Baby Brain Toolkit

Fbrain ERC project: Computational Anatomy of Fetal Brain

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1 Introduction

BTK stands for Baby Brain Toolkit. This toolkit is developed in the context of the Fbrain ERC project: "Computational Anatomy of Fetal Brain"[1]. Studies about brain maturation aim at providing a better understanding of brain development and links between brain changes and cognitive development. Such studies are of great interest for diagnosis help and clinical course of development and treatment of illnesses. Several teams have begun to make 3D maps of developing brain structures from children to young adults. However, working out the development of fetal and neonatal brain remains an open issue. This project aims at jumping over several theoretical and practical barriers and at going beyond the formal description of the brain maturation thanks to the development of a realistic numerical model of brain aging.

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[1] http://lsiit-miv.u-strasbg.fr/miv/index.php?contenu=erc

1.2 Dependencies and Compilation

Baby Brain Toolkit (BTK) depends on:

- The most recent version of the Insight ToolKit (ITK) – www.itk.org. Please compile ITK with flags ITK_USE_OPTIMIZED_REGISTRATION and ITK_USE_REVIEW set to ON.

- Tclap library: this library can be installed for debian-based distribution using the following command line : `apt-get install libtclap-dev`

- OpenMP library: this library can be installed for debian-based distribution using the following command line : `apt-get install libgomp1`

2 Applications

2.1 Denoising

btkNLMDenoising This program applies a non-local mean filter to a 3D image for denoising purpose. Usage: `-i input_image_filename -o output_image_filename`. The best results are usually obtained by using a mask (or a padding value).

btkNLMDenoising4DImage This program applies a non-local mean filter to each 3D image of a 4D image, for denoising purpose. Usage: `-i input_image_filename -o output_image_filename`. The best results are usually obtained by using a mask (or a padding value).

2.2 Anatomical reconstruction

btkImageReconstruction This program allows to obtain a high-resolution image from a set of low-resolution images, typically axial, coronal, and sagital acquisitions [1].

Minimal usage: `btkImageReconstruction -i image1 ⋯ -i imageN -o output --box`.

Recommended usage: `btkImageReconstruction -i image1 ⋯ -i imageN -m mask1 ⋯ -m maskN -o output --mask`. The use of a mask provide better results since it allows an accuratelly estimation of the initial transform, and constrains the registration to the region of interest.

The full list of optional parameters of the method can be obtained by `btkImageReconstruction --help`

btkReorientImageToStandard After reconstruction, sometimes it is useful to reorient the image to the standard orientation. This is necessary with fetal images since in general the fetus is in a random orientation with respect to the scanner.

Usage: `btkReorientImageToStandard -i image -o output -l landmarks`. `landmarks` is a text file containing the spatial coordinates (in RAS world coordinates) of points defining the left-right and the posterior-anterior directions. This information must be organized as follows:

$$
\begin{array}{ccc}
l_x & l_y & l_z \\
r_x & r_y & r_z \\
p_x & p_y & p_z \\
a_x & a_y & a_z
\end{array}
$$

where the points $l = (l_x, l_y, l_z)$ and $r = (r_x, r_y, r_z)$ define the left $\rightarrow$ right direction, and the points $p = (p_x, p_y, p_z)$ and $a = (a_x, a_y, a_z)$ define the posterior $\rightarrow$ anterior direction. Such file can be easily generated by using Slicer[2].

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[2] http://www.slicer.org

Figure 1: Example of an anatomical reconstruction of a fetal brain by using `btkImageReconstruction`. (a) axial, (b) coronal, and (c) sagital view.
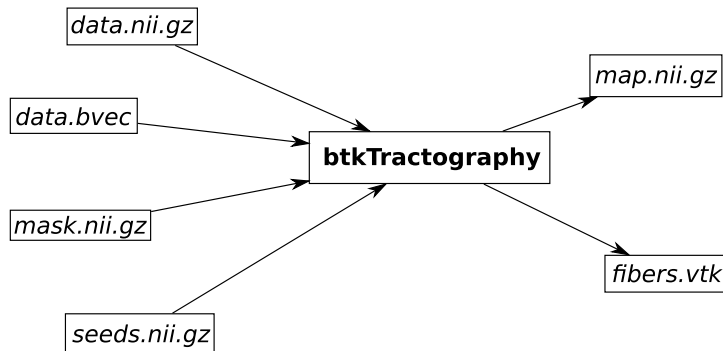

Figure 2: Standard pipeline of the btkTractography program.

2.3 Tractography

Theory

Standard usage

Suppose you want to perform a tractography on a diffusion weighted MRI dataset. You should have a dwi image, the corresponding gradient vectors' coordinates, a mask of the brain white matter and a label image of the seeds. Assume this data is stored in files named repsectively for instance `data.nii.gz`, `data.bvec`, `mask.nii.gz` and `seeds.nii.gz`. The tractography is accomplished by the command below.

```
btkTractography -d data.nii.gz -v data.bvec -m mask.nii.gz -l seeds.nii.gz
```

When the program terminates its task, the probability connection map and the fibers estimation are saved in files respectively named `map.nii.gz` and `fibers.vtk`. The connection map is a volume image of probability intensities (`i.e.` intensities between 0 and 1) with the same origin, orientation and spacing as the diffusion weighted image. The fibers are polygonal data of VTK library in world coordinates. The standard pipeline of the program is shown in Fig. 2.

Advanced usage

In addition to standard arguments of `btkTractography` program, there are some other parameters that let you to alter algorithm's behaviour. Since the default parameters values may work in the most of cases, they are optional. A list is of optional features is avaible by using the command

```
btkTractography --help
```
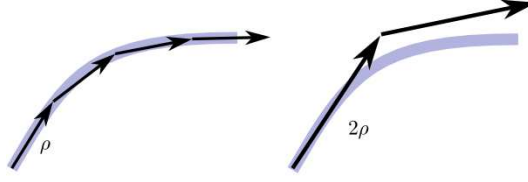
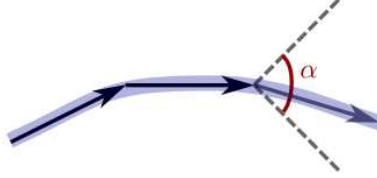and program's arguments are much more described below.

Figure 3:

Figure 4:

Model's order

The model's order (i.e. the spherical harmonics' order) can be specified by the option

    --model-order <n>,

for n∈ $\{2, 4, 6, 8\}$. The default value is 4.

Model's regularization

A Laplace-Beltrami regularization coefficient is used to assume a better estimation of the model. This coefficient can by manually modified by the option

    --model-regularization <r>,

for r∈ $\mathbb{R}$. The default value is set as 0.006.

Displacement step size

Angular threshold

Rigidity

Number of particles

Resampling threshold

3   Utilities

btkModifyImageUsingLookUpTable This program modifies one image using a look up table defined in a ascii file (2 columns, one for the original values, one for the final values). Usage: `-i input_image_filename -t input_table_filename -o output_image_filename`
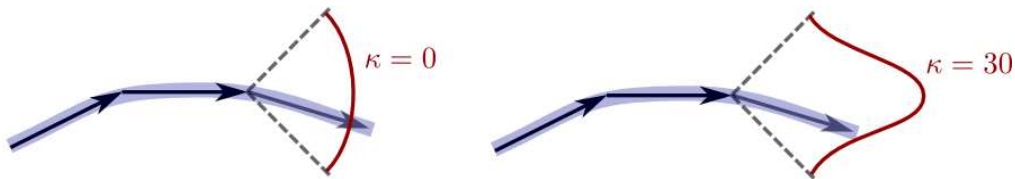

Figure 5:

Acknowledgment

References

[1] Francois Rousseau, Orit A Glenn, Bistra Iordanova, Claudia Rodriguez-Carranza, Daniel B Vigneron, James A Barkovich, and Colin Studholme. Registration-based approach for reconstruction of high-resolution in utero fetal MR brain images. *Acad Radiol*, 13(9):1072–1081, Sep 2006.