3D Image Processing for Assistance in Localizing the Deep Cerebral Structures

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EPIDAURE Project

INRIA Sophia Antipolis - France

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Research agreement no 97506

Improvement of Target Determination for Deep Brain Stimulation by Registration of MR Images with a Functional Atlas of the Basal Ganglia

- Medtronic - Bakken Research Center B.V.
  Maastricht - The Netherlands

- INSERM U289 - Institut National de la Santé et de la Recherche Médicale
  Service de Neuroradiologie - Centre d'Investigation Clinique
  Hôpital de la Salpêtrière, Paris - France

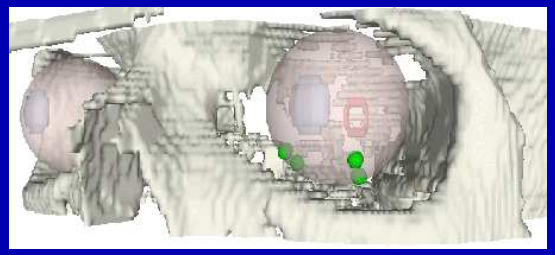
- INRIA - Institut National de la Recherche en Informatique et en Automatique
  EPIDAURE Project
  Sophia Antipolis - France

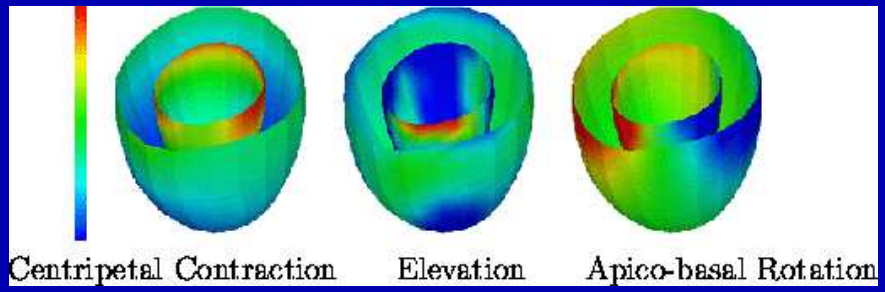
The objective of the EPIDAURE Project is to design and develop tools for the computer analysis of multidimensional, multimodal medical images (CT, MR, US, nuclear medicine).

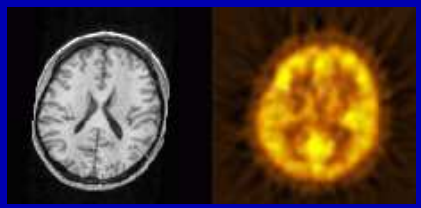
Headed by Prof. Nicholas Ayache, 20 people (6 senior researchers, 10 Ph.D. students).

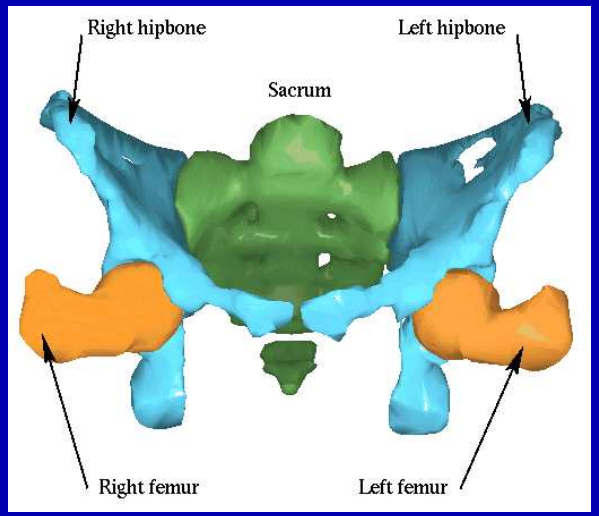
4 European Community Projects (video-surgery simulation, brain morphometry for MS and SC, analysis of CJD in MR images, 3D-US guided manipulator for neurosurgery).

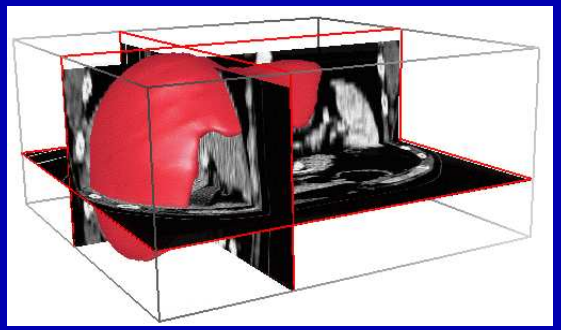
Numerous industrial (Focus Imaging, GEMS, Nycomed, Medtronic, Philips, Sanofi, ...) and medical (Boston, Edinburgh, Liverpool, Leuven, London, Nice, Paris, Strasbourg hospitals) collaborations.

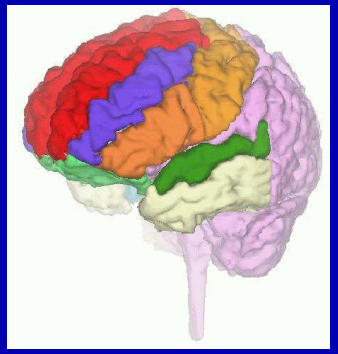


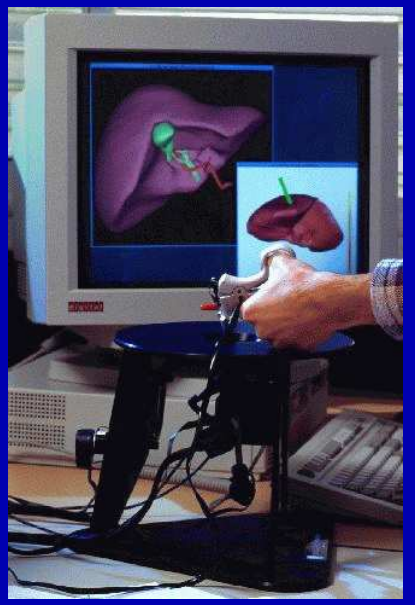


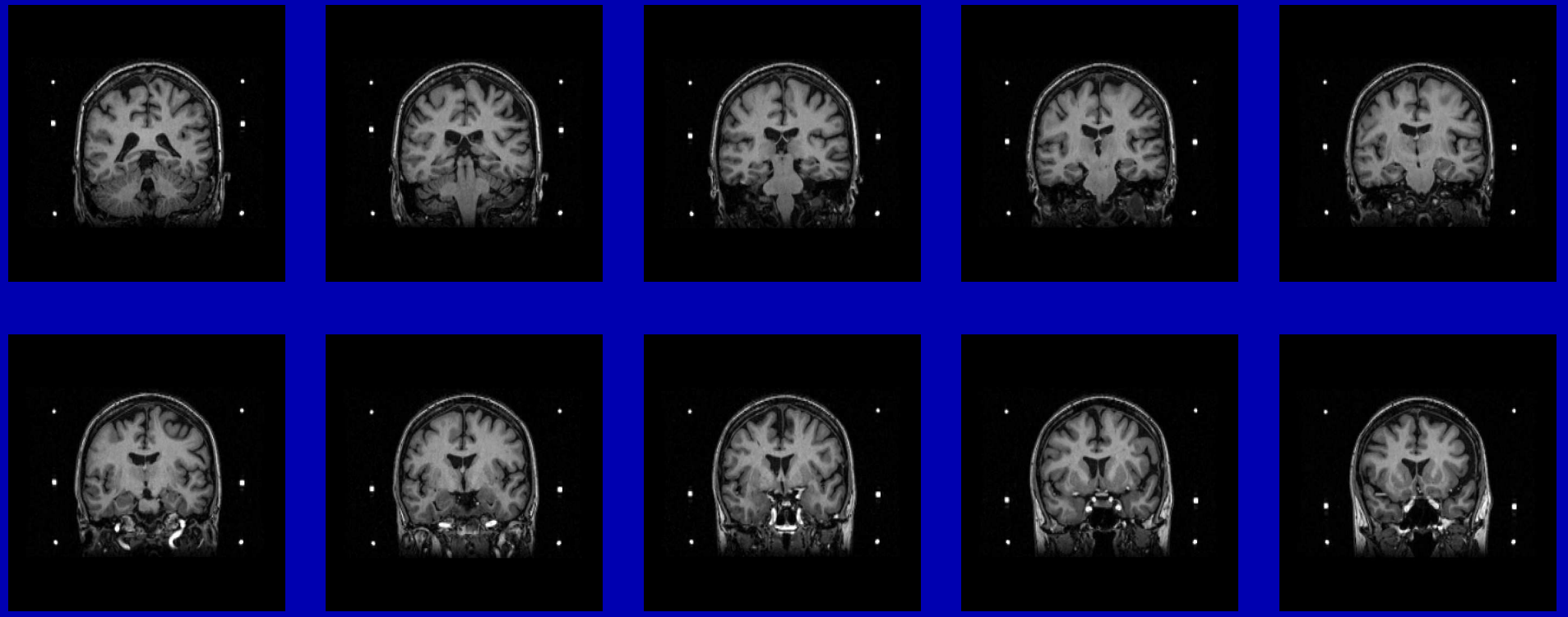


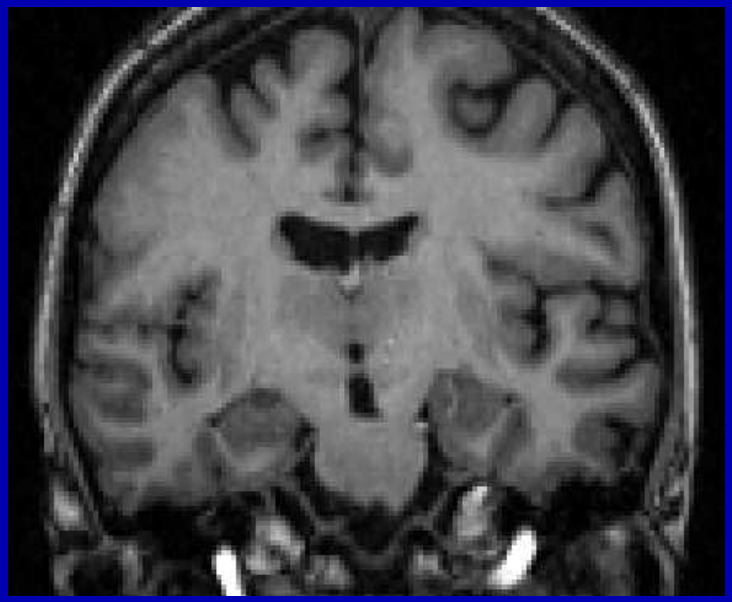








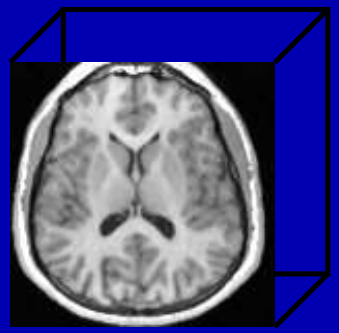




How to localize accurately the deep cerebral structures that are not clearly visible in the stereotactic MR image?

Superposition

MRI



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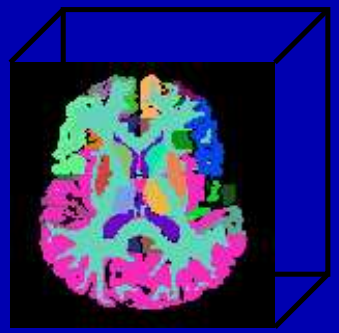
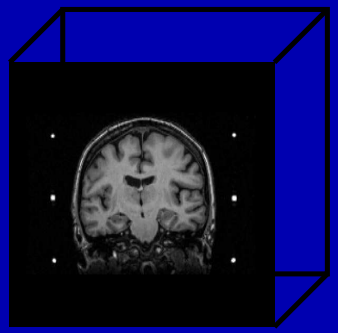


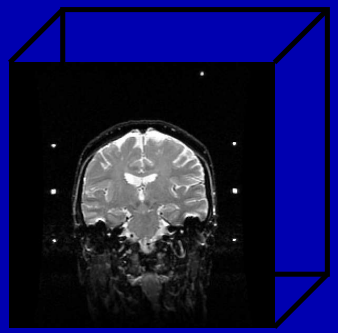
contours
in histological data

3D ATLAS

Ste-MRI



Superposition



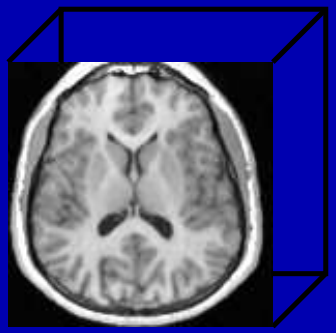
HR T2-MRI

PATIENT

Adapt and develop 3D image processing algorithms for assisting the localization

1. Preprocessing of data

MRI



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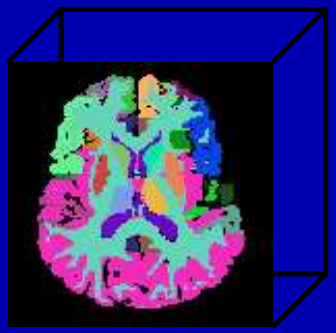
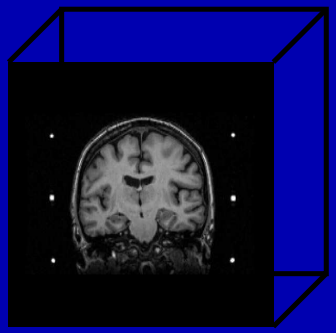


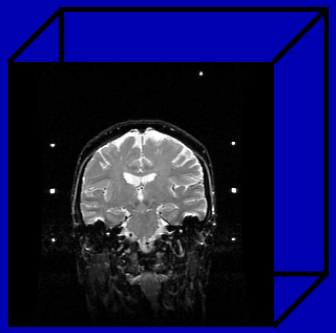
contours
in histological data

3D ATLAS

Restoration
Segmentation
Slices alignment
3D reconstruction

Ste-MRI





HR T2-MRI

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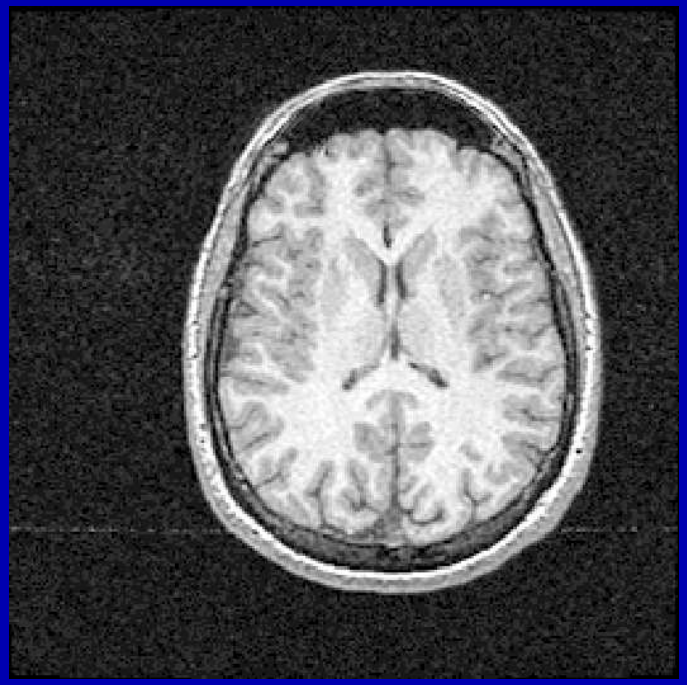
Restoration
Segmentation

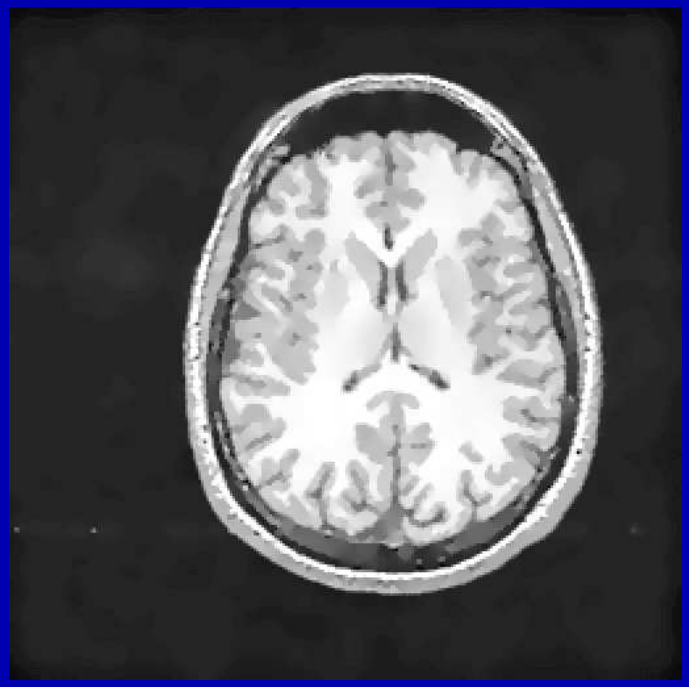
Processing of MR data: restoration of images

MR images can be corrupted by noise or a non-homogeneous multiplicative bias.

Deep structures are difficult to perceive, especially in 3D.

➤ Smoothing the image in 3D yet preserving important intensity discontinuities



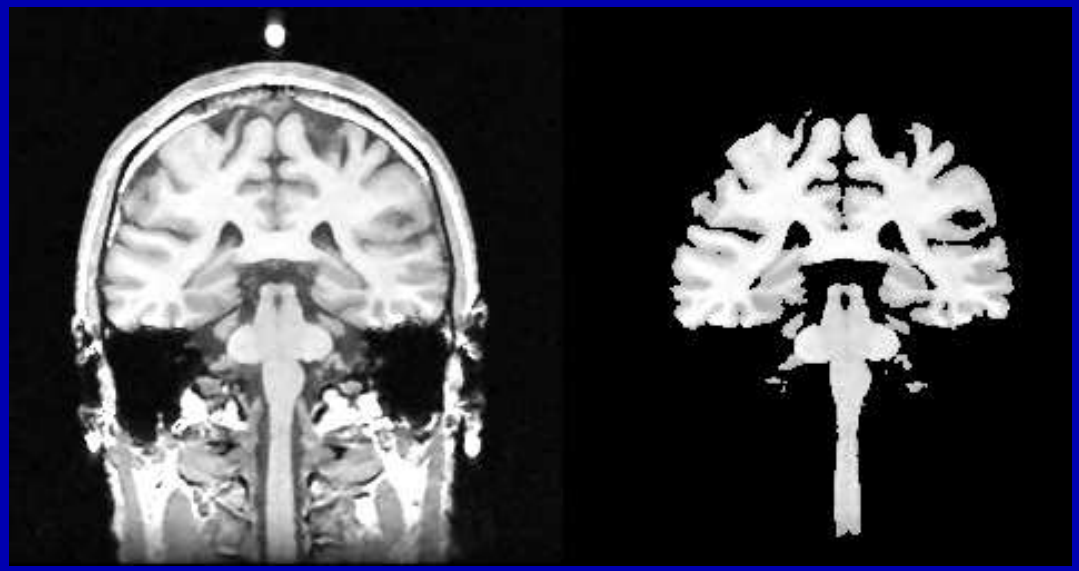


Non-isotropic diffusion applied to a MR image

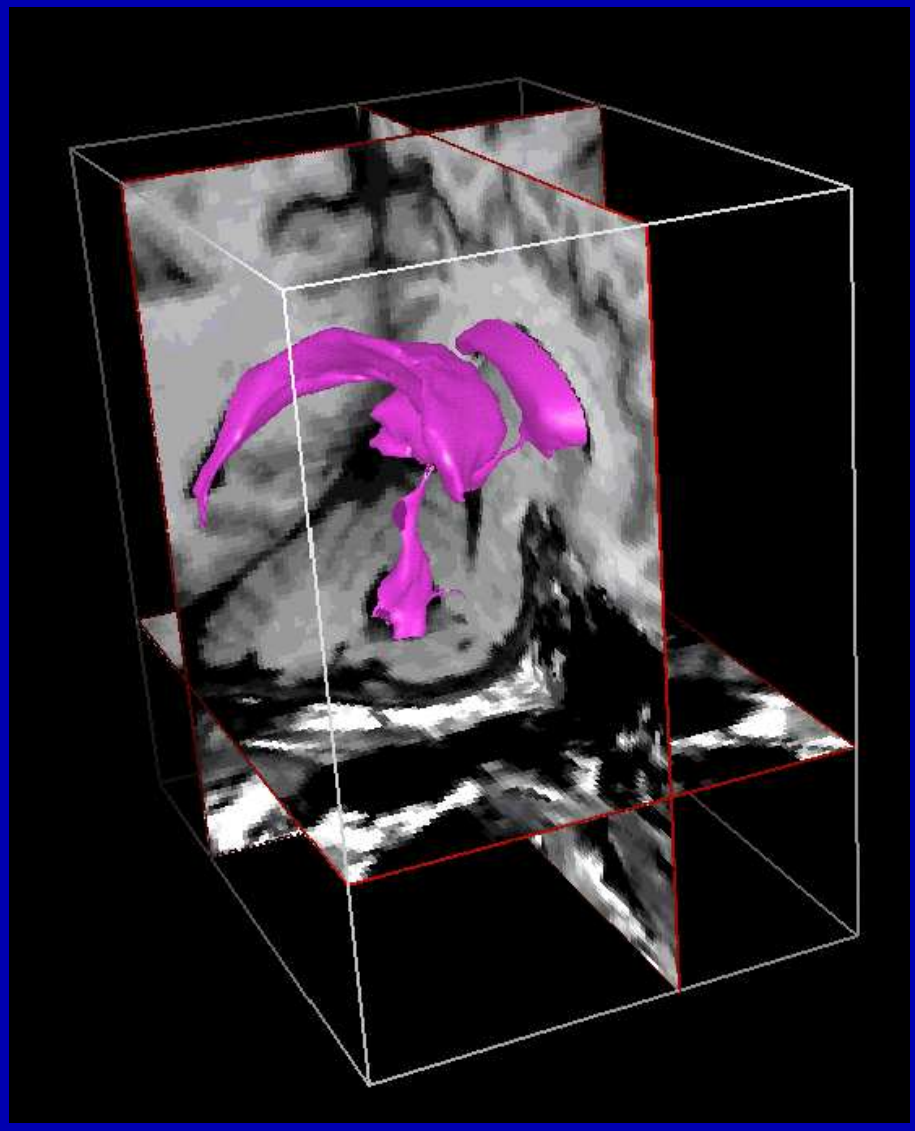
Processing of MR data: segmentation of structures

Difficult to take into account the 3D consistency.

Need for a 3D tool



Automatic segmentation of the cortical boundary

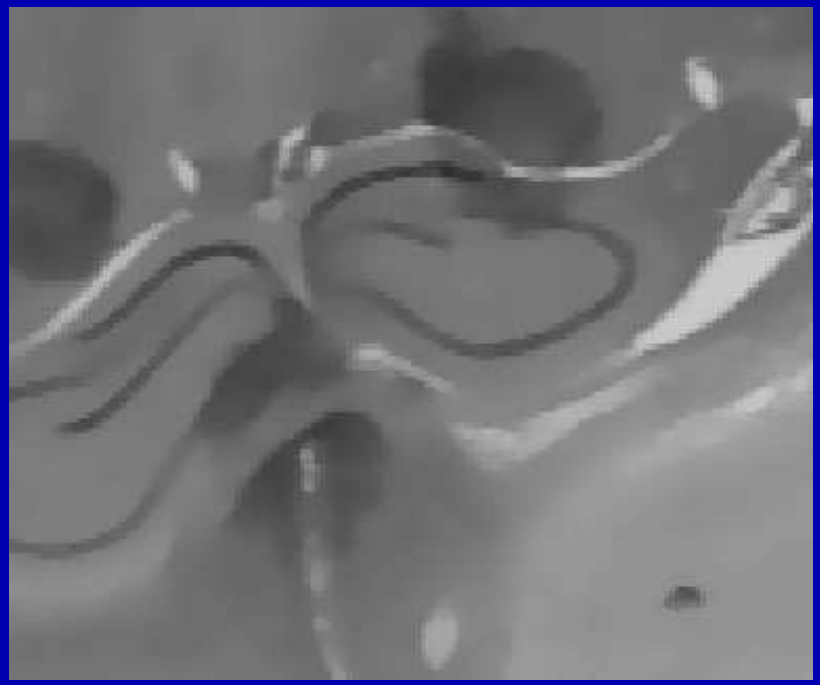


A deformable surface eases the segmentation of cerebral ventricles

Construction of a 3D atlas: restoration of histological slices

- Images can be corrupted by artifacts or noise.
- Some structures can be difficult to perceive.

➡ Smoothing the image yet preserving important intensity discontinuities

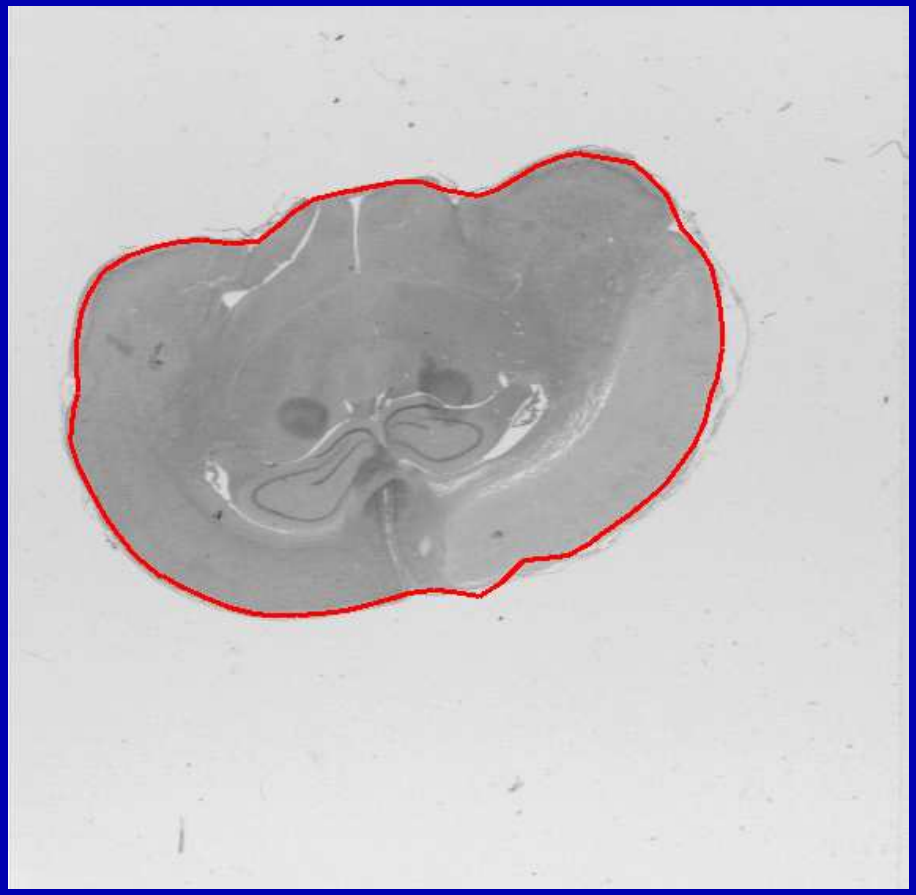


Non-isotropic diffusion applied to a rat's brain histological slice

Construction of a 3D atlas: segmentation of structures

- Delineating structures needs high anatomy knowledge.
- Tedious task.
- Difficult to achieve the pixel resolution.

➡ Need for a user-guided tool

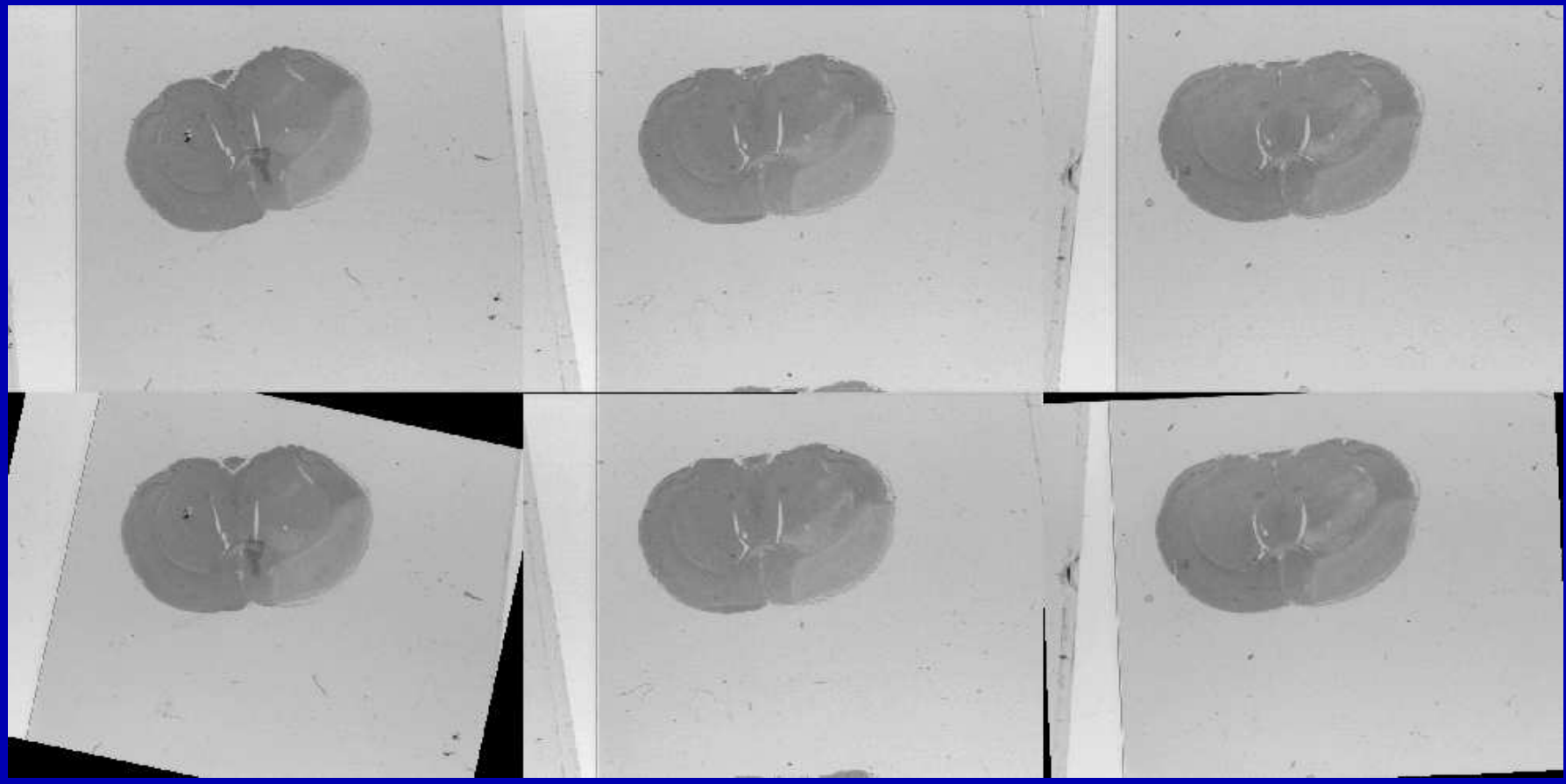


A deformable contour (in red) eases the segmentation in a rat's brain histological slice

Construction of a 3D atlas: alignment of slices

Images of histological slices can be shifted during the acquisition process.
Manual or fiducial-based alignment may be not accurate enough .

➤ Aligning automatically the slices

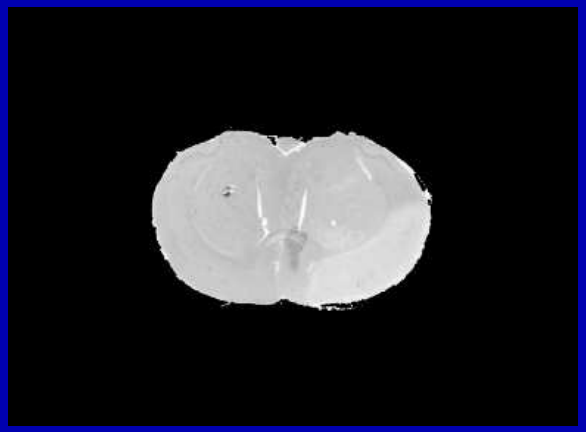


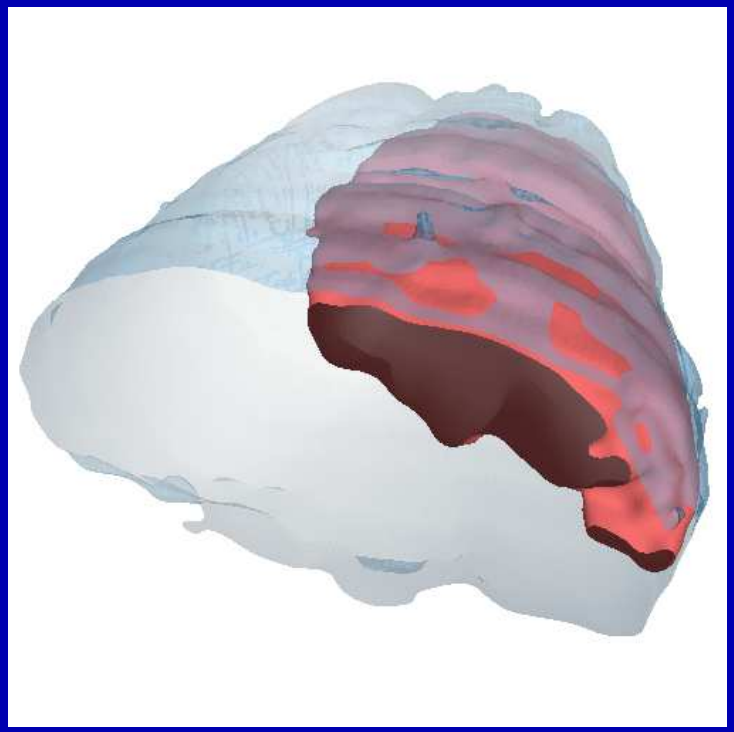
Automatic alignment of three successive rat's brain histological slices

Construction of a 3D atlas: 3D reconstruction

Once the slices are segmented and aligned:

- **The 3D surface reconstruction allows us to visualize the structures from any point of view**

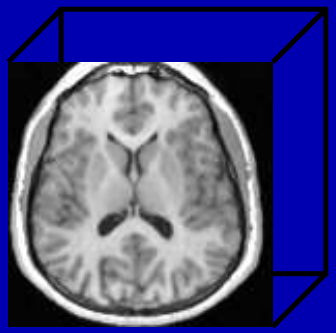




3D reconstruction of the cortical surface and the ischemic area from rat's brain histological slices

2. Registration of data

MRI



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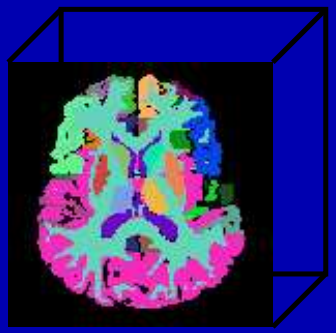
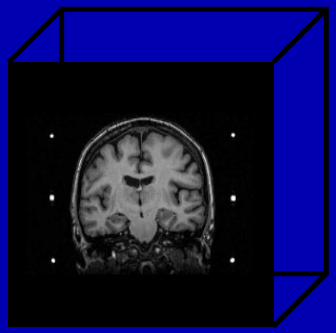


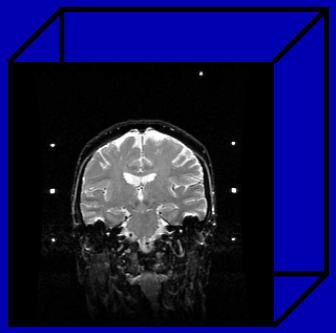
contours
in histological data

3D ATLAS

Different subjects
Same modality
Same FOV

Ste-MRI





HR T2-MRI

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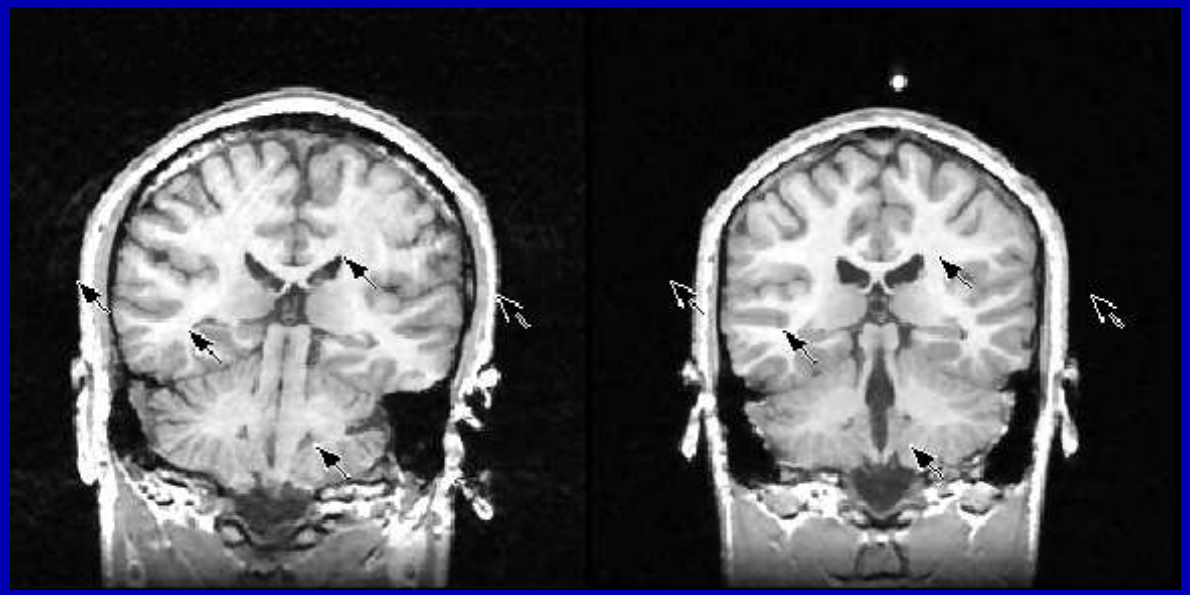
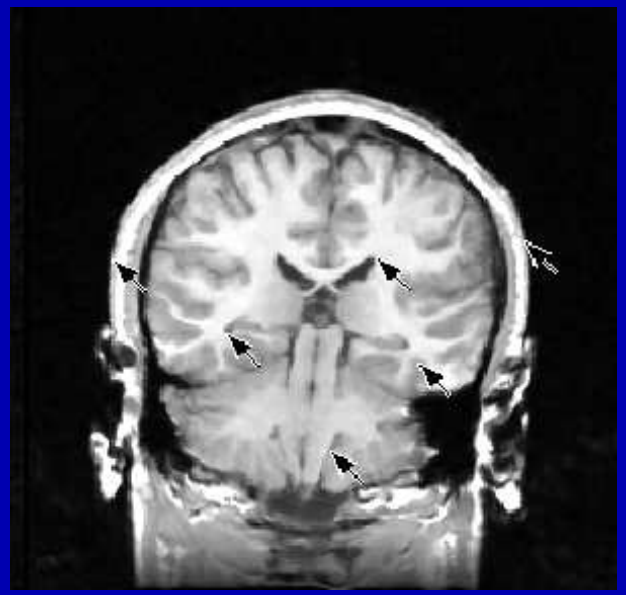
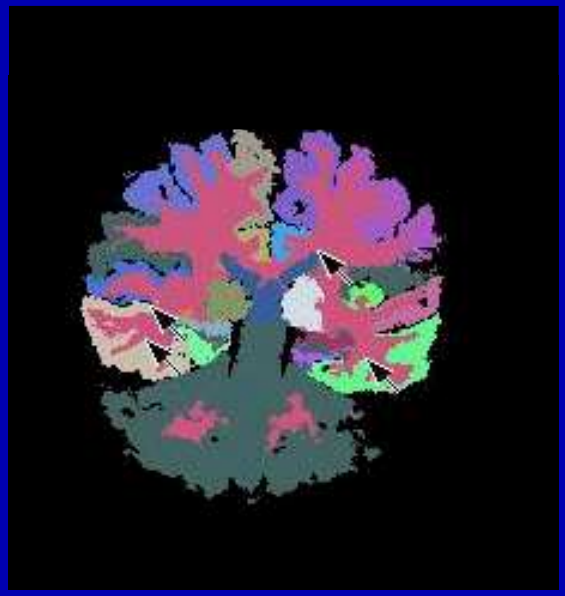
Same subject
Different modality
Different FOV
Artifacts

Different subject, same modality, same FOV

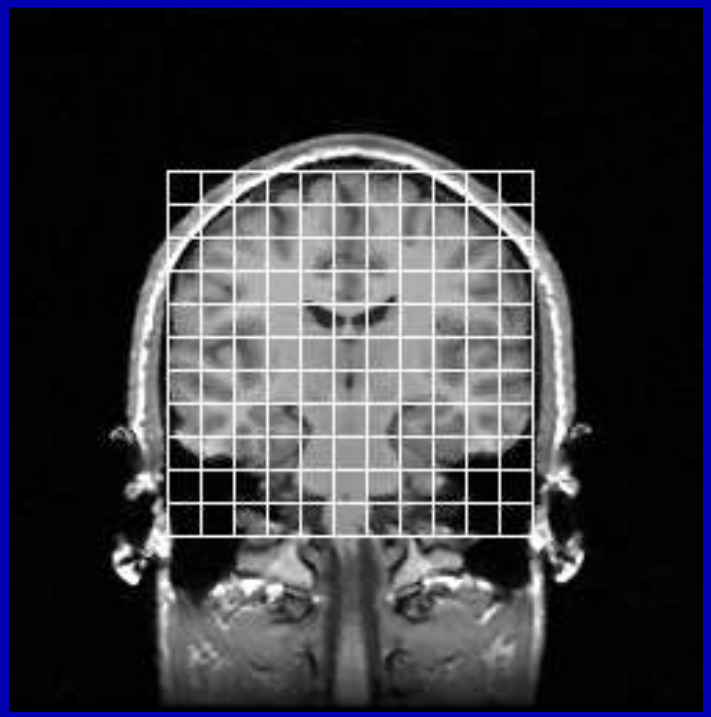


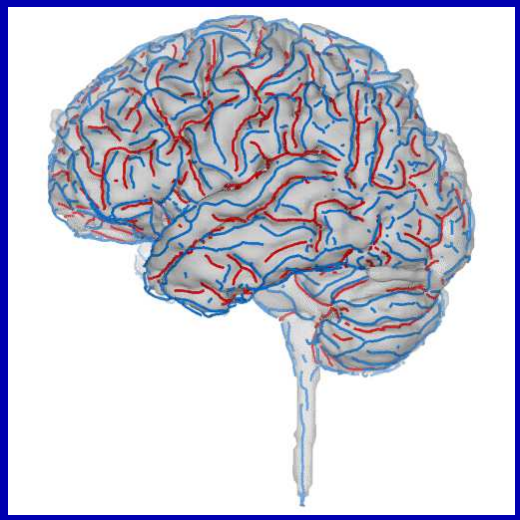




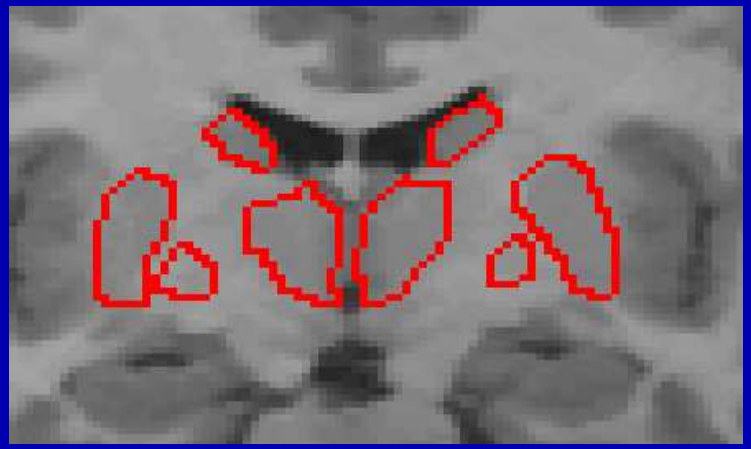
The right image deforms smoothly to the left image in order to superimpose the contours.

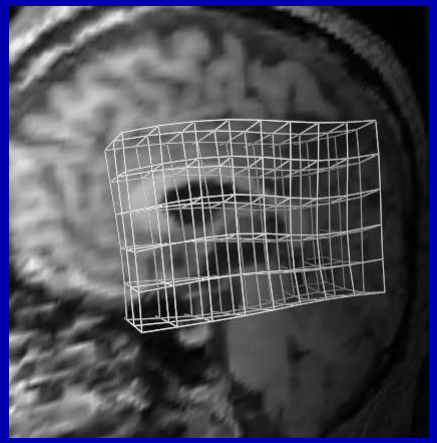
Different subject, same modality, same FOV

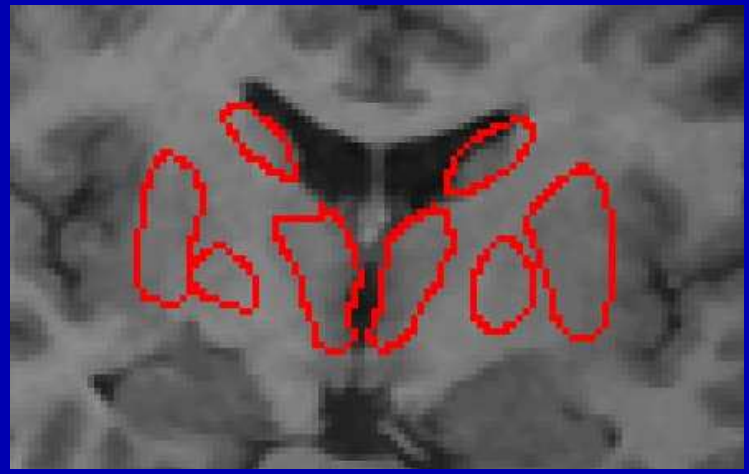




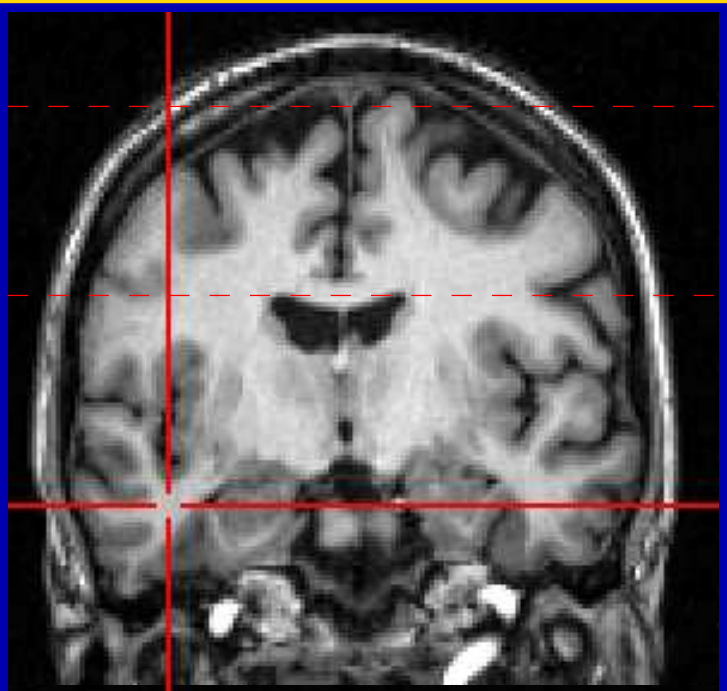
The crest lines are extracted in the two images. They are matched and this defines a volume transformation.

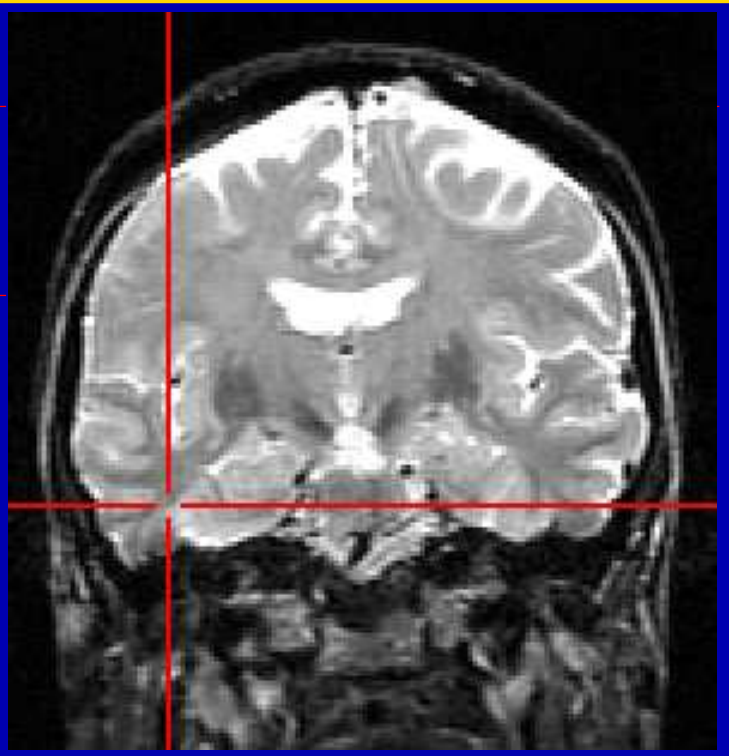




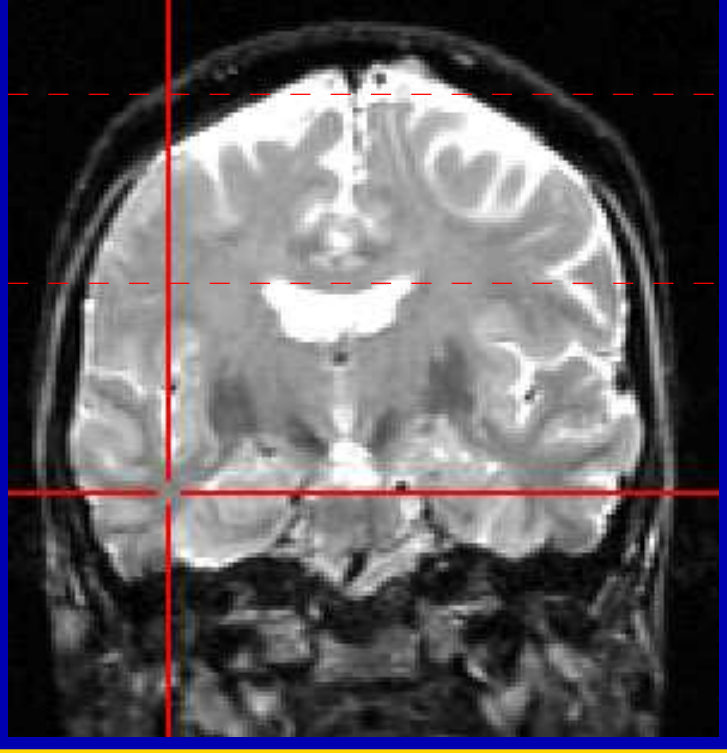


Ste-T1





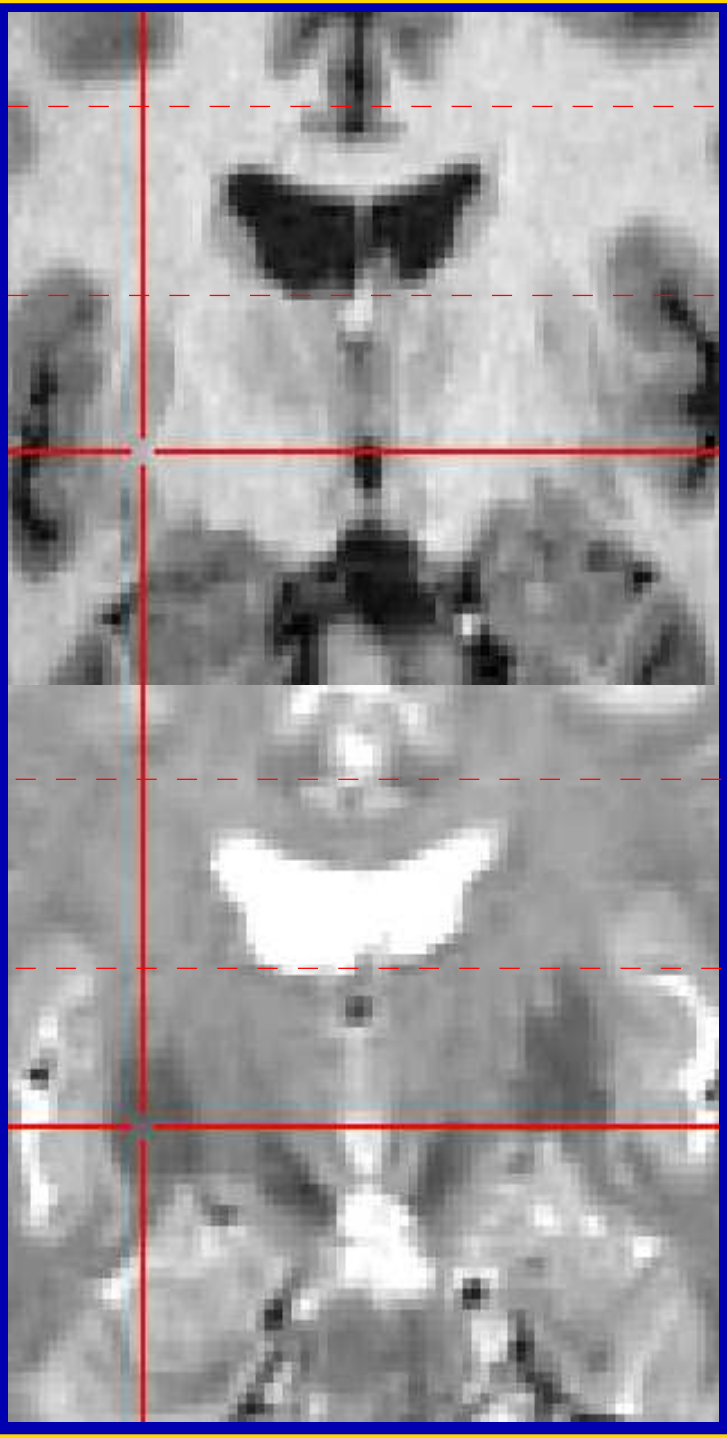
High contrast T2

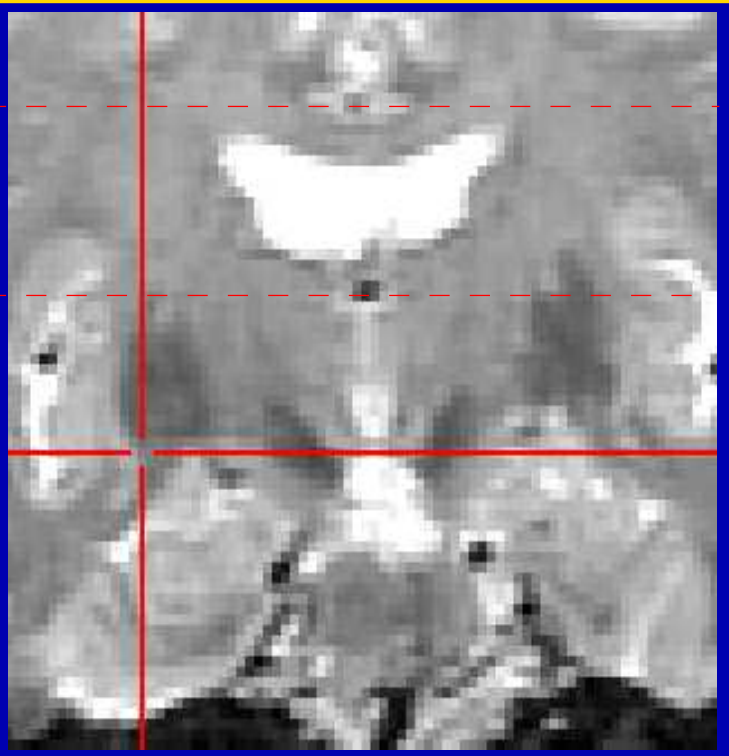


Same subject
Different modality
Different FOV
Artifacts

A local similarity measure gives a local displacement vector at each voxel. Based on this vector field, a 3D transformation is computed.

Ste-T1





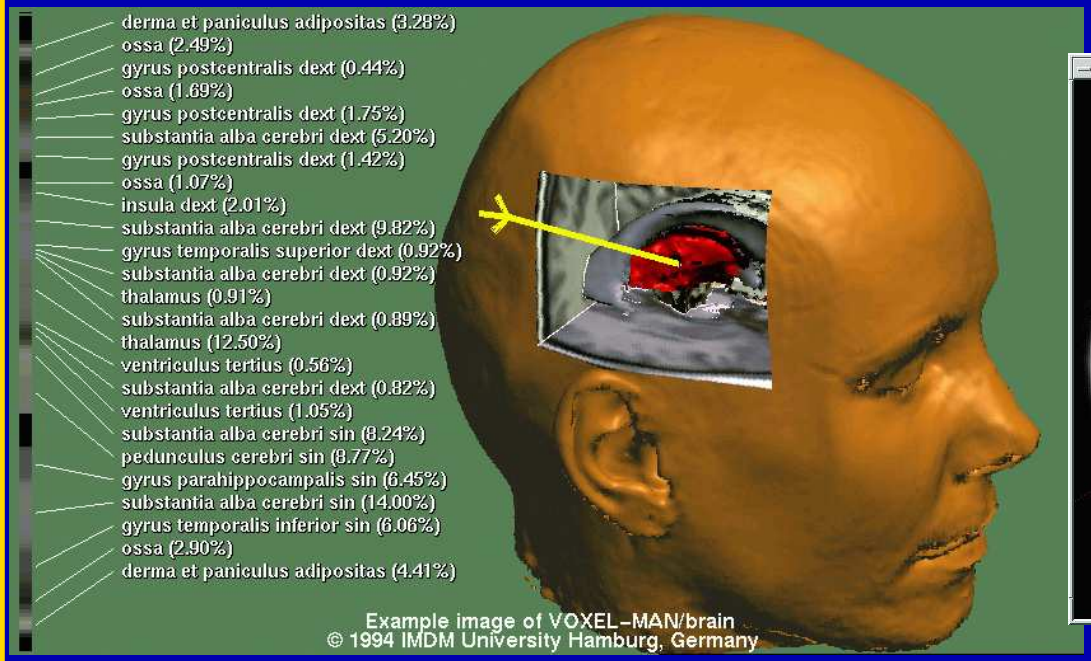
High contrast T2

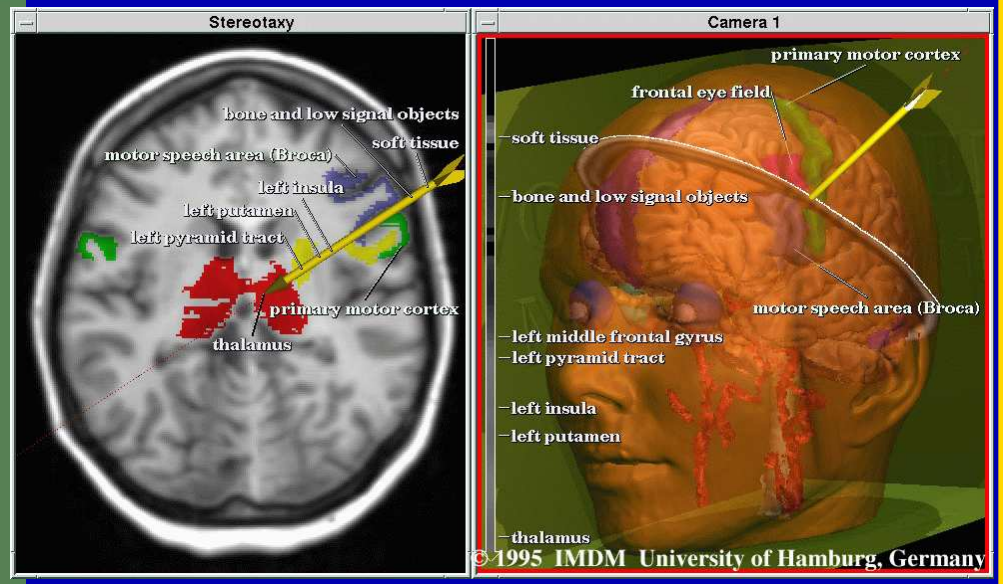
Same subject
Different modality
Different FOV
Artifacts

Assistance to the surgery

Once the stereotactic images has been labelled:

- **find the optimal trajectory to the target**
  avoid passage through critical structures





Example of using a stereotaxy simulation
on a reference patient (for teaching purpose)
Voxel-Man, IMDM, University of Hamburg, Germany

Future Work

- **Construction of the 3D atlas**

  Now: test and improvement of software
  collaboration on the elaboration of the acquisition procedure of histology data

  Soon: test of software, in particular the reconstruction, on existing sections

- **Registration to ste-MR image**

  Now: first result of registration betwen HR-T2 and ste-T1 MR images
  test of registration between atlas / T1 and ste-T1 images

  Soon: extension to 3D of T2 / T1 registration algorithm
  quantitative study of the distorsions