Pinned snakes: A technique to extract mouse brain data from whole head MRI

Y. Liu[1,2], M. Uberti[1,2], and M. Boska[1,2]

[1]Radiology, University of Nebraska Medical Center, Omaha, NE, United States, [2]Center for Neurovirology and Neurodegenerative Disorders, University of Nebraska Medical Center, Omaha, NE, United States

Introduction: Extracting the brain volume from the whole head MRI is the precursor of further processing. Brain extraction (or "skull stripping" called by some investigators) techniques that developed for human head MRI failed for mouse head MRI due to the particular anatomical properties of the mouse head including similar MRI signal intensity (spin density-, T1- and T2*-wt) of brain parenchyma and peripheral tissues and very narrow or disappearing CSF space between the brain and skull. These anatomical properties make the techniques employing image intensity and gradient for image segmentation invalid. We developed a technique based on an active contour model ("snake") to extract brain from the mouse head MRI. A snake is a deformable contour moving to the location with minimal energy. The energy functional which is minimized is a weighted combination of internal (such as the shape and continuity of the snake) and external forces (including intensity and/or intensity gradient and/or higher level image constraints). Our technique automates the introduction of the high level image constraints to the snake energy functional and the initial snake definition.

Materials and Methods: Normal mouse brain images (T_2^*-wt, n=5) were acquired using a Bruker 7T scanner. With a closer observation of the in vivo MRI, the skull-brain connection (where the gap disappears) only occurs at localized places. An easy and logical method to prevent the snake from missing the brain boundary is including hard constraints (constraints that cannot be violated) at these locations. The hard constraints along with the first- and second-order continuity constraints which are inherent in the energy function can generate a continuous smooth snake representing the brain border. We call this method "pinned snake" as the snake is like being pinned at the points where hard constraints are defined (pins). The minimal energy is set at the pins, and the weightings of the energy function are relaxed. At the snake points close to the pins, the gradient weighting is relaxed. The pins are defined by extracting them from the brain contour drawn on the sagittal and axial planes. The number of contours to draw, and positions of these contours are determined by the researcher. The brain extraction procedure can be illustrated in Table 1:

Table 1.

1. Draw contours on sagittal and/or axial planes
2. Extract pins from these contours
3. Run the snake on one coronal slice
   a) Define the initial snake from the pins
   b) Set the parameters for the snake including weighting factors of internal and external forces.
   c) Restrain the snake at the pins, and relax the restrictions of the external forces.
   d) Run the snake iteratively.
4. Go to the next coronal slice.

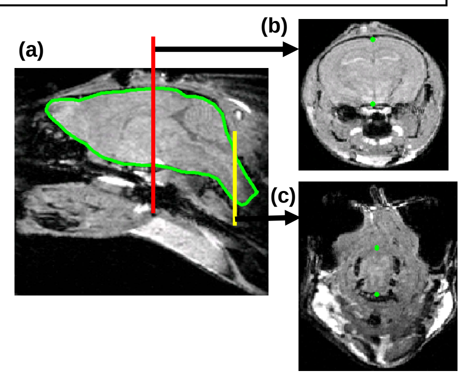

Figure 1. An illustration of the pin definition from a central sagittal brain contour

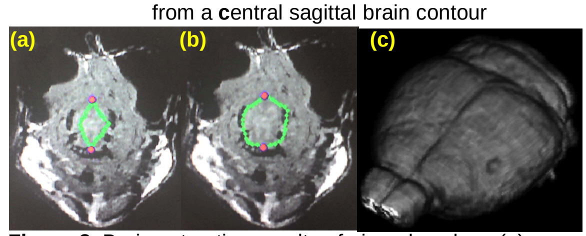

Figure 2. Brain extraction results of pinned snakes. (a) an initial pinned snake; (b) a final pinned snake; (c) The 3D brain extracted using pinned snakes

Results: Fig. 1 shows the results of the brain extraction of one mouse. To be concise, only one contour was drawn on the central sagittal slice (Fig. 1a). The pins on each coronal slice were extracted from this contour (Fig.1b, c). The initial snake on a slice was generated from its pins (Fig 2a) and the pins along with the energy functional of continuity, smoothness, balloon force and gradient deformed the snake and accurately segmented the brain tissue (Fig 2b). This coronal slice is chosen to show the pinned snake because the brain and skull are connected and have similar intensity. The 3D volume of the extracted brain is shown in Fig. 2c. The brain extraction results were compared to the brains manually extracted by an experienced researcher, and the error is <1%.

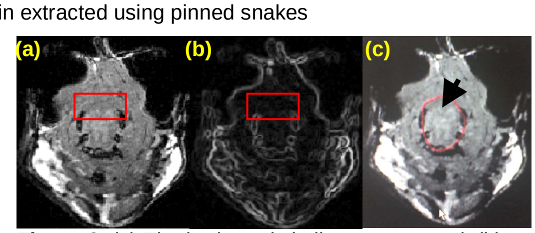

Figure 3. (a) The brain and skull are connected. (b) Gradient is 0 between the brain and skull. (c) Conventional snake without pins missed the brain

Discussion: We developed a technique to automatically introduce hard constraints (pins) in the snake energy functional and define initial snakes. This technique can accurately extract the mouse brain from an in vivo head MRI. The inclusion of pins is necessary as conventional snakes without pins missed the brain boundary and failed to segment the brain tissue from the head MRI as shown in Fig. 3. User intervention is minimal which only includes drawing one or two brain contours. The method is fast if using gradient vector flow or greedy snake. By relaxing the weighting of the smoothness, the snake can capture sharp corners. We are developing the 3D version of this technique.

References: M Kass et al, IJCV, 1998; DJ Williams and M Shah, CVGIP: Img Understanding, 1991; C Xu and JL Prince, IEEE Trans. Img. Proc., 1998