Mapping to the Talairach coordinate system using MIPAV and application to Atlas-based volumetric measurements

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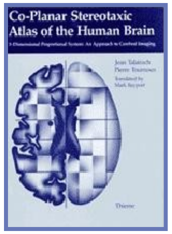
MEDIC

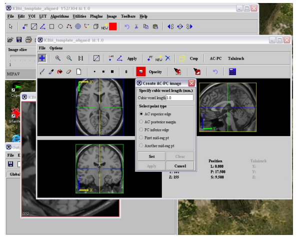
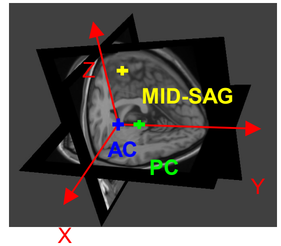
MIPAV

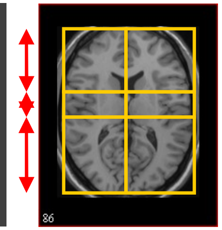
MEDICAL IMAGE PROCESSING, ANALYSIS AND VISUALIZATION

Outline

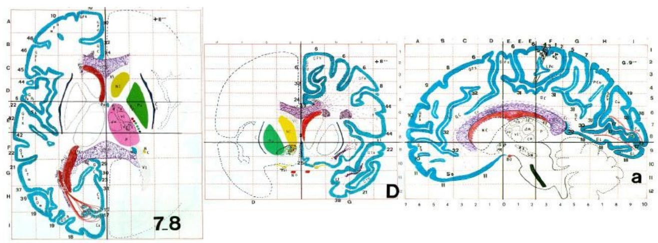
1. Transforming datasets into the Talairach coordinate system

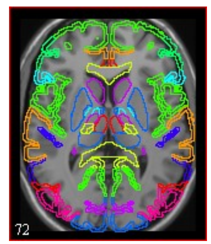


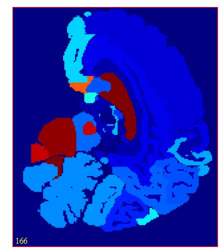





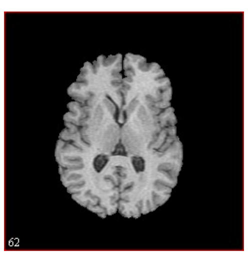
2. The Talairach atlas, ICBM/MNI atlas and custom atlases

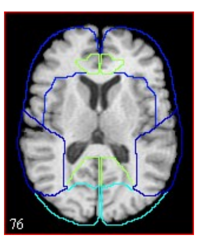


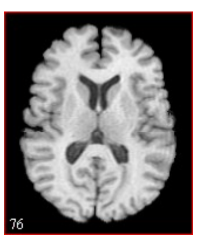


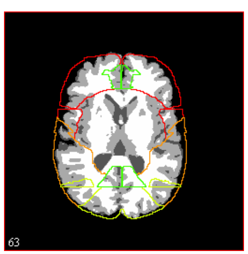


3. Putting all together: Talairach transform, atlas, skull stripping and segmentation for volume measurements of brain regions





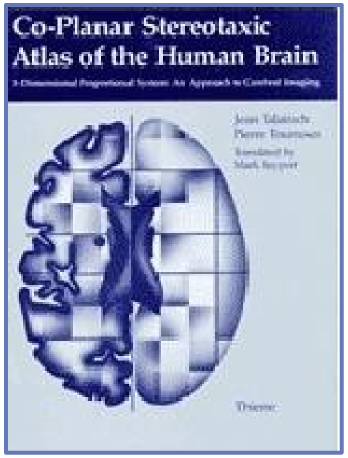




1. Transforming datasets into the Talairach coordinate system

The Talairach coordinates

Measurements of regions in the human brain
require a *common coordinate space*



The standard:

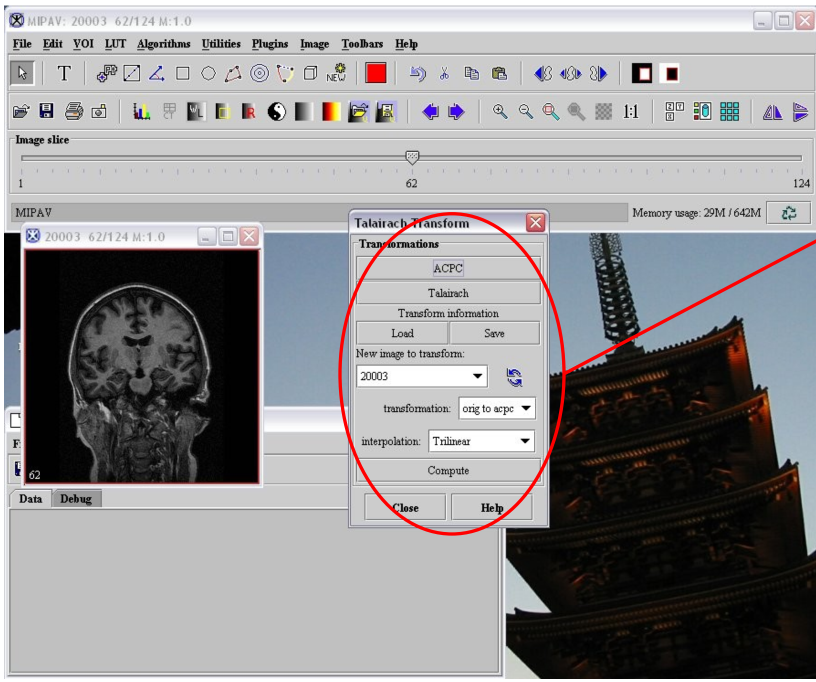
Jean Talairach and Pierre Tournoux
“Co-Planar Stereotaxic Atlas of the Human Brain”
Thieme Medical Publishers, New York, 1988

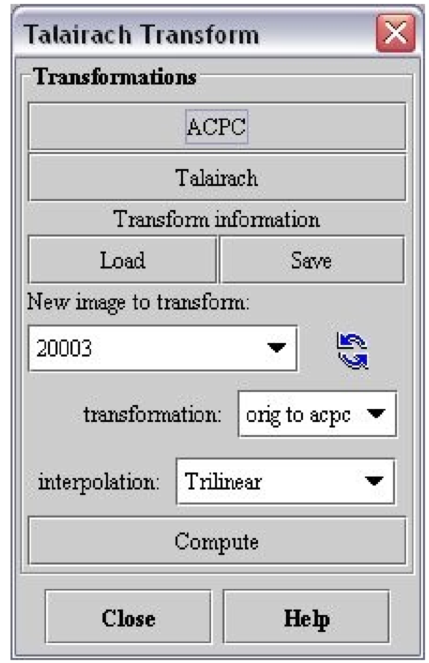
It requires a sequence of two transformations:

- a *rigid alignment* of the anterior and posterior commissures (AC-PC)
  (rotation, translation: 6 DOF, linear)
- a piecewise linear *deformation* of the brain
  (piecewise-linear scaling: 12 DOF, non-linear)

The Talairach coordinates in MIPAV

The “Talairach Transform” plugin:
a wizard for multiple Talairach coordinates transformations





1. AC-PC alignment

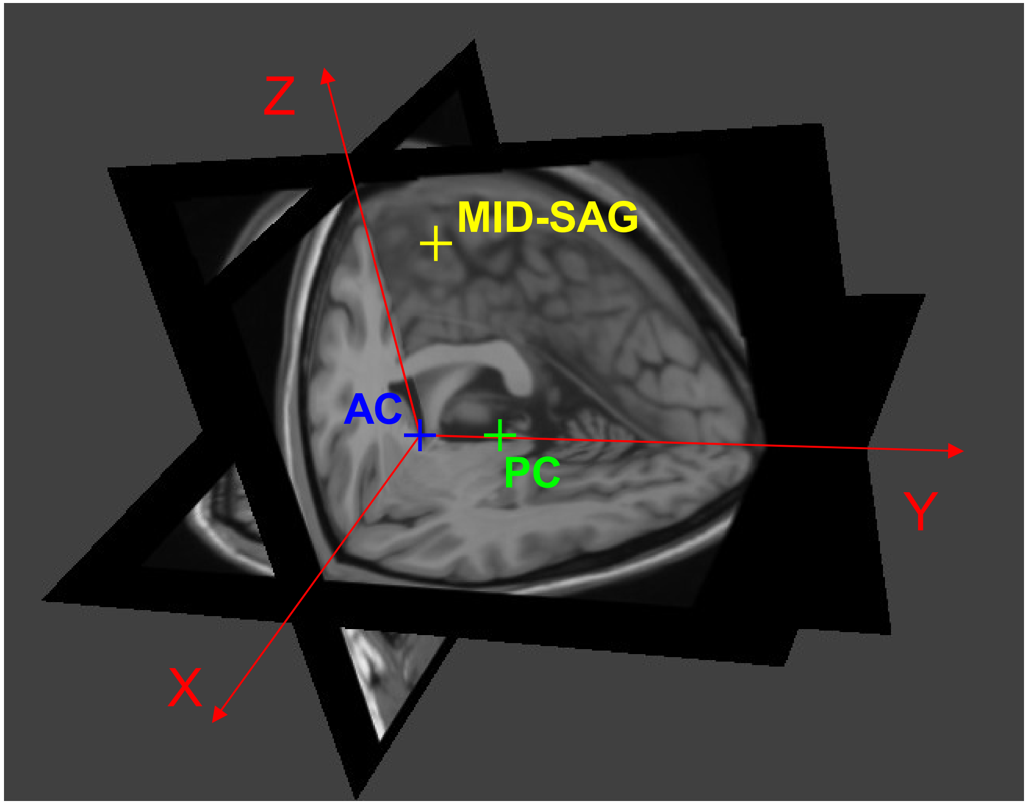
2. Talairach transformation

3. Transformation of other images

The Talairach transformation can be used to bring other *co-registered* images into Talairach space and to send atlas information into the original image space

The AC-PC alignment

The **AC** (anterior commissure), **PC** (posterior commissure) points and a **mid-sagittal** (or inter-hemispheric) point completely define the coordinate system:



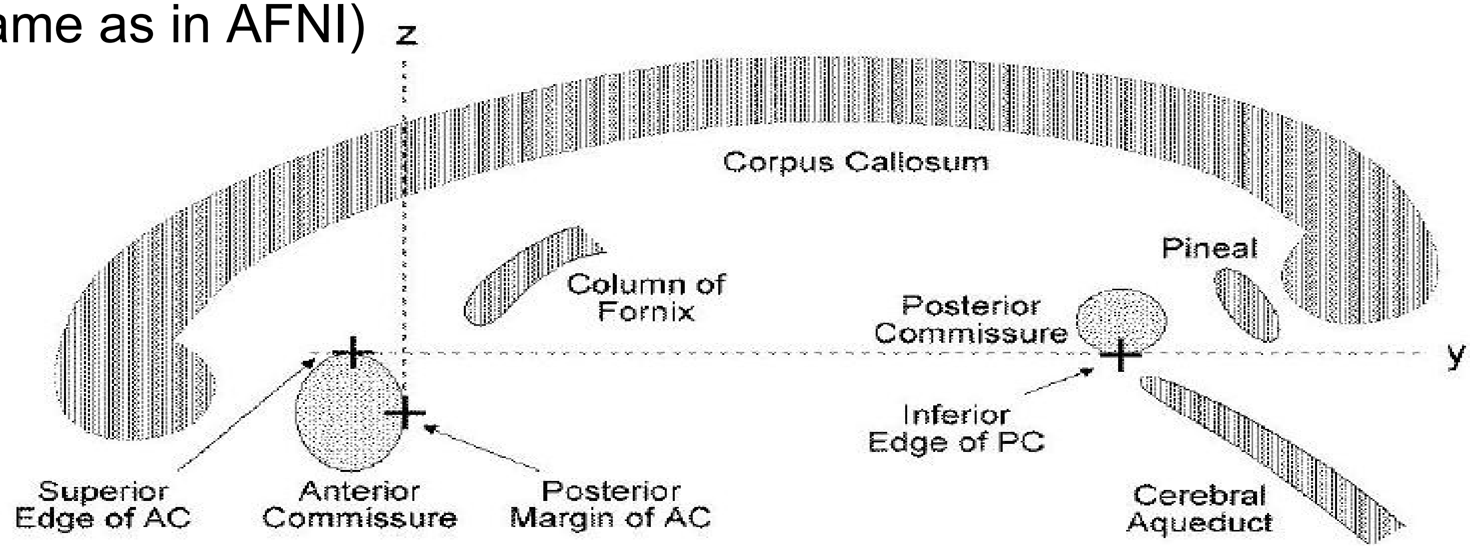
<u>AC-PC coordinates:</u>

- AC point = origin
- AC-PC line = Y axis
- AC-PC-mid-sag plane = YZ plane

- Z axis = perpendicular to Y axis in YZ plane
- X axis = perpendicular to Y and Z axes

The AC-PC alignment

The procedure followed in MIPAV
(same as in AFNI)

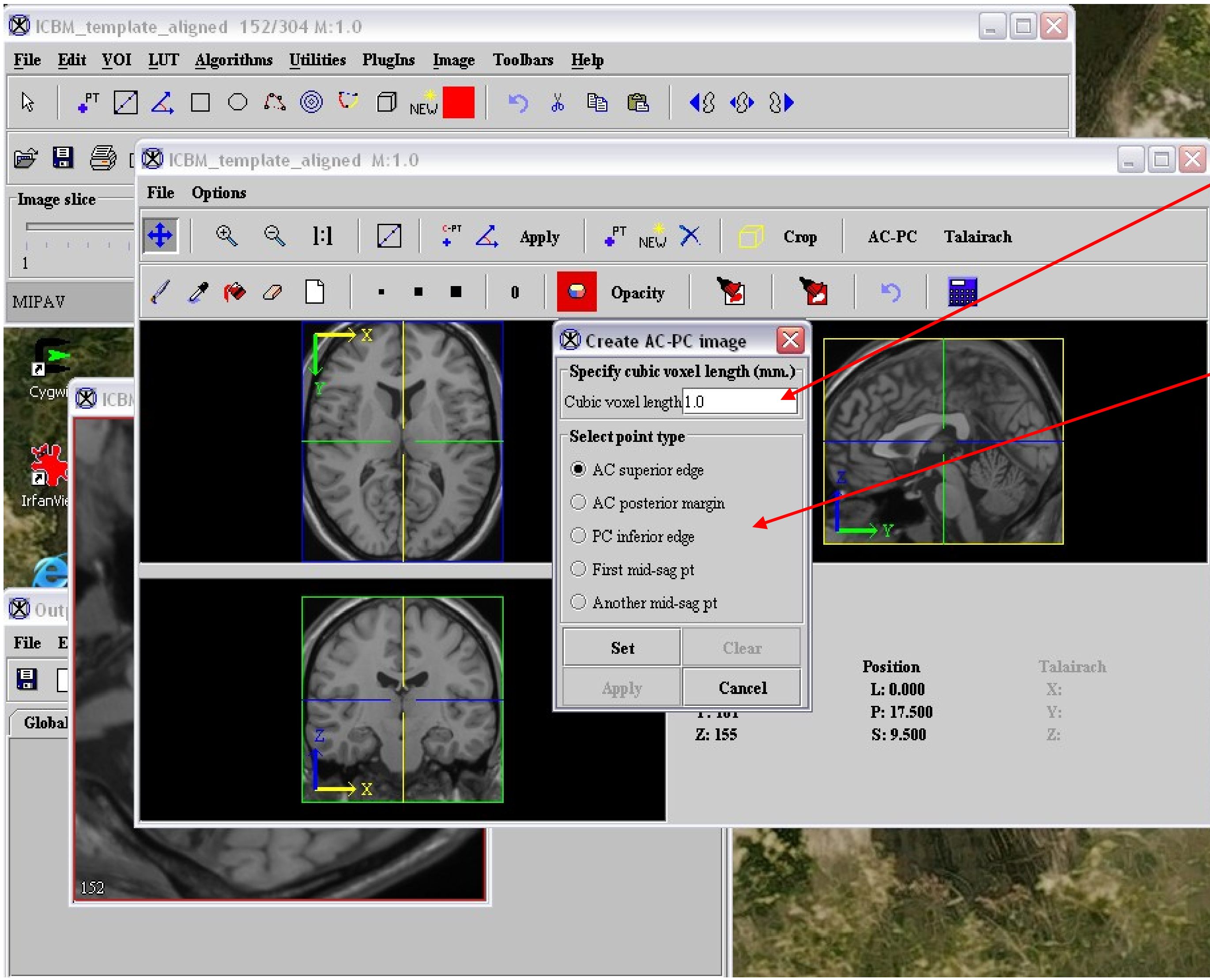


<u>Acknowledgements:</u>thanks to the SSCC/NIMH group for providing good online material related to AFNI

Five markers are needed to perform the alignment:

<u>AC superior edge</u>	= top middle of anterior commissure
<u>AC posterior margin</u>	= rear middle of anterior commissure
<u>PC inferior edge</u>	= bottom middle of posterior commissure
<u>First mid-sag point</u>	= some point in the mid-sagittal plane
<u>Second mid-sag point</u>	= some other point in the mid-sagittal plane

The AC-PC alignment



Set the scale

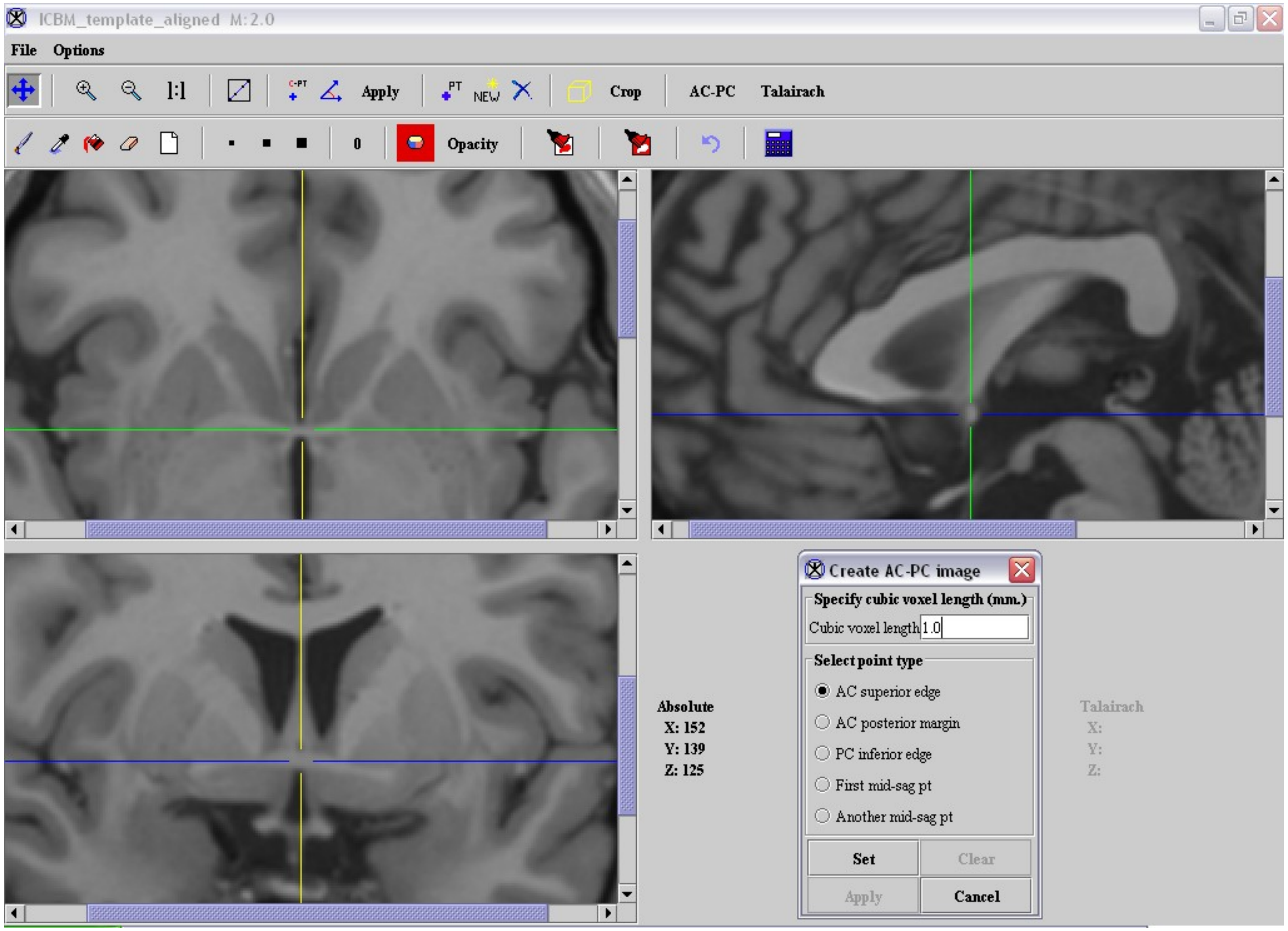
For each point, set the crosshair at the proper location in the triplanar view

The interface in MIPAV

The AC-PC alignment

<u>First goal is to mark top middle and rear middle of **AC**</u>

- **Sagittal**: look for AC at bottom level of corpus callosum, below fornix
- **Coronal**: look for “mustache”
- **Axial**: look for inter-hemispheric connection

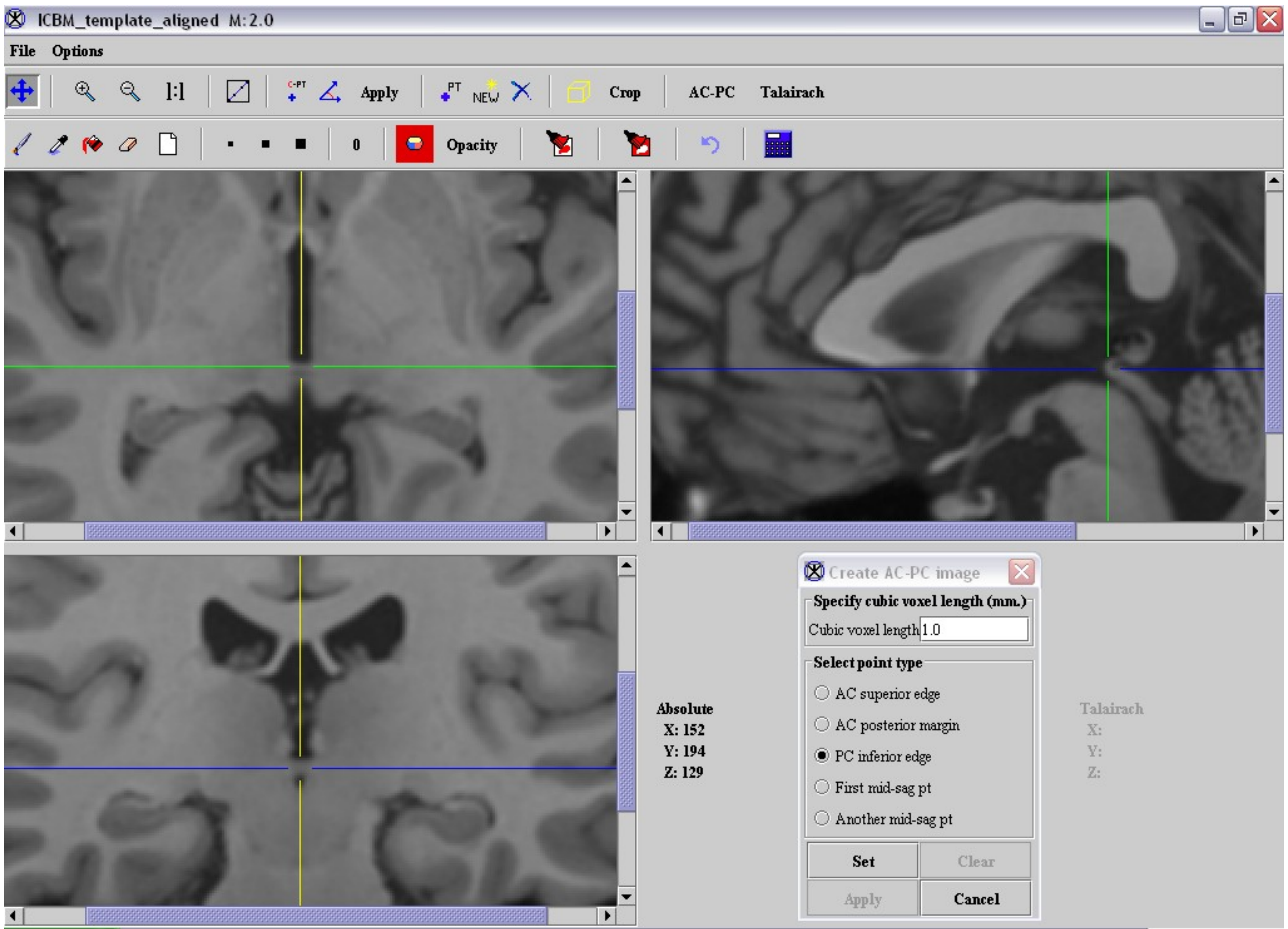


- Get AC centered at focus of crosshairs (in Axial and Coronal)
- Move superior until AC disappears in Axial view; then inferior 1 pixel
- Set **AC superior edge**
- Move focus back to middle of AC
- Move posterior until AC disappears in Coronal view; then anterior 1 pixel
- Set **AC posterior margin**

The AC-PC alignment

<u>Second goal is to mark inferior edge of **PC**</u>

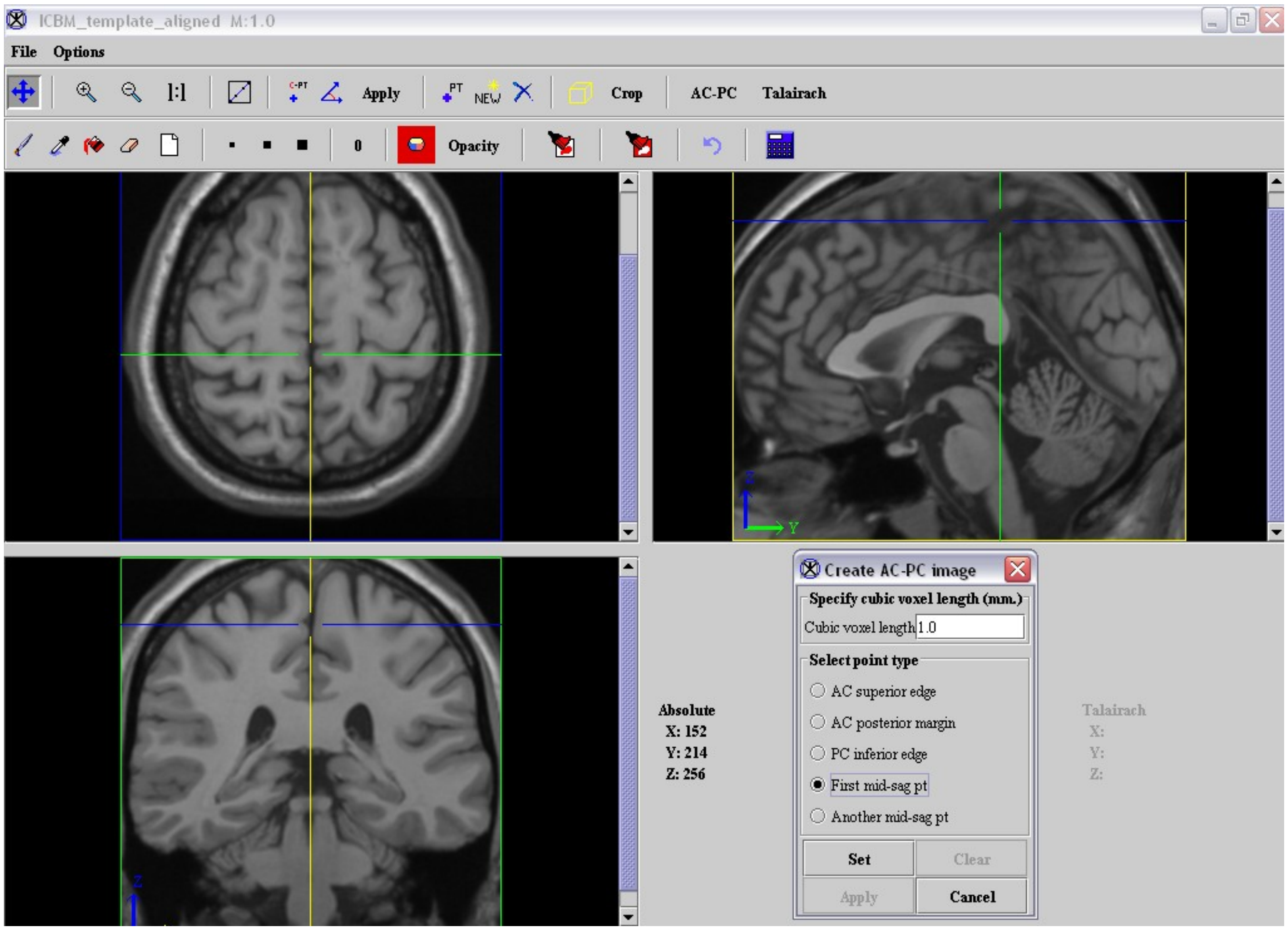
- This is harder, since PC doesn't show up well at 1 mm resolution
- Fortunately, PC is always at the top of the cerebral aqueduct, which does show up well (at least, if CSF is properly suppressed by the MRI pulse sequence)



Therefore, if you can't see the PC, find mid-sagittal location just at top of cerebral aqueduct and mark it as **PC inferior edge**

The AC-PC alignment

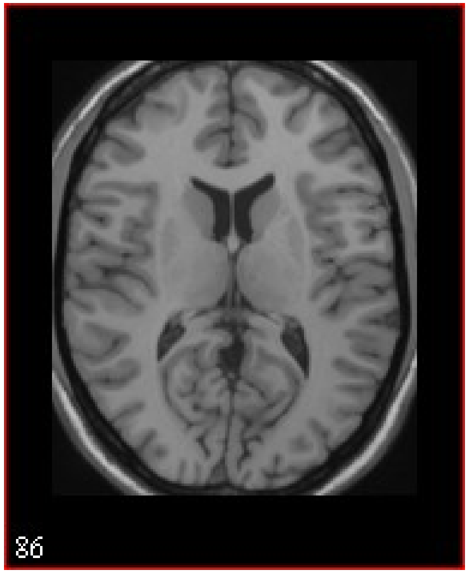
Third goal is to mark **two mid-sagittal points** (above corpus callosum)

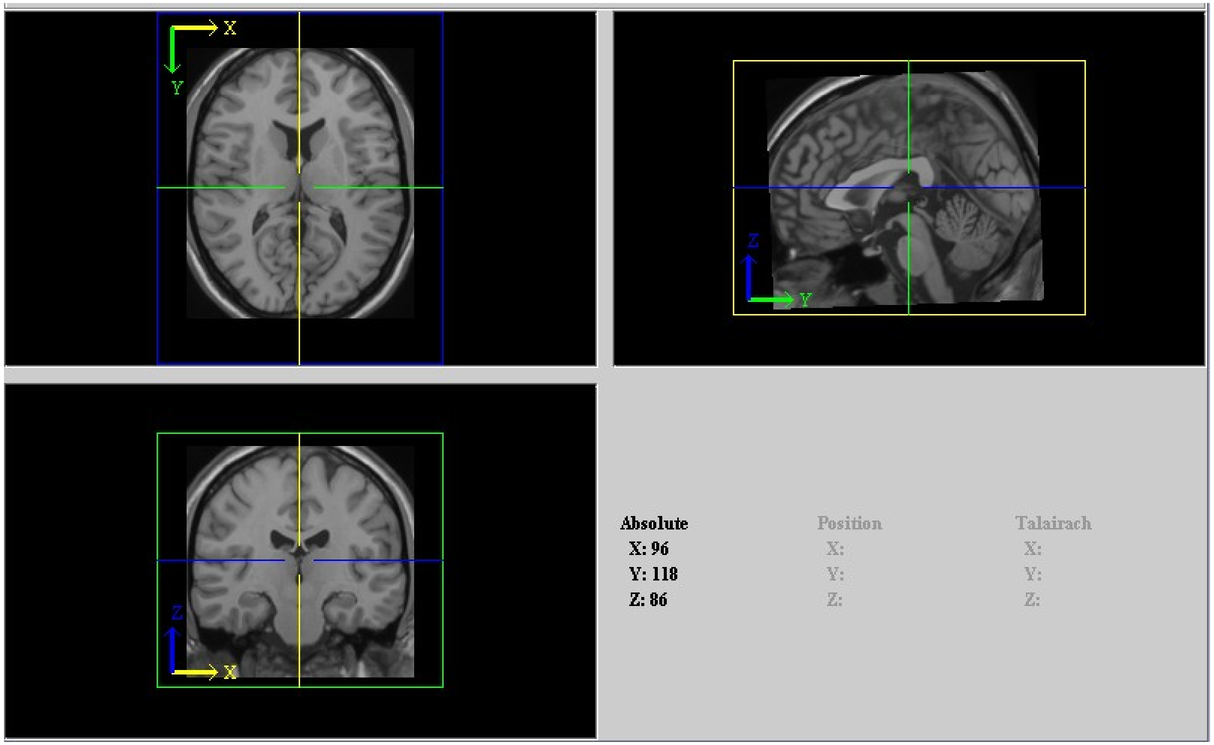


In practice, good candidates for SG1 and SG2 are often **far** from AC and PC and from each other

The AC-PC alignment

Result: AC-PC aligned image





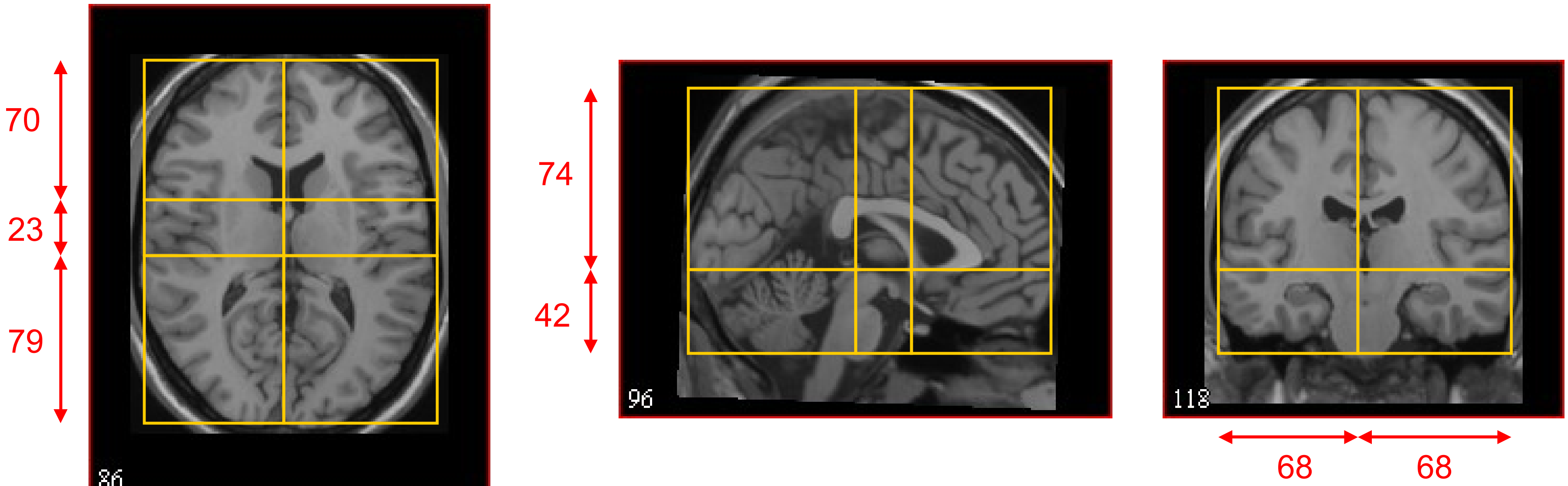
Classical alignment problems:

- the original image *orientation* is not set properly
- the original image *resolutions* and/or resolution *units* are not set properly

Always check the *image attributes* beforehand

The Talairach alignment

The brain is **stretched/shrunken** to fit the following dimensions:



Most anterior to AC	70 mm
AC to PC	23 mm
PC to most posterior	79 mm

Most inferior to AC	42 mm
AC to most superior	74 mm

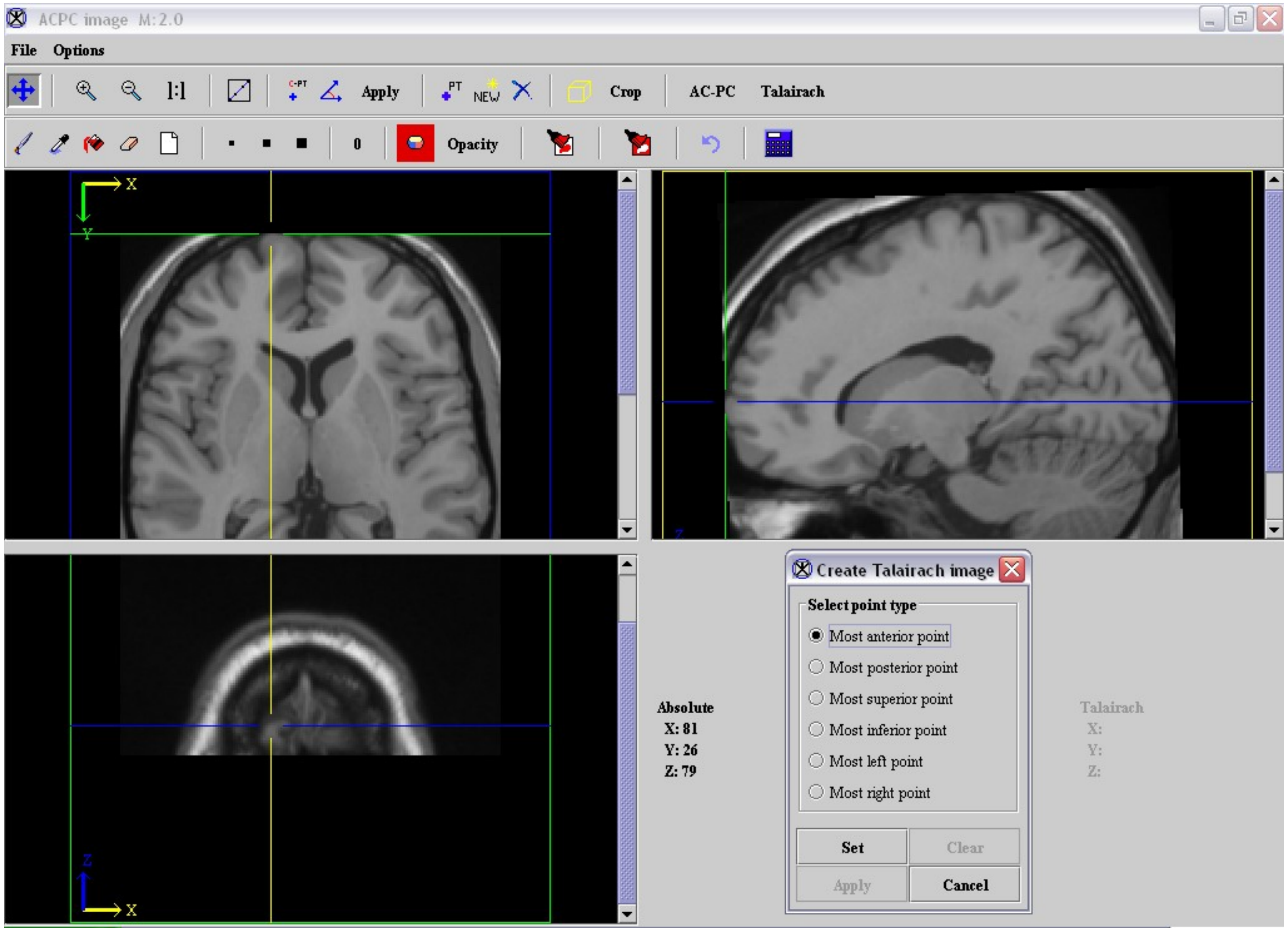
AC to left or right	68 mm

Length of cerebrum	172 mm
Height of cerebrum	116 mm
Width of cerebrum	136 mm

The Talairach alignment

<u>The goal is to mark the limits of the brain</u>

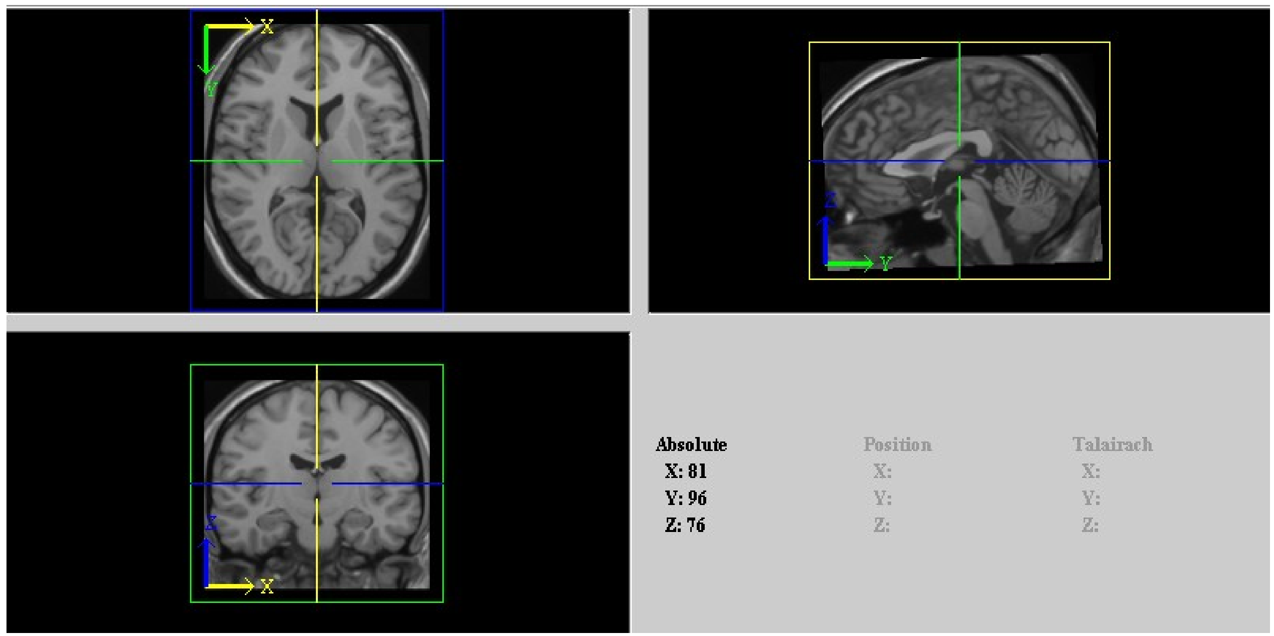
- Most anterior, posterior, superior, inferior, left and right points are needed
- The exact location of the points is not important, as long as they bound the cerebrum



For the most anterior point here, the important information is the position of the green line

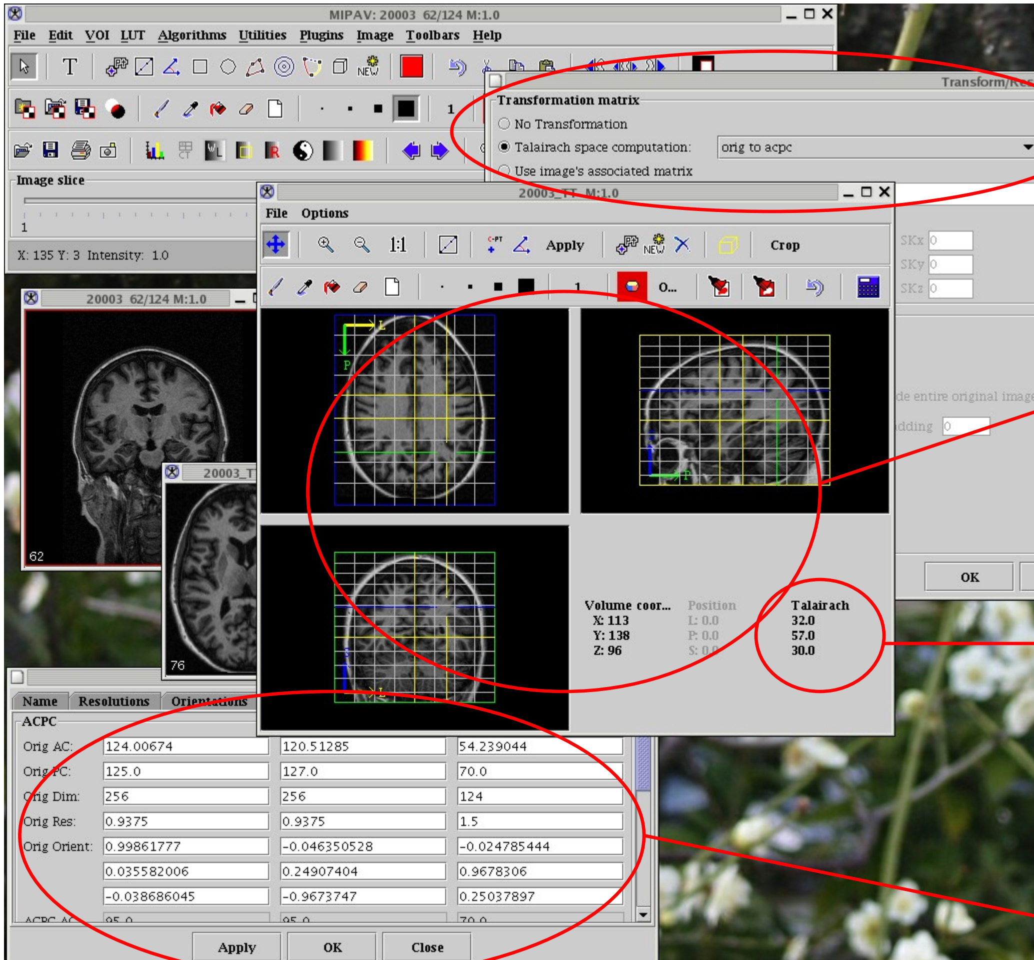
The Talairach alignment

Result: Talairach aligned image



The image is now ready for measurements with the Talairach atlas

Extra features for Talairach-aligned images



A Talairach transform option in the Transform algorithm

The Talairach grid in triplanar view

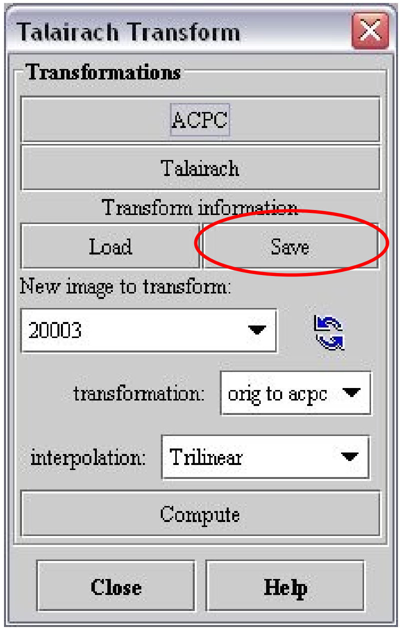
(*aligned image only*)

Talairach coordinates in triplanar view

Talairach parameters in the Image Attributes

For both the Talairach aligned and the original images

Saving AC-PC and Talairach alignments



Saving to a text file:

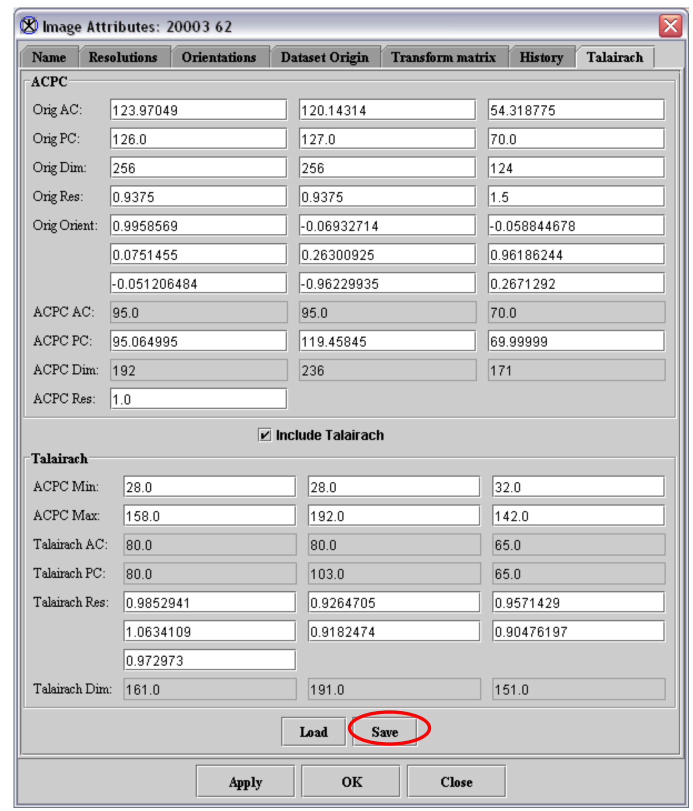
"Save" button of the wizard creates a text file

Saved transformations can be loaded in the plug-in

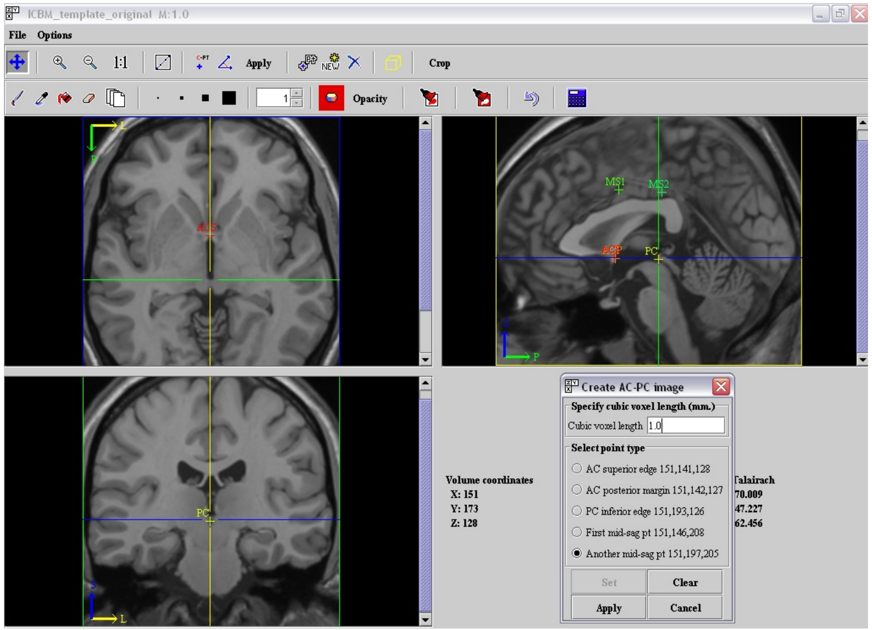
Saving with the image:

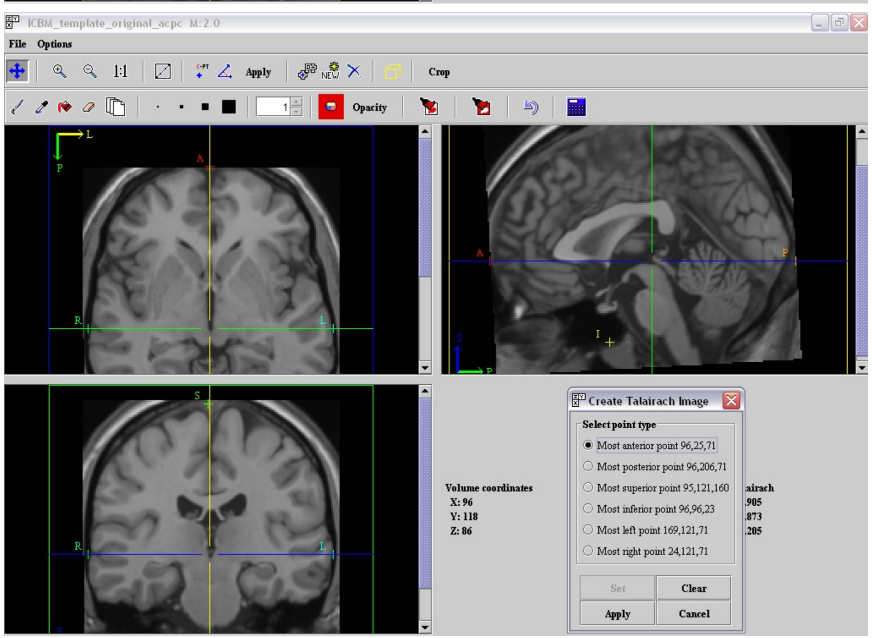
The Talairach transformation is saved with the image header in MIPAV's XML format

The transformation can be saved or loaded as a text file also from the "Image Attributes"



Editing AC-PC and Talairach alignments





!

The Talairach alignment parameters are dependent on each other

Editing the transformation parameters can make them inconsistent

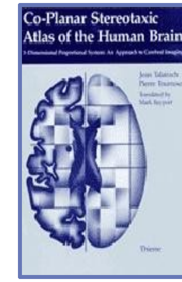
Saved alignment

The Talairach plug-in automatically recovers the points needed for alignment

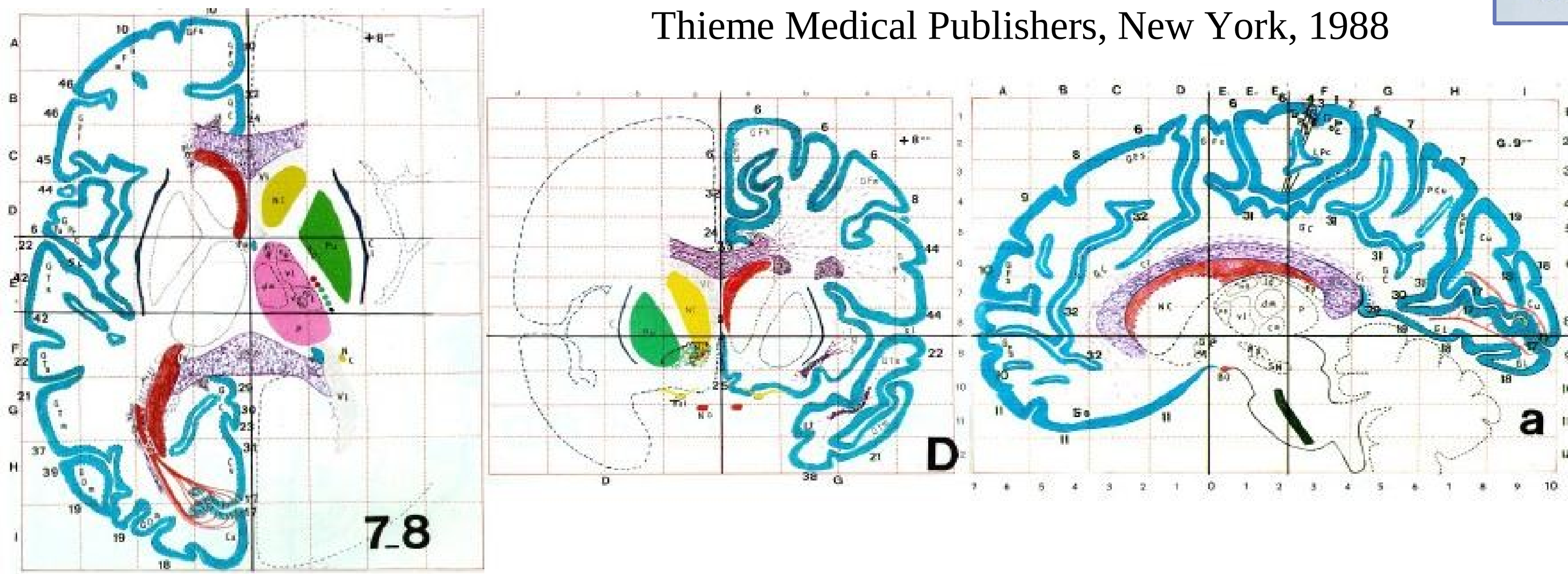
- Any point can be set to a new value
- Generate a new transformation

2. The Talairach atlas and other normalized atlases

The Talairach atlas



Printed version: the reference book: Jean Talairach and Pierre Tournoux
"Co-Planar Stereotaxic Atlas of the Human Brain"
Thieme Medical Publishers, New York, 1988



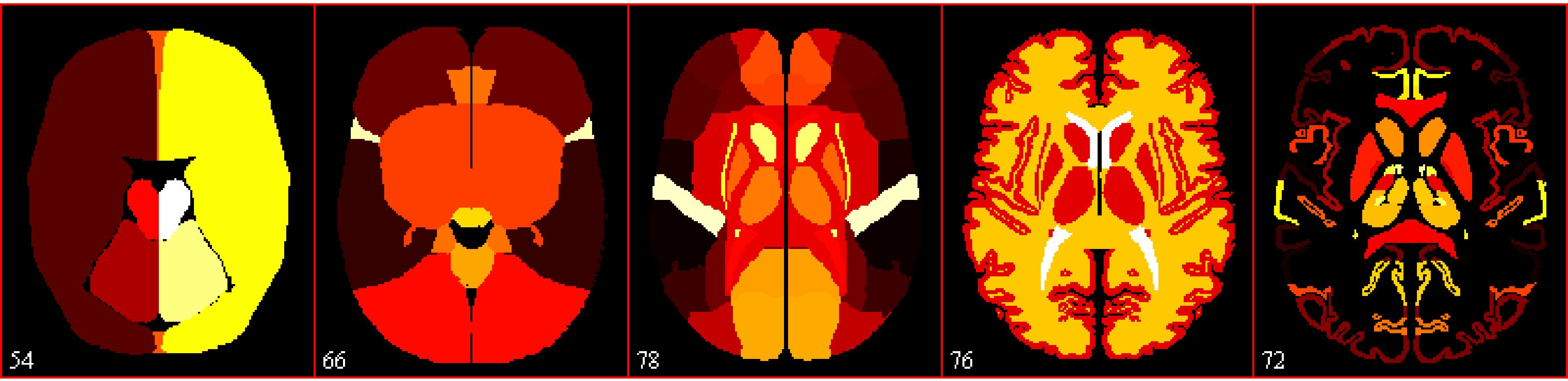
5 levels of structures outlined:

Main structures	**Lobes**	**Gyri**	**Matter**	**Brodmann areas**
(left, right cerebrum, cerebellum, brainstem…)	(temporal, frontal, parietal, posterior, occipital, limbic, anterior; midbrain…)	(temporal, precentral, fusiform; thalamus, ventricles…)	(white matter, Gray matter, CSF)	(areas 1-47, hippocampus, putamen…)
7 regions	12 regions	55 regions	3 regions	71 regions

The Talairach atlas

The MIPAV version: label volumes

Main structures **Lobes** **Gyri** **Matter** **Brodmann areas**



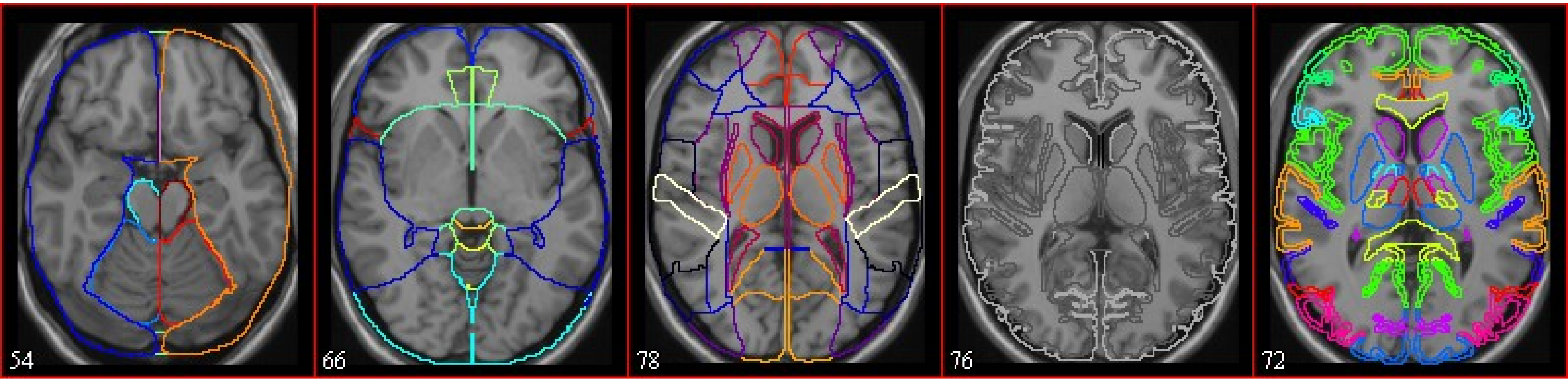
Acknowledgements: this Talairach atlas has been created and enhanced from the publicly available *Talairach Daemon* database

J.L. Lancaster, J.L. Summerlin, L. Rainey, C.S. Freitas and P.T. Fox, "The Talairach Daemon, a database server for Talairach Atlas Labels", in Neuroimage vol.5, num.4, 1997

The Talairach atlas

The MIPAV version: VOIs of labels

Main structures **Lobes** **Gyri** **Matter** **Brodmann areas**



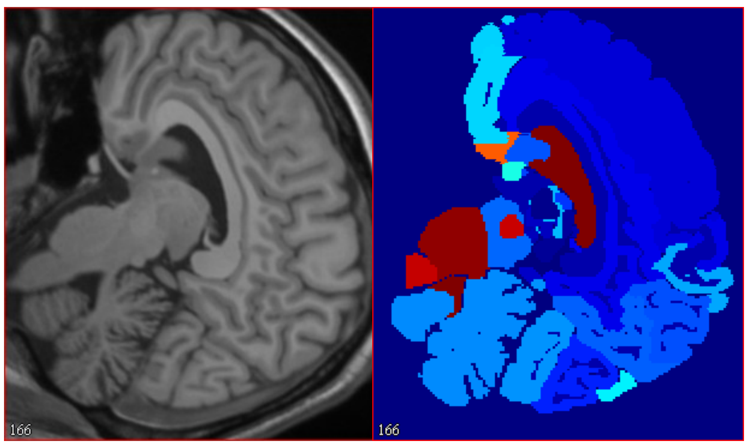
Interest:

- each structure has its own VOI, one can create custom groups of labels
- the VOIs can be easily manipulated and overlaid on the image data
- volume measurements in MIPAV use VOIs

The ICBM/MNI atlas

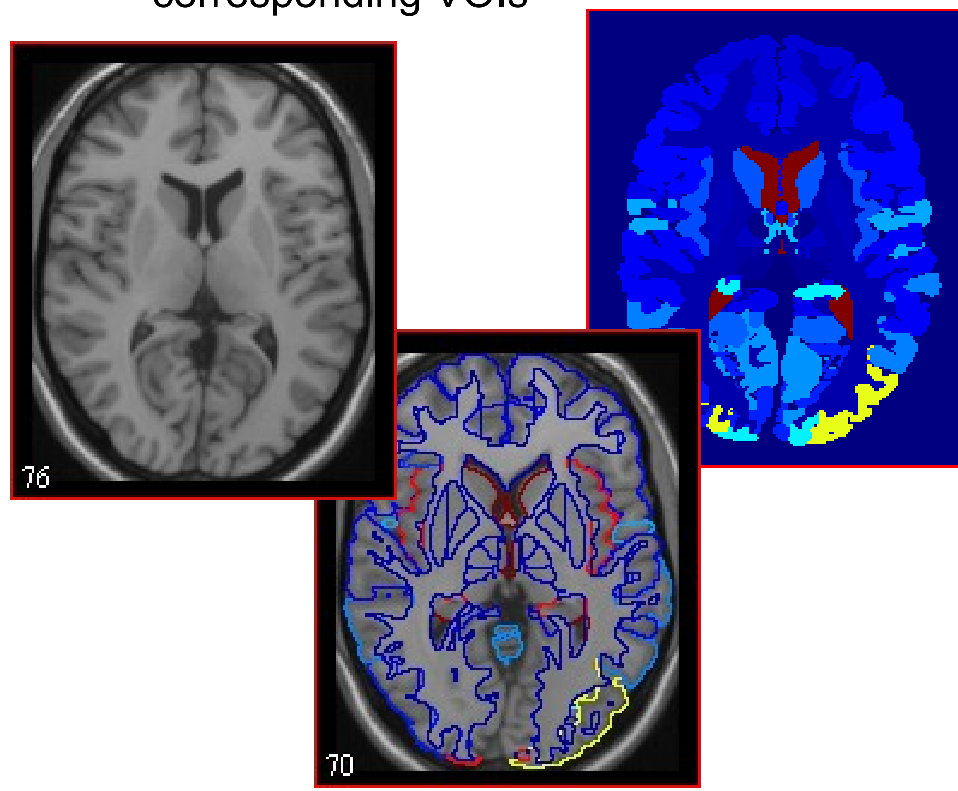
Atlas created by the International Consortium on Brain Mapping (ICBM)

<u>Original data</u>: high resolution image (0.5mm) and volume of labels in own AC-PC like coordinate system



<u>MIPAV version:</u>

- image and label volume in 1.0mm and 0.5mm Talairach coordinates
- corresponding VOIs



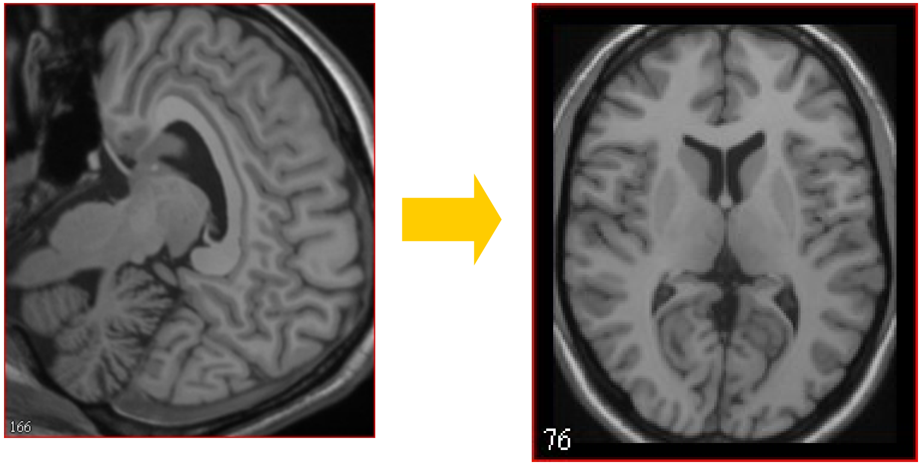
<u>Features:</u>

- very fine level of detail
- atlas paired with MR image

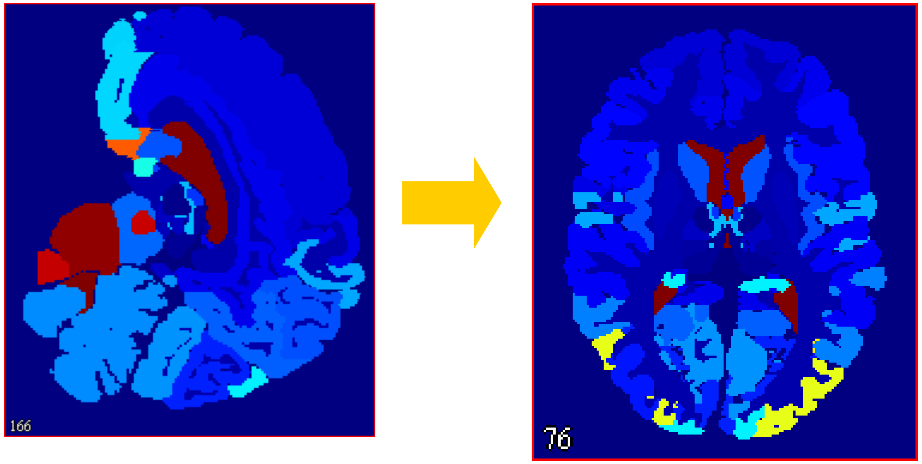
Customized atlases in MIPAV

New atlases can be integrated easily into the MIPAV framework

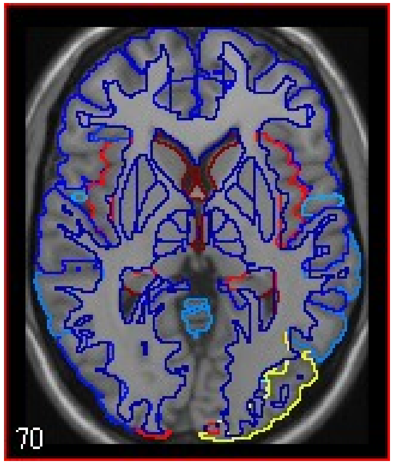
1. Align your image data into Talairach space



2. Apply the transformation to the atlas image



3. Extract VOIs

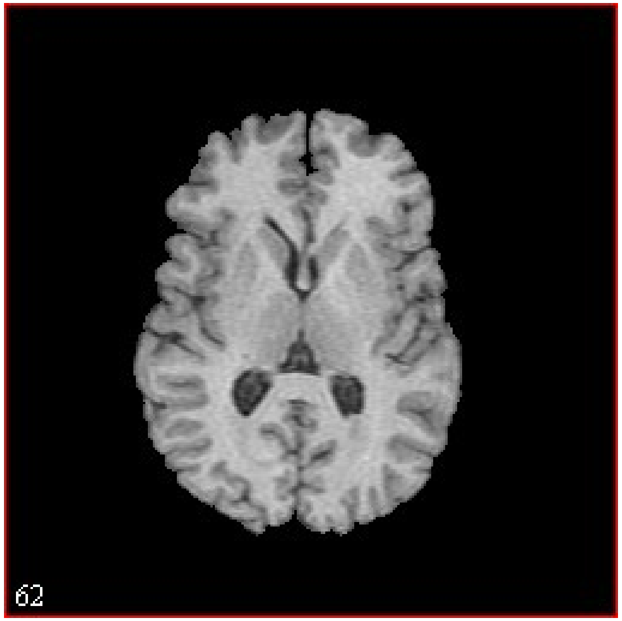


4. Contribute to the MEDIC atlas repository

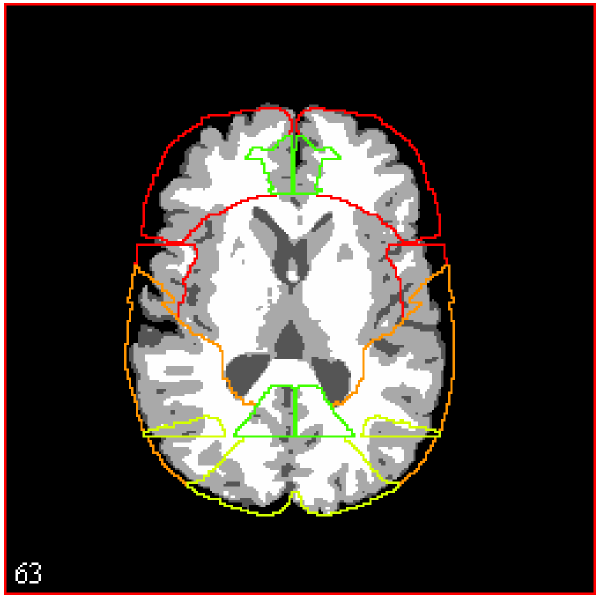
3. Putting all together: Talairach transform, atlases, skull stripping and segmentation for volume measurements in brain regions

Volume measurements

Goal: to measure the volume of gray matter in each and every lobe of a brain image



Original image (stripped)

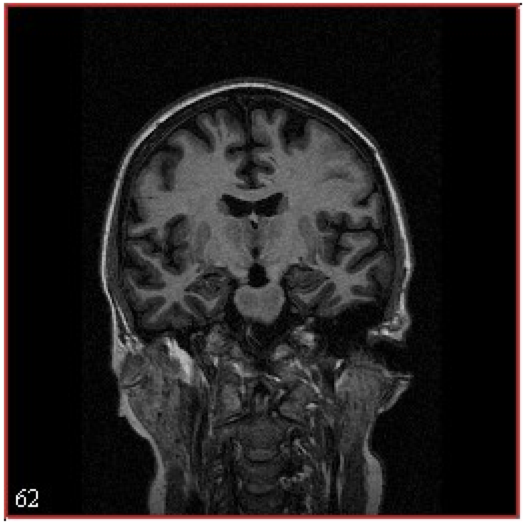


Segmented image with separate lobe regions

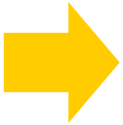
Frontal lobe	169,600 mm^3
Parietal lobe	79,800 mm^3
Temporal lobe	115,200 mm^3
Occipital lobe	65,000 mm^3
Limbic lobe	66,000 mm^3

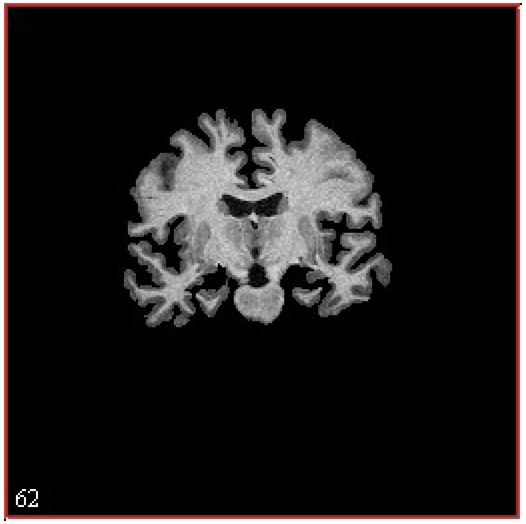
Pre-requisites: skull stripping

Goal: to remove the skull tissues



Original image





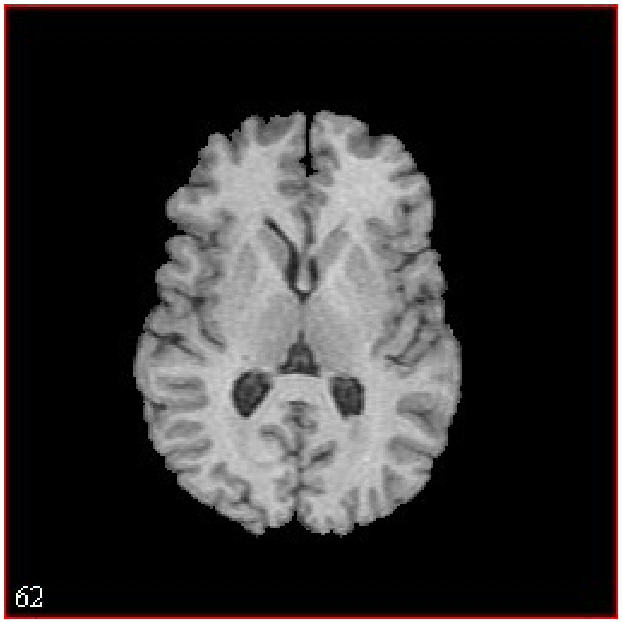
Stripped

<u>Techniques available in MIPAV:</u>

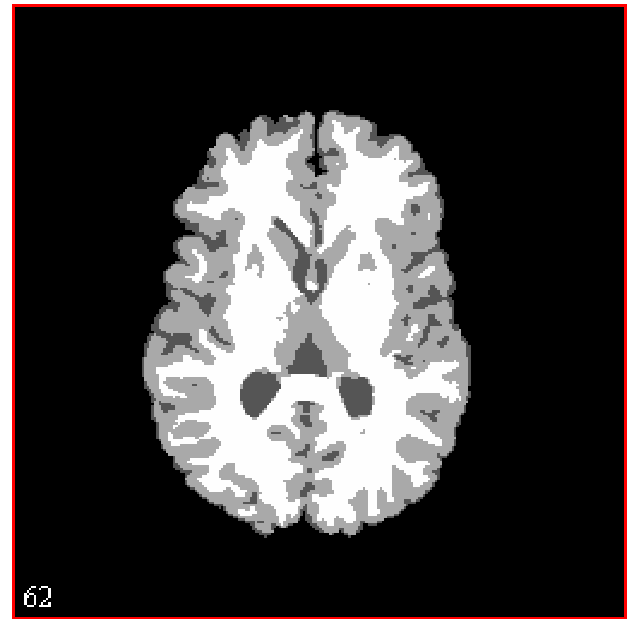
- fully automated techniques: BET, BSE
- semi-automated technique: Brainstrip (MedIC plug-in)

Pre-requisites: segmentation

Goal: to segment the stripped image into white matter, gray matter and CSF



Original stripped image



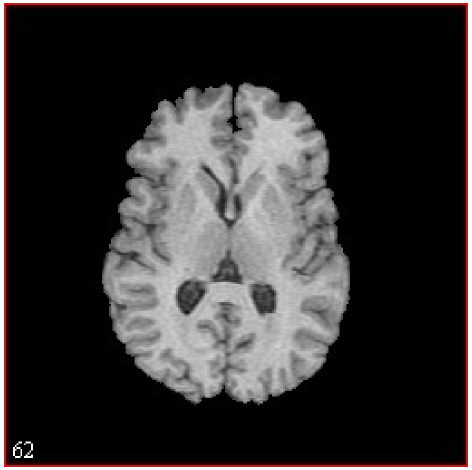
Segmented image

<u>Techniques available in MIPAV:</u>

- fully automated techniques: Fuzzy C-means, Fantasm (MedIC plug-in)
- semi-automated technique: Thresholding, Region growing

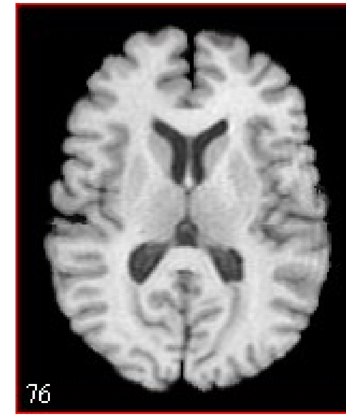
Procedure

1. Normalize the volume into Talairach space



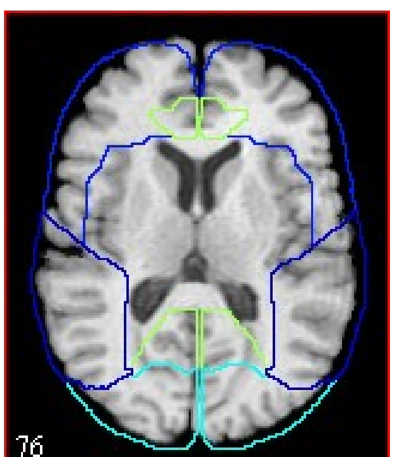
Original image

AC-PC aligned



Talairach aligned

2. Overlay the Talairach lobe labels onto the image

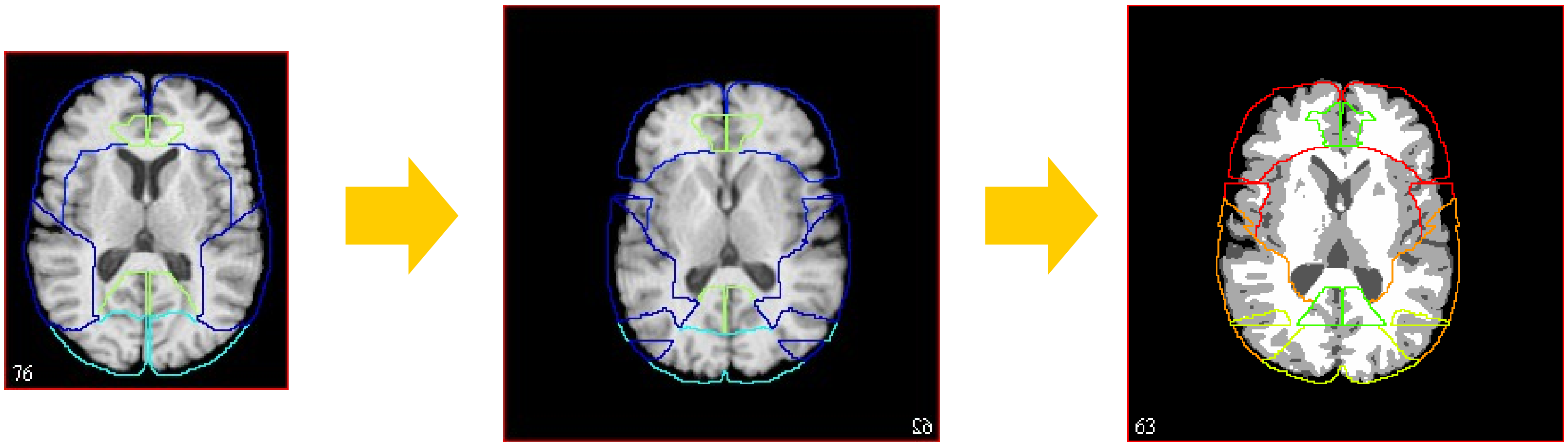


VOIs:
Frontal lobe,
Parietal lobe,
Temporal lobe,
Occipital lobe,
Limbic lobe

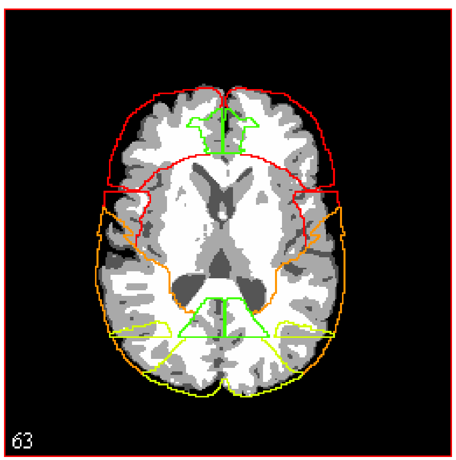
! The Talairach transformation deforms the brain: measurements are not correct in Talairach space

Procedure

3. Transfer the labels to the original space and copy them onto the segmentation



4. Compute the gray matter volumes for each VOI

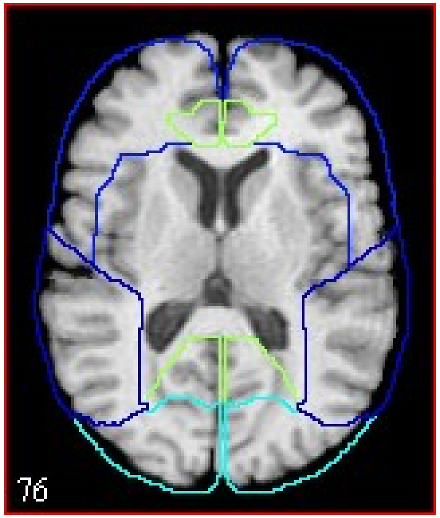


Results

VOIs:

Frontal lobe	169,600 mm^3
Parietal lobe	79,800 mm^3
Temporal lobe	115,200 mm^3
Occipital lobe	65,000 mm^3
Limbic lobe	66,000 mm^3

Comments



The Talairach transformation is simple

- **Fast, reliable computations**
- **Good structure localization**
- **Crude structure alignment**

The Talairach atlas has a low resolution, and different levels of detail

- **Better adapted to align structures from different brains**
- **Easier to create customized sub-atlases**
- **Poor results on small structures**

(alternative: non-linear registration with fine level atlases like ICBM is computationally intensive and may not work with diseased brains)

The regional measurements using Talairach alignment have been evaluated and found **accurate at the level of lobes**:

N. Andreasen, R. Rajarethinam, T. Cizadlo, S. Arndt, V. Swayze II, L. Flashman, D. O'Leary, J. Ehrhardt and W. Yuh, ”Automatic Atlas-based Volume Estimation of Human Brain Regions from MR Images”, in Journal of Computer Assisted Tomography, vol.20, num.1, 1996

Resources

To get and install the software:

M I P A V

Medical Image Processing, Analysis and Visualization

http://mipav.cit.nih.gov/download/

(the complete MIPAV software)

Launch the MIPAV installer and follow the instructions

MEDIC

http://medic.rad.jhu.edu/download/public/

(the plug-ins: Talairach Transform, Brainstrip, Fantasm)
(the atlases: Talairach Atlas, ICBM Atlas, custom atlases)

Follow the instructions of the ‘readme’ file

Resources

To get further information and help

MIPAV -> Help -> Help Topics

The MIPAV user guide and main documentation

http://mipav.cit.nih.gov/documentation/

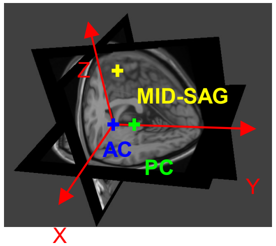
All the online documentation about MIPAV

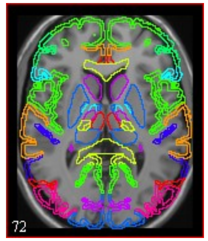
http://medic.rad.jhu.edu/forums/

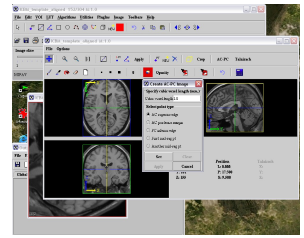
The official discussion forum for questions related to both MIPAV and the MedIC plug-ins

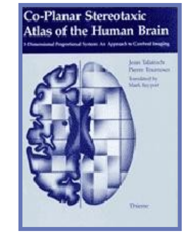
MIPAV
MEDICAL IMAGE PROCESSING, ANALYSIS AND VISUALIZATION

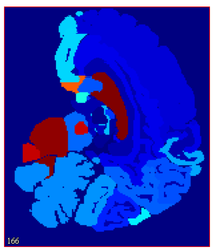
MEDIC



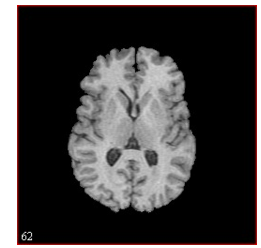


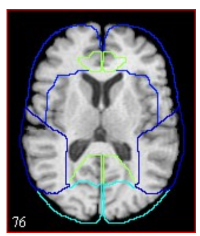


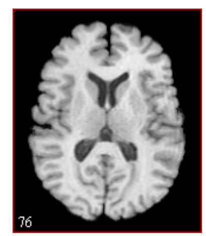




Thank you for your attention







Questions ?