Ayache. MICCAI'00

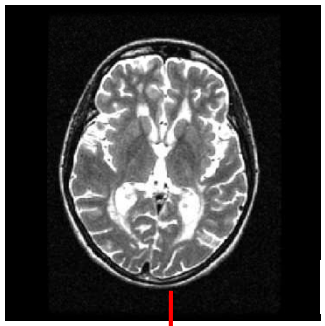
The pipeline

Brain MRI segmentation pipeline: Five main steps

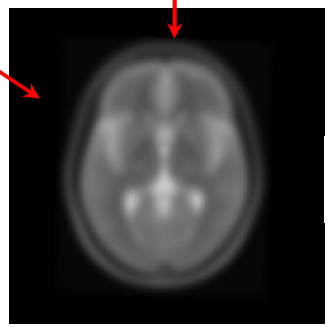
A rigid registration of the atlas images on the T2 sequence is performed.



Atlas T2 sequence



T2 sequence



Atlas T2 sequence registered

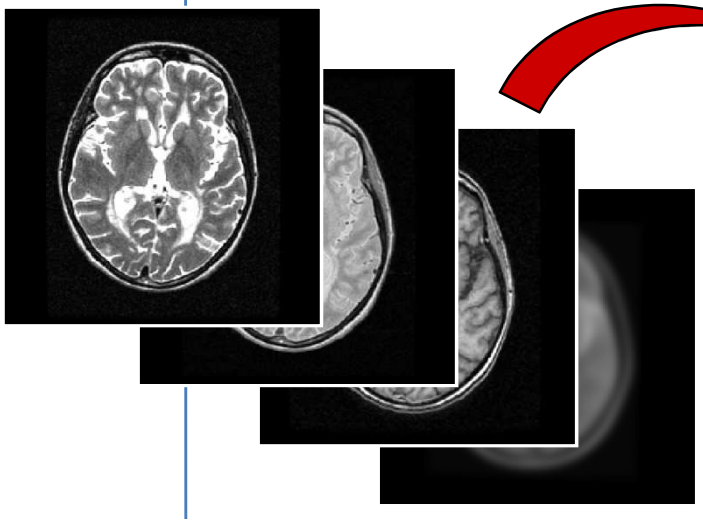
Spatial normalization

MNI atlas registration

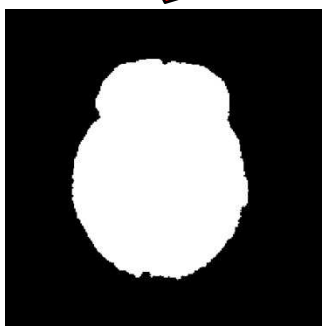
The pipeline

Brain MRI segmentation pipeline: Five main steps

A skull-stripping method is used
to isolate the brain healthy compartments



Patient and Atlas sequences



Brain mask

- Spatial normalization
- MNI atlas registration
- Skull-stripping

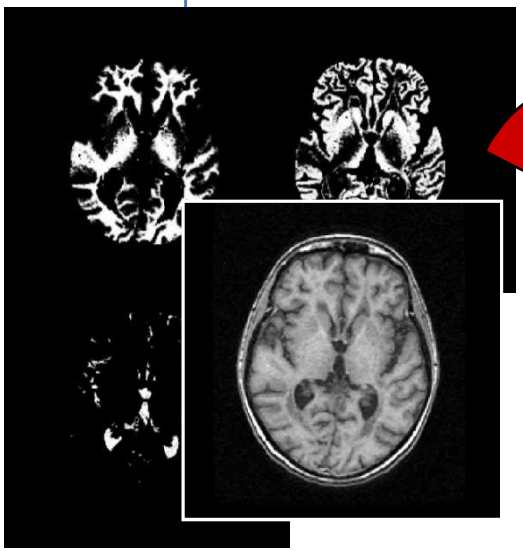
Hierarchical segmentation of multiple sclerosis lesions in multi-sequence MRI. G. Dugas-Phocion, M. Angel G. Ballester, C. Lebrun, S. Chanalet, C. Bensa, G. Malandain, and N. Ayache. ISBI'04.

The pipeline

Brain MRI segmentation pipeline: Five main steps

A first classification of the brain into WM, GM and CSF classes is realized.

Parameters of bias field are then computed from these segmentations.



T1 sequence and brain compartements

T1 sequence unbiased

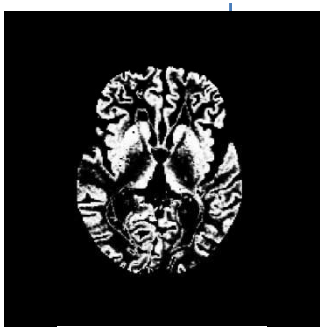
- Spatial normalization
- MNI atlas registration
- Skull-stripping
- Intensity normalization

Maximum likelihood estimation of the bias field in MR brain images: Investigating different modelings of the imaging process.
S. Prima, N. Ayache, T. Barrick, and N. Roberts. MICCAI'01

The pipeline

Brain MRI segmentation pipeline: Five main steps

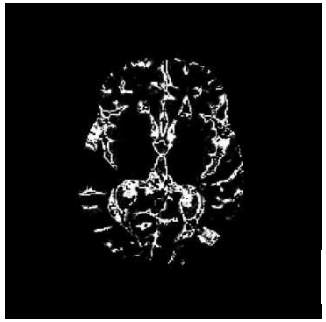
The Expectation Maximization method is used once again to classify brain MRI voxels from unbiased images.



Grey matter

White matter

CSF

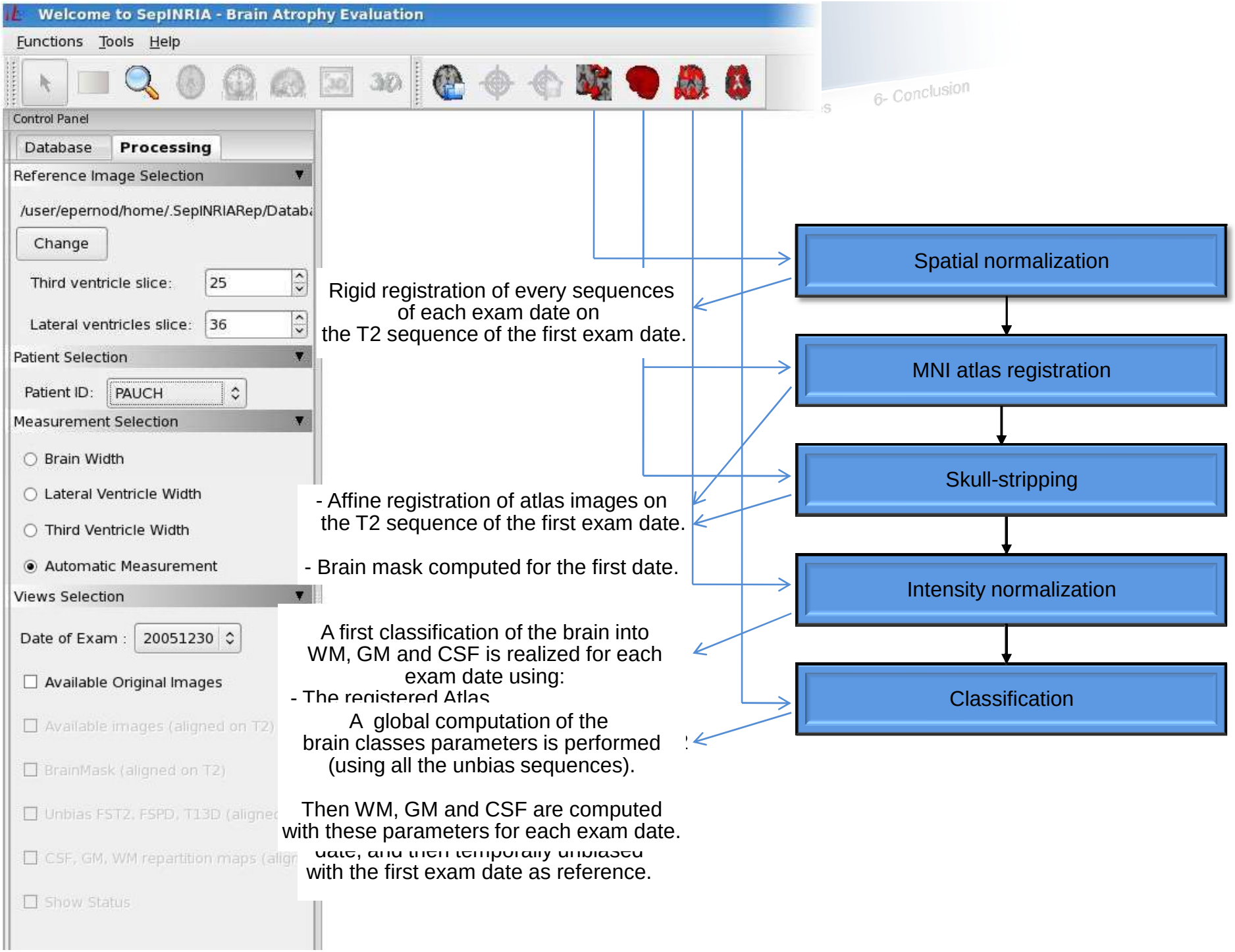


PVE

- Spatial normalization
- MNI atlas registration
- Skull-stripping
- Intensity normalization
- Classification

SepINRIA improvement: Automatic atrophy measurement functionality

(Created by Jean-Christophe Souplet)


Welcome to SepINRIA - Brain Atrophy Evaluation
Functions
Tools
Help
Control Panel
Database
Processing
Reference Image Selection
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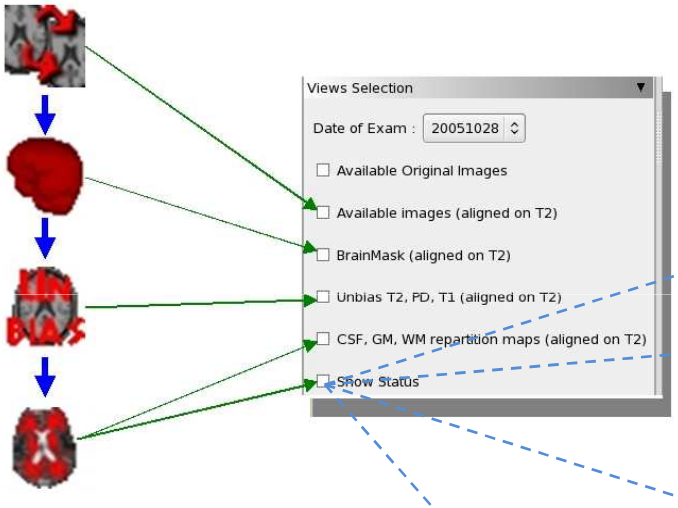
Change
Third ventricle slice:
25
Lateral ventricles slice:
36
Patient Selection
Patient ID:
PAUCH
Measurement Selection
Brain Width
Lateral Ventricle Width
Third Ventricle Width
Automatic Measurement
Views Selection
Date of Exam :
20051230
Available Original Images
Available images (aligned on T2)
BrainMask (aligned on T2)
Unbias FST2, FSPD, T13D (aligned
CSF, GM, WM repartition maps (align
Show Status
Rigid registration of every sequences of each exam date on the T2 sequence of the first exam date.
- Affine registration of atlas images on the T2 sequence of the first exam date.
- Brain mask computed for the first date.
A first classification of the brain into WM, GM and CSF is realized for each exam date using:
- The registered Atlas
A global computation of the brain classes parameters is performed (using all the unbias sequences).
Then WM, GM and CSF are computed with these parameters for each exam date.
date, and then temporally unbiased
with the first exam date as reference.
Spatial normalization
MNI atlas registration
Skull-stripping
Intensity normalization
Classification

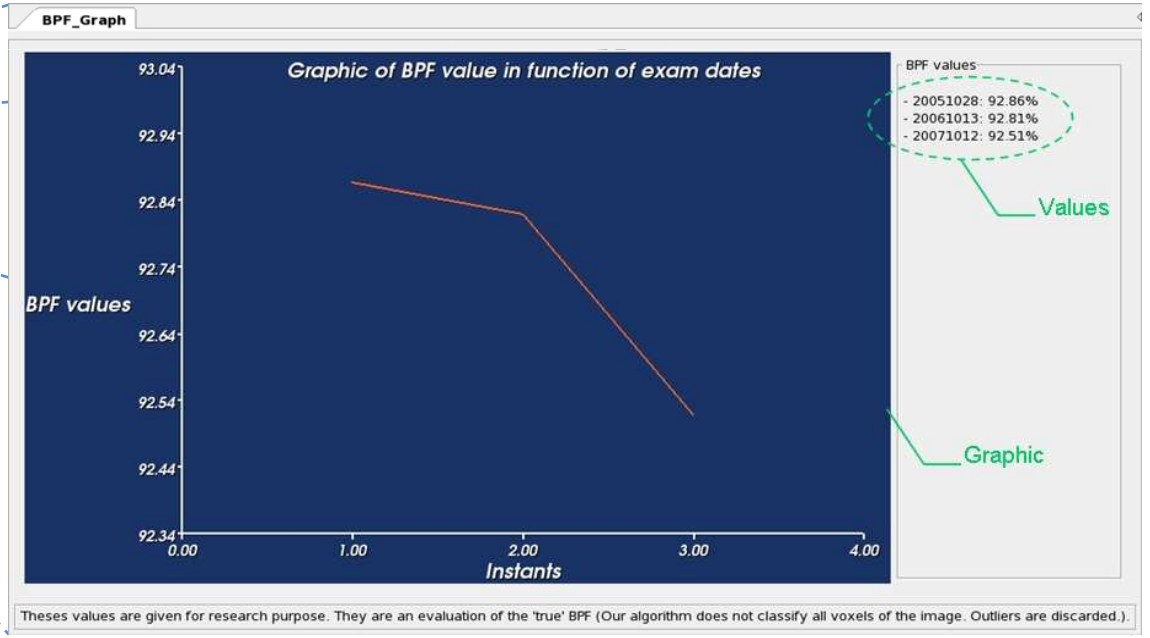
Final step:

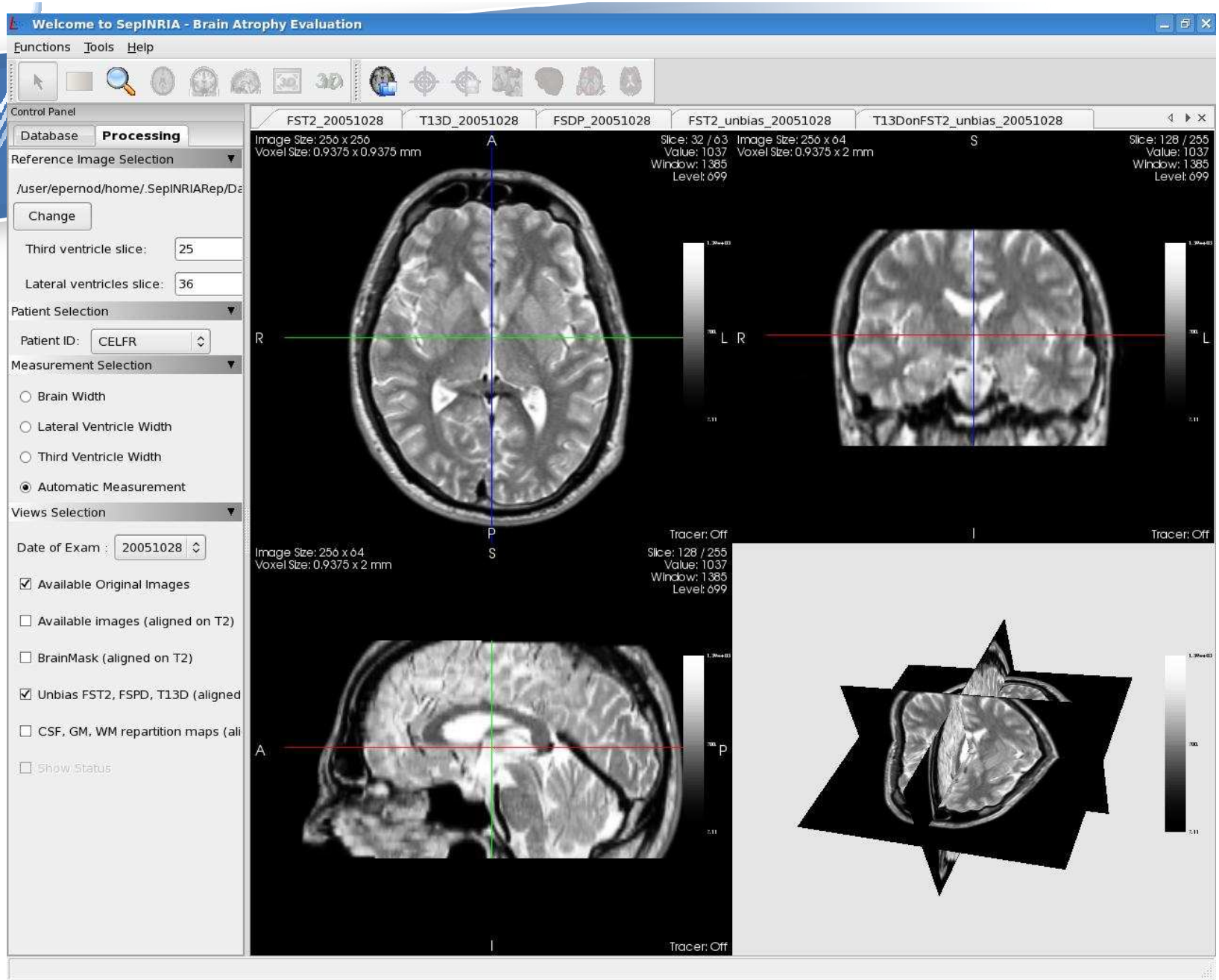
-WM, GM and CSF segmentations are used to compute the brain parenchymal fraction (BPF).

- The graph showing BPF value in function of the exam date reflects the evolution of atrophy

$$BPF = \frac{Volume(GM) + Volume(WM)}{Volume(GM) + Volume(WM) + Volume(CSF)}$$



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Third ventricle slice:
25
Lateral ventricles slice:
36
Patient Selection
Patient ID:
CELFR
Measurement Selection
Brain Width
Lateral Ventricle Width
Third Ventricle Width
Automatic Measurement
Views Selection
Date of Exam :
20051028
Available Original Images
Available images (aligned on T2)
BrainMask (aligned on T2)
Unbias FST2, FSPD, T13D (aligned
CSF, GM, WM repartition maps (ali
Show Status
FST2_20051028
T13D_20051028
FSDP_20051028
FST2_unbias_20051028
T13DonFST2_unbias_20051028
Image Size: 256 x 256
Voxel Size: 0.9375 x 0.9375 mm
Slice: 32 / 63
Value: 1037
Window: 1385
Level: 699
Tracer: Off
Image Size: 256 x 64
Voxel Size: 0.9375 x 2 mm
Slice: 128 / 255
Value: 1037
Window: 1385
Level: 699
Tracer: Off
Image Size: 256 x 64
Voxel Size: 0.9375 x 2 mm
Slice: 128 / 255
Value: 1037
Window: 1385
Level: 699
Tracer: Off

Workflow creation

Problematic: How to deploy and parallelize an algorithm on a grid?

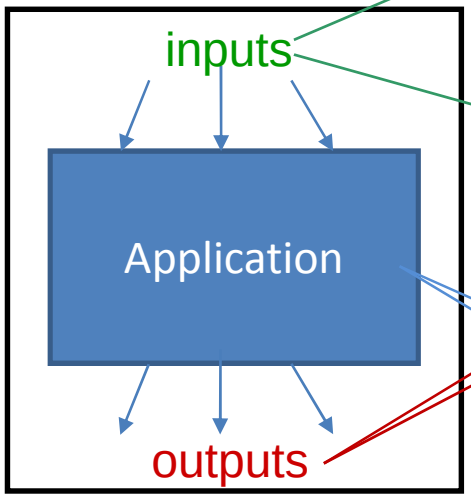
- Needed transformations of the pipeline ?
- How to create and execute a workflow ?
- Performances ?

- First, what is a grid?
  - Network of shared computing resources.
  - Different from a cluster.

Workflow creation

Services creation

- Splitting the pipeline in black
- Description of each black bo
- Use of GASW (Generic Applica

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      <access type="LFN"/>
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    <input name="float_image_inr" option="nob">
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    </input>
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    </input>
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    </input>
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</description>
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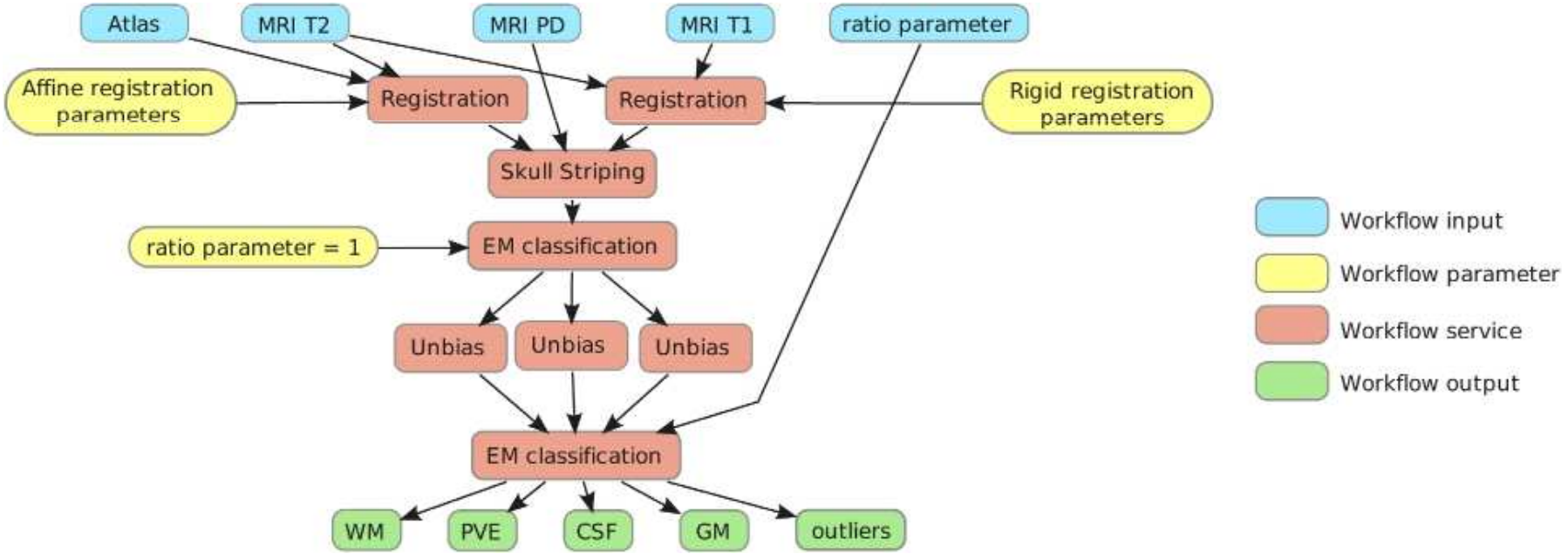
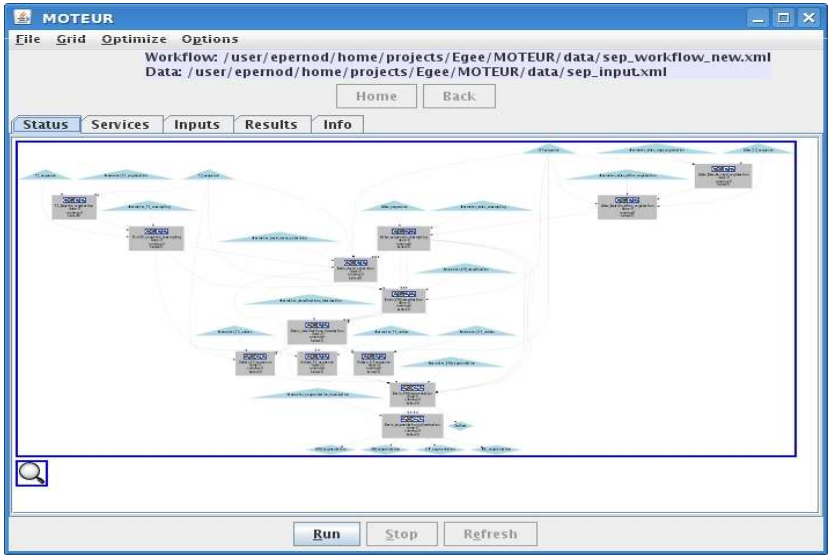
Workflow creation

Use of the software Taverna to build the structure of the workflow



Workflow execution

- Need a account on one computer of the grid
- Execution of the workflow (XML file) using MOTEUR

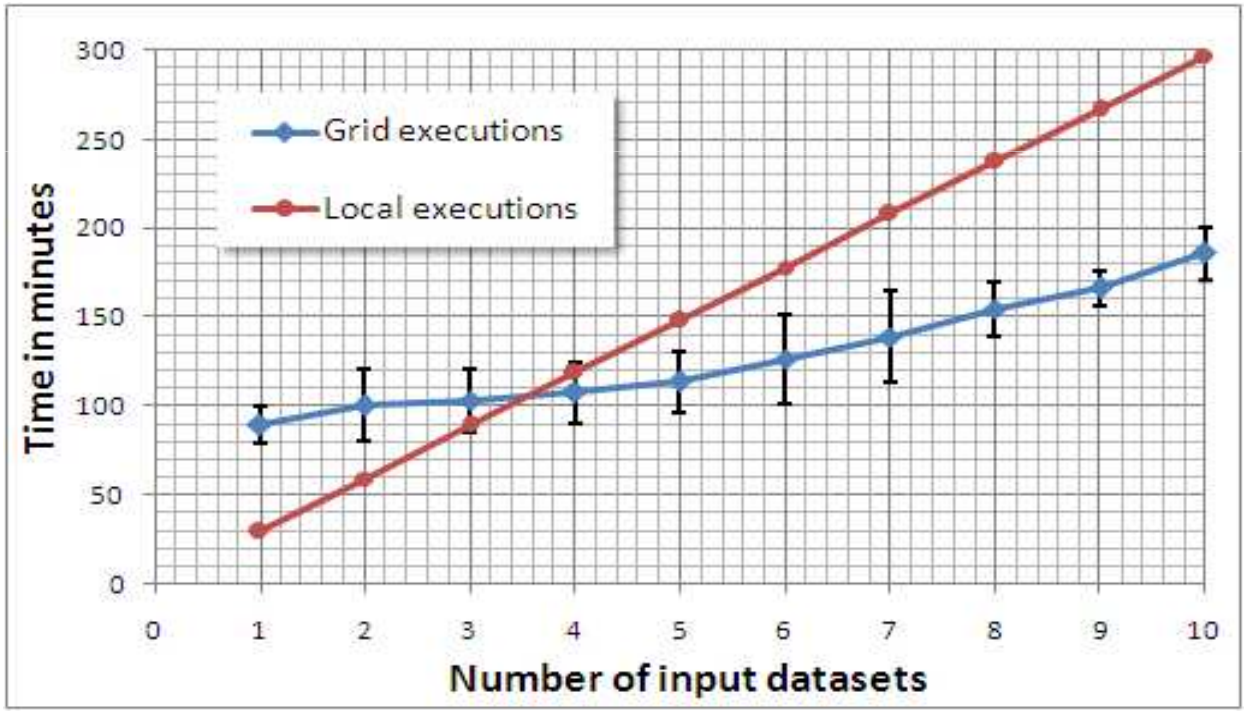


Efficient services composition for grid-enabled data-intensive applications.
T. Glatard, J. Montagnat, and X. Pennec. HPDC'06

- MOTEUR takes in charge all the interactions with the grid

Performances

- Possibility of multiple concurrent executions
- Time performance:



Potential issues

- The EGEE grid use the gLite middleware. *http://glite.web.cern.ch/glite/*

- In this framework, the Resource Broker is responsible for the matchmaking between job requests and resources.

  - Fastest responding resources are chosen. (after filtration)
  - Not necessarily the most powerful
  - Nor directly available.

- Workload management could becomes a bottleneck.

Parameter-sweep test

- Validation of the deployment on the grid
  - Comparison with a sequential execution on one single computer: identical results

- The power of the grid allows to perform parameter sweeping in a reasonable amount of time

- Goal: To find a good compromise between accuracy and speed in the EM method. Study of the performance for different percentage of points used to estimate brain classes.

Ratio Parameter of the EM

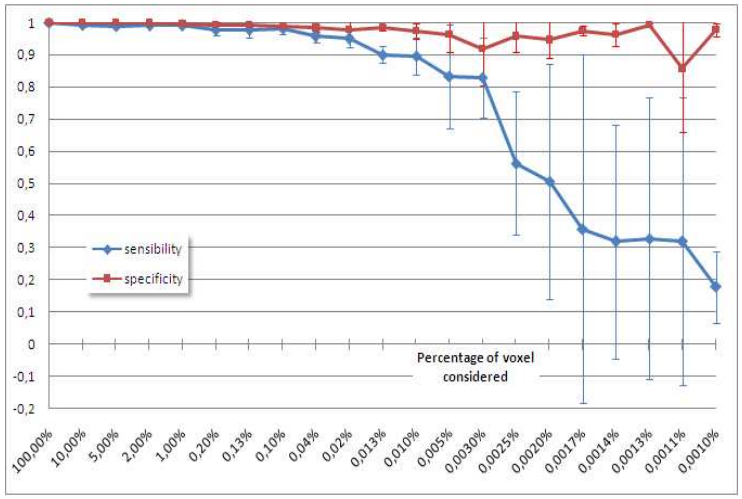
- Generation of WM segmentations obtained using different ratio value in the EM method.

- Comparaison of these segmentation to the segmentation of reference (ratio = 1)

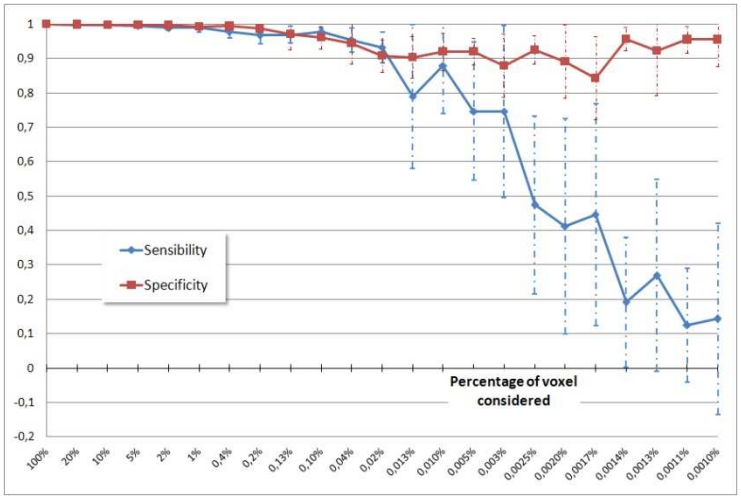
$$\text{Percentage of voxel considered} = 100 \times \frac{1}{\text{ratio parameter}}$$

$$\text{Sensibility} = \frac{\text{true positives}}{\text{true positives} + \text{false negatives}}$$

$$\text{Specificity} = \frac{\text{true negatives}}{\text{true negatives} + \text{false positives}}$$

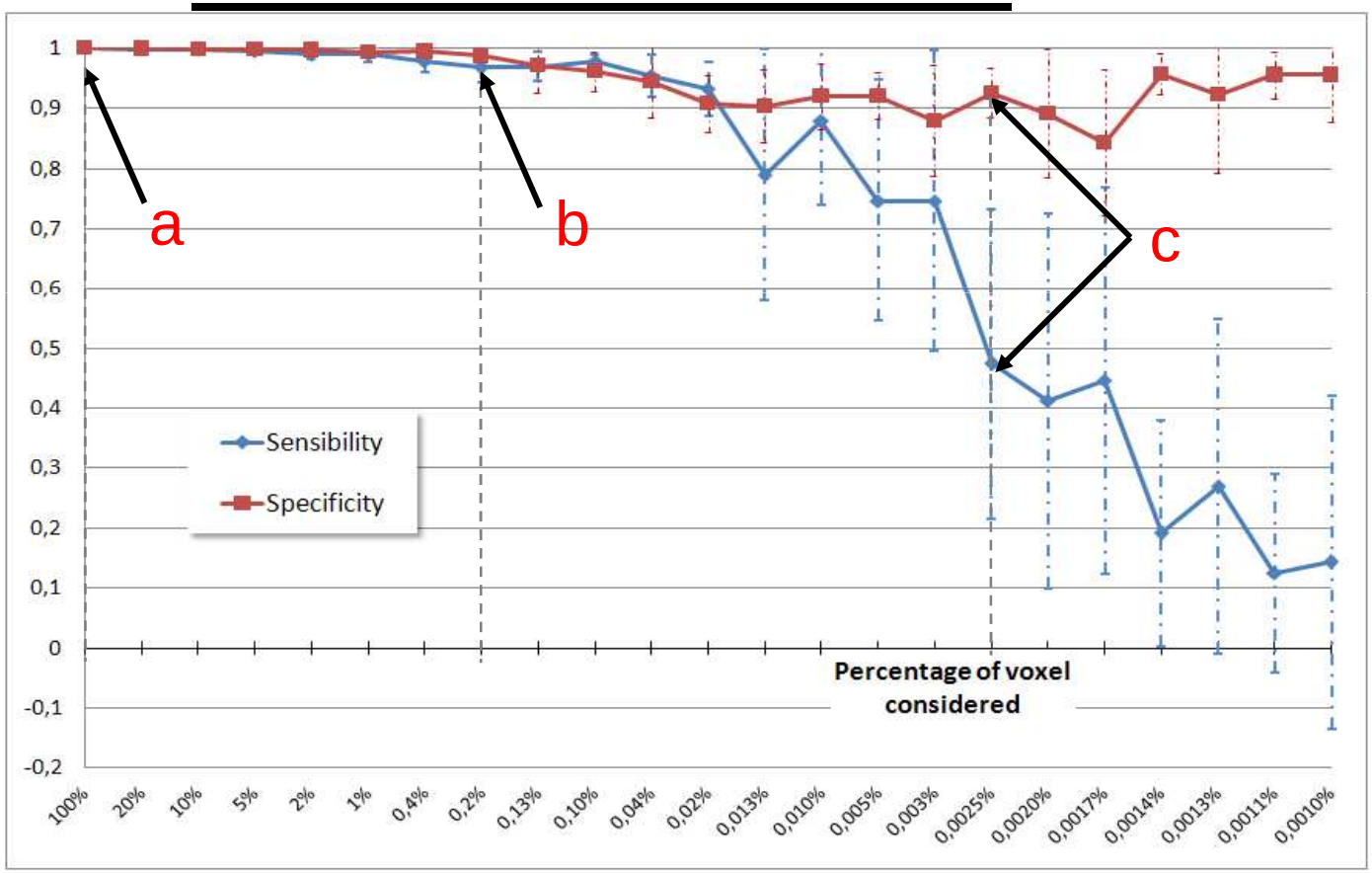


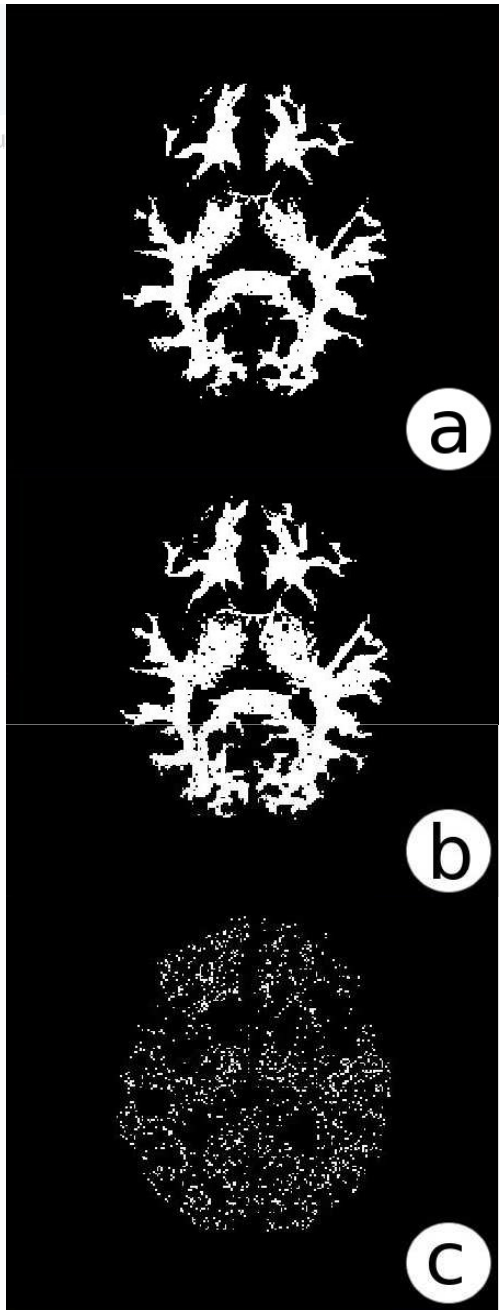
MR image of a control subject



MR image of a MS patient

Ratio Parameter of the EM





Ratio Parameter of the EM

- Using only 1% of the image voxels in the EM method:
  - Divides the execution time of the method by ~3
  - Still provides segmentation of sufficient quality
- Taking less than 1% of the voxels may leads to poor results
- ~ 210 workflow executions (10 per ratio value) have been computed (per image set).
  - Local execution time (sequential): ~ 100 hours (estimated)
  - Grid execution time: ~ 40 hours (4 hours per bunch of 21 workflow executions)

Conclusion:

- Implemented tools in the software SepINRIA have been validated and recognized useful for clinician research and application (article accepted) :

  Erik Pernod, Jean-Christophe Souplet, Mikael Cohen, Nicolas Toussaint, Christine Lebrun et Grégoire Malandain. SepINRIA v1.7.2: Multiple Sclerosis Brain MRI: visualisation, comparison and analysis Software. In World Congress for Treatment and Research in Multiple Sclerosis (WCTRIMS), Montreals, Canada, September 2008.

- Deployment demonstration of a “real” medical image processing solution on the grid:
  - The power of the grid allows multiple concurrent executions and a sizeable gain of time.
  - As a consequence, it allows computation costly tests, e.g. parameter sweeping.
  - This implementation on the grid leads to the article:

  Erik Pernod, Jean-Christophe Souplet, Javier Rojas Balderrama, Diane Lingrand et Xavier Pennec. Multiple Sclerosis Brain MRI Segmentation Workow deployment on the EGEE Grid. In MICCAI-Grid Workshop (MICCAI-Grid), New York, NY, USA, September 2008

Future work:

- Generalization of the services to support more image formats
  - Does not require to modify the workflow nor the web service descriptions
  - Can be done directly at the application level
  - Allows the workflow diffusion to other research groups
- Add new services to the workflow to get the lesions segmentation.