

CENTRE FOR
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3-D DIGITAL RODENT BRAIN ATLAS

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INTRODUCTION

Conventional atlases contain 2-D diagrams of sections cut perpendicular to standard axes through the brain. We present a method for 3-D reconstruction of series of such atlas diagrams, and a tool for visualization and analyses of the reconstructed structures. The motivation is four-fold: 1) Structures can be added to the reconstruction at different levels of granularity and alternative parcellation schemes can be used. 2) The reconstruction facilitates understanding of size, shape, and spatial relationships. 3) Re-slicing allows the user to generate customized atlas diagrams, at any chosen angle. 4) Volumes and surface areas can be extracted from the reconstruction. We use our tools in combination with a database system, The Rodent Brain Navigator. Data imported in Navigator are images of histological sections or tomographic volumes.

APPROACH

The procedure is applicable to any stereotaxic brain atlas, provided that the atlas sections are available in digital format (EPS or Adobe Illustrator format) and are reasonably well aligned. We have reconstructed two coronal rat and mouse brain atlases^{1,2}.

SOFTWARE

- Adobe Illustrator
- Amira 4.0 (Mercury Computer Systems Inc.)
- m3d viewer (in-house visualization tool, NeSys)
- Adobe Photoshop

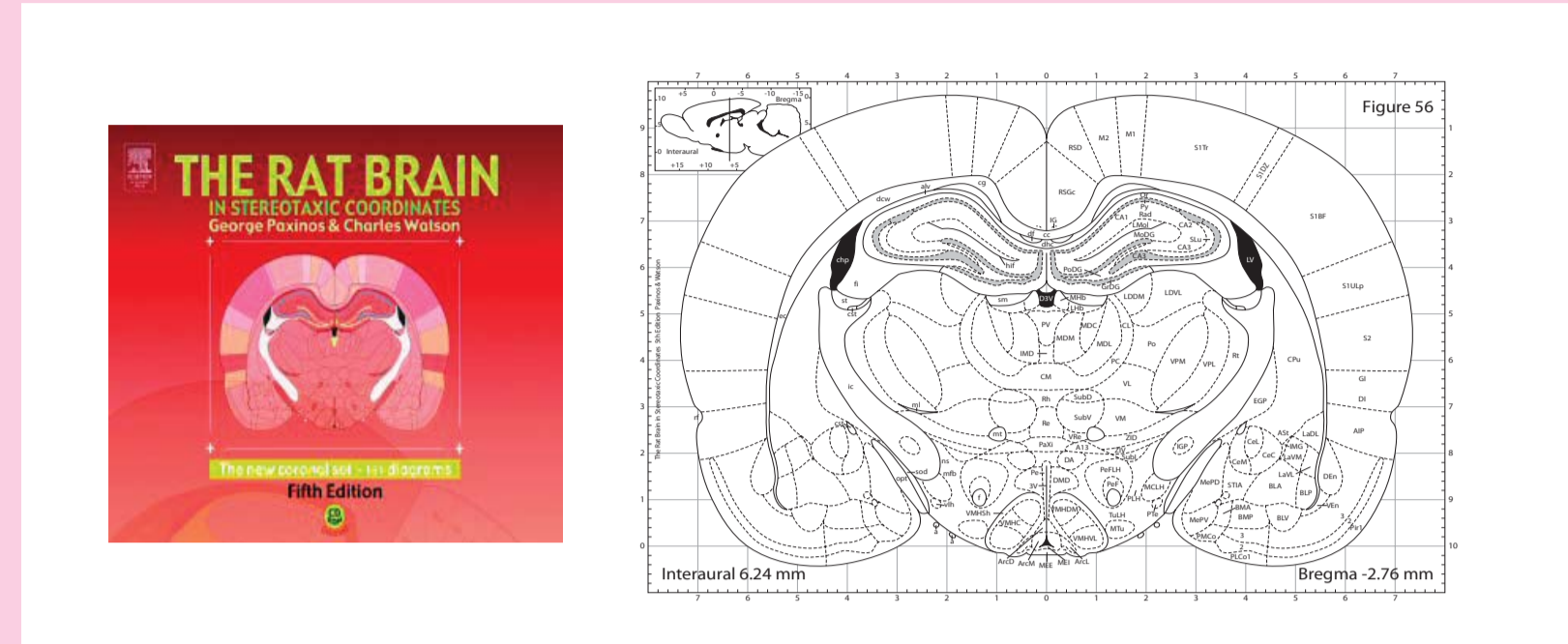
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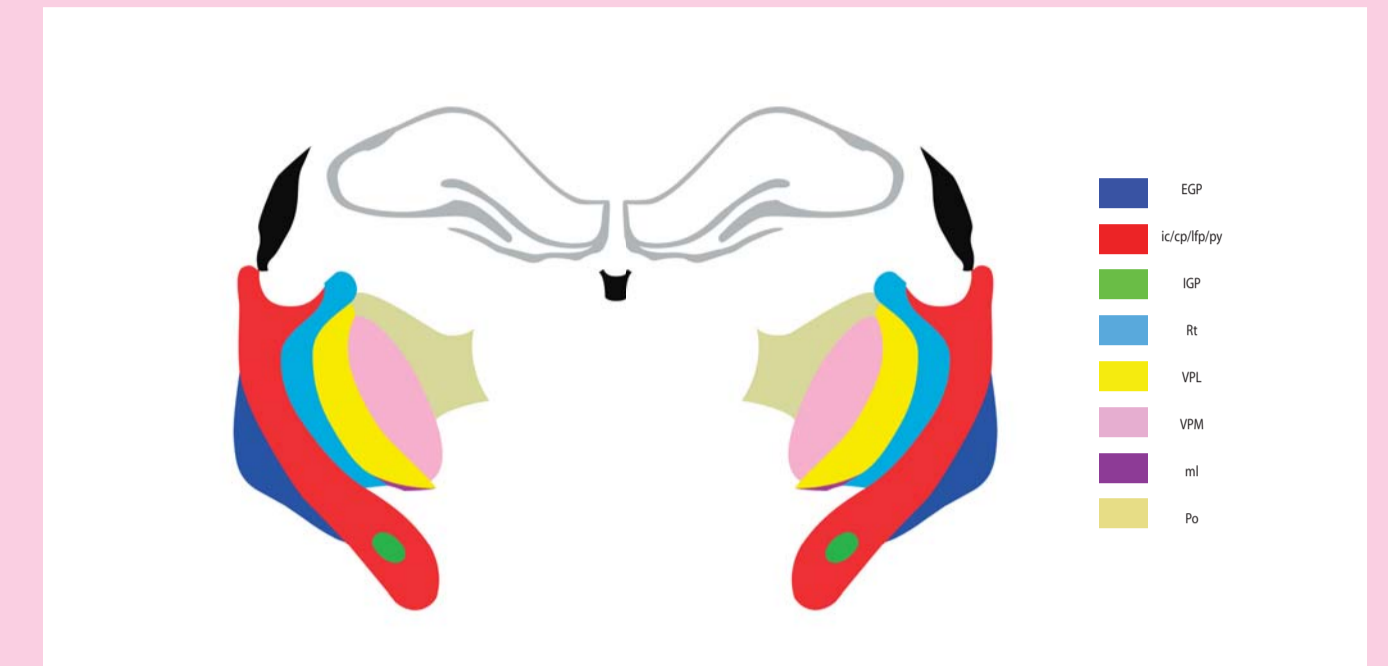
REFERENCES

1. Paxinos G, Watson C (2005), The Rat Brain in Stereotaxic Coordinates, 5th ed, Academic Press.
2. Paxinos G, Franklin KB (2001) The Mouse Brain in Stereotaxic Coordinates, 2nd ed, Elsevier.
3. Bjaalie JG, Leergaard TB, Lillehaug S, Odeh F, Moene IA, Kjode JO, Darin D (2005) Neuroscience 136:681-696.
4. Leergaard TB, Bjaalie JG, Devor A, Wald LL, Bjaalie JG, Dale AM (2003), Neuroimage 20:1591-1600.

Alignment and colorization (Adobe Illustrator)



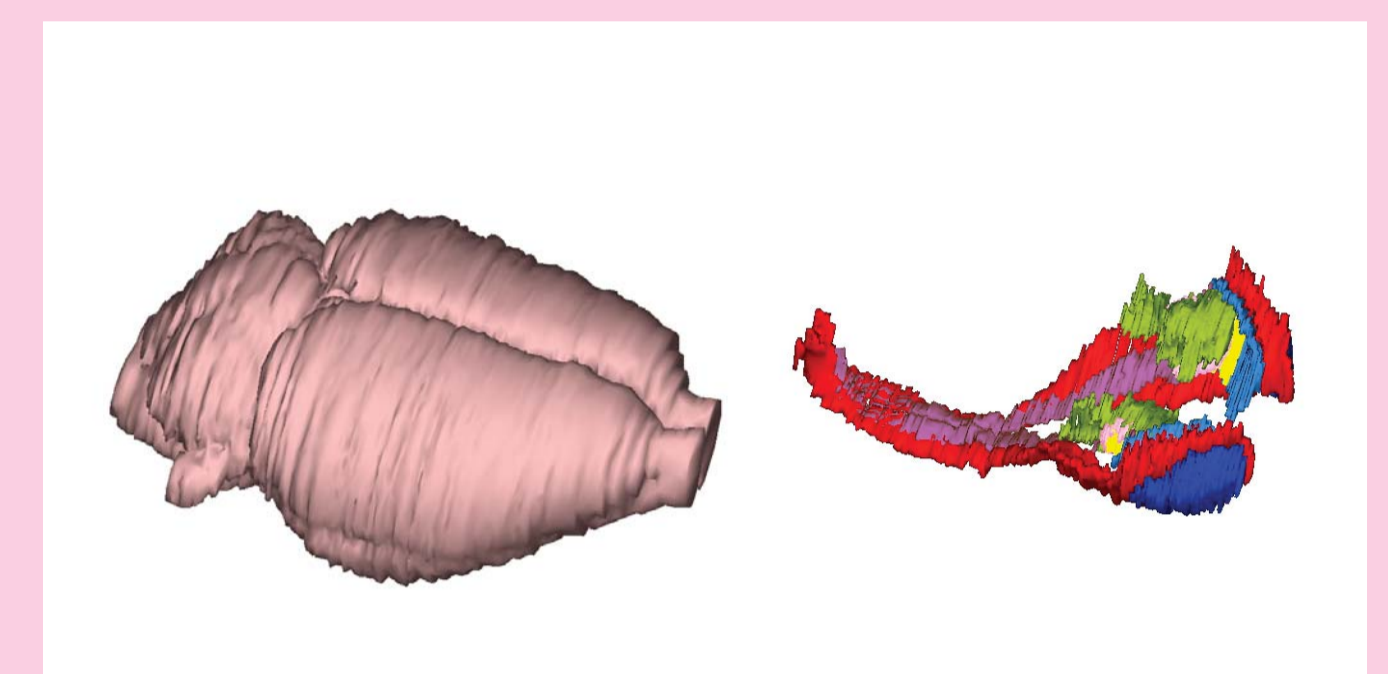
Atlas diagrams (here taken from¹) are imported to Adobe Illustrator and organized in separate layers in one file. Each layer / diagram is aligned on basis of the given coordinate system.



Regions of interest are selected and assigned specific colors in all relevant diagrams / layers. If necessary, boundaries are re-defined to obtain closed contours. Each atlas diagram / layer is saved as a tiff file.

3-D reconstruction and segmentation (Amira)

The aligned and colorized atlas images are imported into Amira 4.0 as a stack of images, using distance from Bregma to define through-plane position. Anatomical structures are segmented on basis of respective color, and reconstructed in 3-D using the surface rendering module in Amira (without use of smoothing algorithms). Following simplification of surface rendering triangulation, individual structures are exported as VRML (Virtual Reality Modeling Language) files.



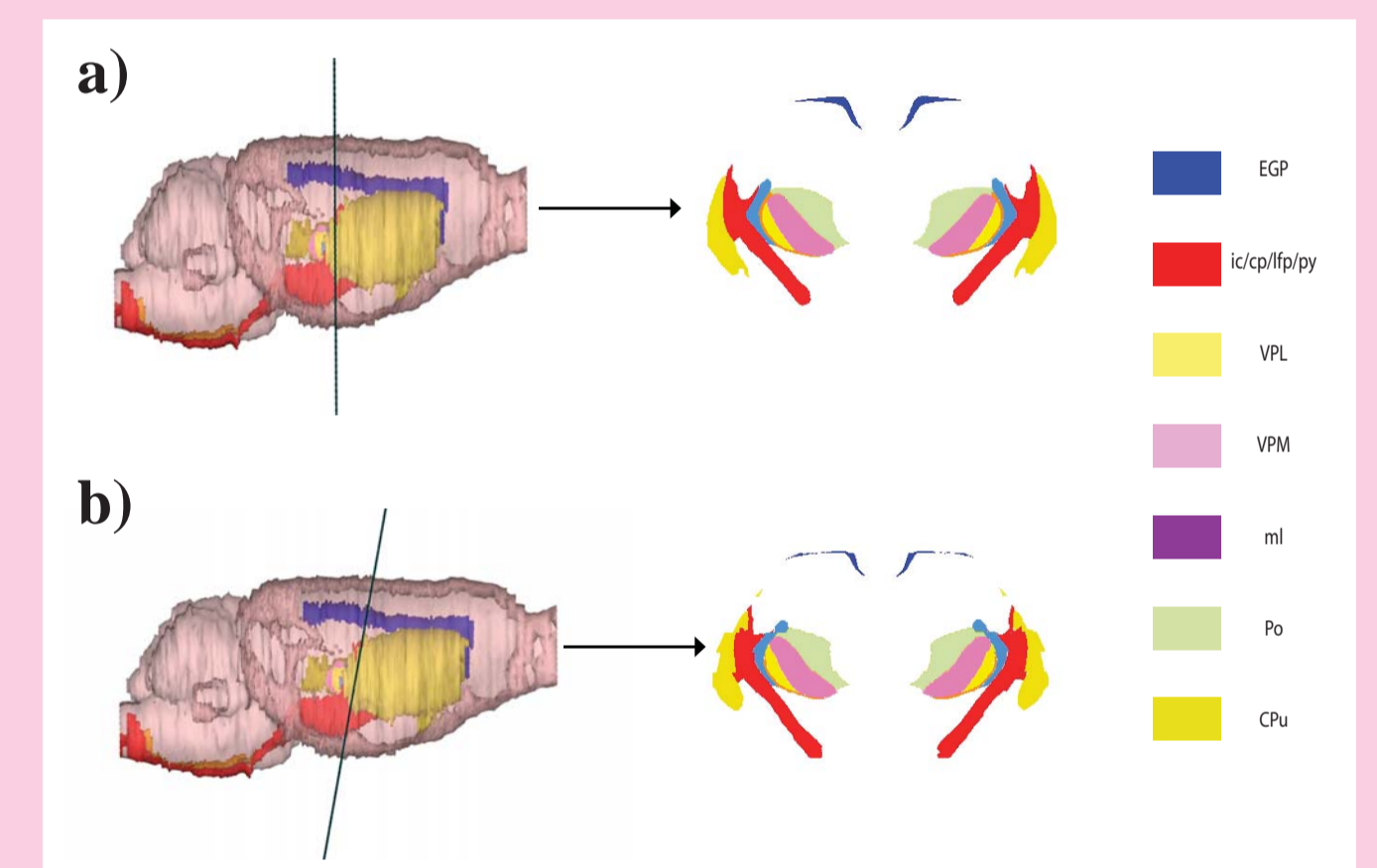
Visualization (VRML viewers)

VRML files may be visualized using commercial (e.g. Amira) or downloadable (e.g. Cortona VRML viewer) tools allowing dynamic rotations and inspection from any angle of view. We use m3d, an in-house JAVA based tool³.

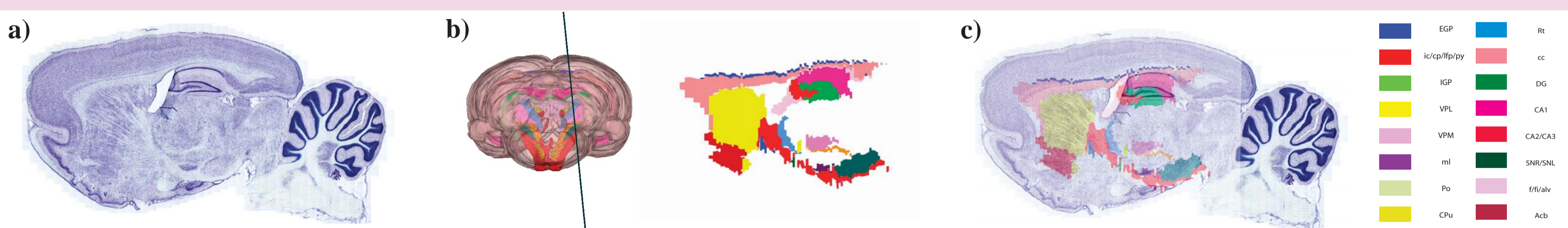
Customized atlas slices (m3d)

We use m3d to generate atlas diagrams at user defined angles through the 3-D model, in order to match the slicing angle of experimental sections.

- Coronal atlas slice, similar to the original rat brain atlas¹
- Customized atlas slice, with a 10 degree rotation from the standard coronal plane



Example: histological section image from unknown location

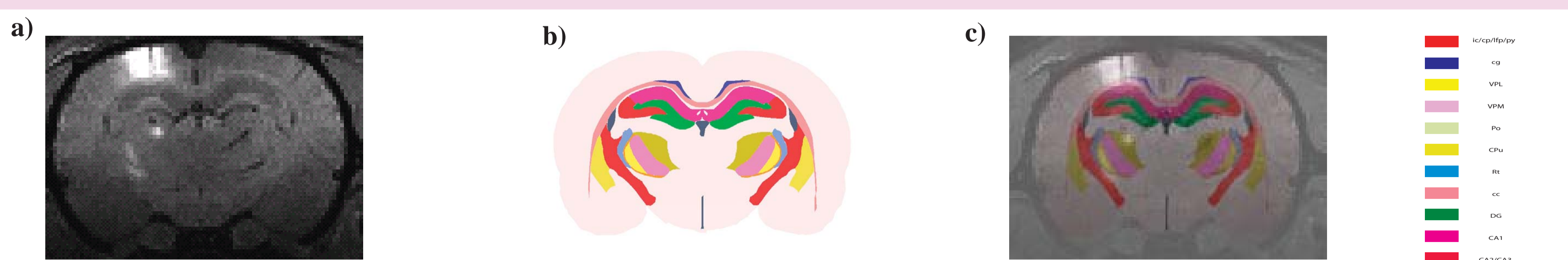


a) High-resolution mosaic image of thionin stained rat brain section (T.B. Leergaard and J.G. Bjaalie, unpublished), cut in approximately sagittal angle, from unknown position in the brain.

b) The m3d slice tool is used to identify the slice position and orientation giving best match of multiple anatomical landmarks between the atlas slice (reconstructed from ¹) and the image.

c) Overlay of atlas slice and image is accomplished using Adobe Photoshop. Despite some structure mismatch, the customized atlas slice aids the identification of anatomical structures in the image.

Example: MRI volume with low structural contrast



a) Coronal, T1 weighted MRI slice from a rat brain showing specific Mn2+ signal enhancement ~10 hours after injection of MnCl2 into the primary somatosensory cortex (T.B. Leergaard, J.G. Bjaalie & A.M. Dale, unpublished, see also ⁴).

b) To facilitate localization of Mn2+ signals, a matching atlas slice is generated on basis of recognizable major landmarks.

c) Overlay of the images reveal that the signal enhancement is located in the internal capsule (ic), ventral posterolateral nucleus thalamus (VPL) and posterior complex of the thalamus (Po).

Summary

We present a method for producing a 3-D digital atlas from conventional atlas diagrams. The 3-D reconstruction maintains the stereotaxic standard space of the atlases. Our tool m3d, which is a part of the Rodent Brain Navigator, allows the user to navigate in 3-D space and to re-slice the standard atlas in any user defined angle.