rBET: Making BET work for Rodent Brains

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Introduction: The Brain Extraction Tool (BET), part of the FMRIB Software Library (FSL) is commonly used to produced brain masks for human data. BET makes several assumptions about the brain's shape, curvature and location within the image that are correct in clinical data, but are unfortunately inappropriate for pre-clinical data such as rodent images. This causes BET to fail when used with such data. We have modified BET to use more appropriate initial estimates for the shape and location of the rodent brain, and also to use more appropriate smoothness constraints. This modified rodent Brain Extraction Tool (rBET) was tested with example data and successfully produced appropriate brain masks.

Algorithm Modifications: The first step of the BET algorithm (1) is the construction of an initial mesh that will subsequently be deformed to fit the surface of the brain. The standard BET, if run with no user intervention, calculates the centre-of-gravity (CoG) of the input image and an average value for the radius (R) of the head in the image. The initial surface is then set to be a sphere with centre equal to the CoG and a radius of R/2. This estimate is entirely valid for typical clinical data, but is invalid for rodents. As can be seen in figure 1, the rodent brain is more elongated than the human brain, and the centre of the brain is displaced from the CoG of the rodent head.

We propose that a more appropriate initial mesh for the rodent brain is an ellipsoid, with major axes aligned with the image volume axes, with lengths in the X,Y & Z directions set to the ratio 1:1:2. The length of the major axis in the Z (Axial) direction should be set to R/2 as for human data. The center of the ellipsoid should be displaced from the CoG of the image by (0, +0.4*R, -0.25*R). These values were determined empirically.

BET also requires the following pairs of constants: r_{min} & r_{max} (which describe the minimum and maximum expected radii of curvature) and d_1 & d_2 (which describe how far to search into the brain for the minimum and maximum intensity). By default in BET these are specified to be 3.33, 10, 7 & 3 mm respectively (extracted from the BET source-code, FSL 5.0). These values are clearly inappropriate for the rodent brain, as in particular a value of 7 mm for d_1 will extend the line search for the maximum intensity value across the entire brain. More appropriate constants were found empirically to be 1, 3.33, 0.7 & 0.3 mm for r_{min}, r_{max}, d_1 & d_2 respectively.

Implementation: The improved algorithm was implemented by modifying the C++ source code for BET version 2, obtained from FSL version 5.0 (http://fsl.fmrib.ox.ac.uk/fsl/). The modified source code is available via the Neuro-Imaging Tools and Resources Clearinghouse (http://www.nitrc.org/projects/rbet). In addition to the automated technique described above for detecting the center and size of the brain, the standard BET options to specify these were retained. An additional option allowing the ratio of the major-axis lengths to be changed was also implemented.

Results and discussion: Figures 1 & 2 show the results of the modified algorithm for two illustrative images obtained with a 7T Direct Drive pre-clinical imaging system (Agilent Plc). Figure 1 shows a 3D T1-weighted Spoiled Gradient Recalled (SPGR) sequence (TE/TR=4.876/11.216 ms, flip-angle=6 degrees, 192x192x192 matrix, FoV 40x40x40mm) of an *ex vivo* female Wistar rat head (fixed in fomblin), while figure 2 shows a 2D T2-weighted Fast Spin Echo (FSE) sequence (TE/TR=10/4000 ms, 256x256 matrix, 44 slices, FoV 40x40x26.4 mm) of an *in vivo* adult female Wistar rat head. The algorithm correctly finds the surface of the brain around in both cases, but excludes the olfactory bulb due to the smoothness constraints preventing the surface following the increased curvature. As shown in figure 2, it is difficult to specify an automatic position for the initial center that will work for all images. In this case the algorithm has still completed successfully, despite the initial ellipsoid being placed partially outside the top of the brain.

References:

1. Smith, S. M. (2002). Fast Robust Automated Brain Extraction. *Human Brain Mapping*, 143-155.

Figure 1 - Axial, sagittal and coronal (left to right) of the initial (a) and final (b) surfaces (outlined in white) generated when the algorithm is run on a T1-weighted SPGR image.

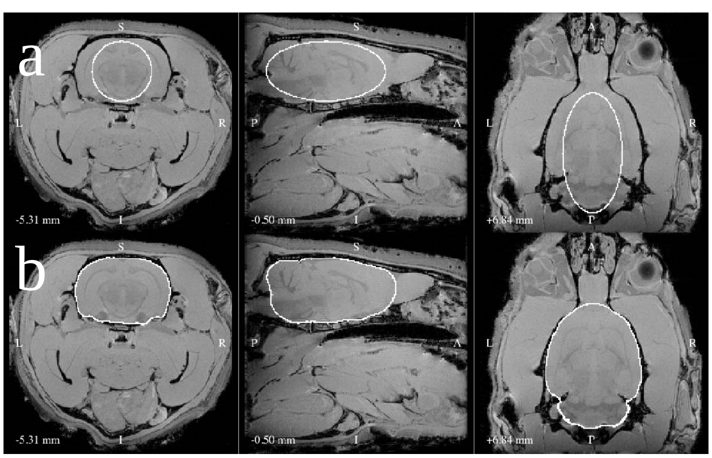

Figure 2 - Axial, sagittal and coronal (left to right) of the initial (a) and final (b) surfaces (outlined in white) generated when the algorithm is run on a T2-weighted FSE image.