Automatic Mouse Embryo Brain Ventricle Segmentation, Gestation Stage Estimation, and Mutant Detection from 3D 40-MHz Ultrasound Data

Motivation and Challenges

Motivation
• Volumetric analysis of brain ventricles (BV) can help detect neurological disorders.
• Mouse embryos are a very useful model for these studies.

Challenges
• High frequency ultrasound (>20MHz, HFU), which is real-time and non-invasive, is gaining a wider acceptance in imaging mouse embryos. An automated segmentation algorithm for 3D HFU image would permit fast and efficient embryo staging and detection of brain phenotypes.

I. BVs and Head Segmentation

• Nested Graph Cut (NGC) [1] can simultaneously segment the BVs, head, amniotic fluid, and uterus.
• NGC defines the missing boundary by limiting the boundary of an object by the convex hull of its outer object.
• NGC does not require training data to build shape models.
• NGC can segment HFU images automatically.

II. Brain Ventricle Decomposition

• BVs are described using a Y-skeleton and the volume profile along the skeleton.

Retrieval Y-skeleton
1. Obtain raw skeleton.
2. Find the longest skeleton.
3. Determine the central node.

Decomposition
1. Obtain the volume profile of the sub-region defined by the Voronoi partition based on the sample points along the skeleton.
2. Find the boundary between components based on the volume profile.

III. Stage Embryo by Volume Vector

• Build the volume vector by computing the volume of the fourth ventricle (4v), aqueduct (aq), third ventricle (3v), and two lateral ventricles (lv).
• Stage the target embryo by computing the square error of its volume vector from the mean volume vector of each stage.

<table>
<thead>
<tr>
<th>Stage</th>
<th>E10.5</th>
<th>E11.5</th>
<th>E12.5</th>
<th>E13.5</th>
<th>E14.5</th>
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<td>13</td>
<td>5</td>
<td>4</td>
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<tr>
<td>False staging by volume vector</td>
<td>1-E11.5</td>
<td>1-E12.5</td>
<td>1-E11.5</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

IV. Detect Mutant by Volume Profile

• Enrolled 1 mutants in E12.5 are detected by comparing the volume profile in a short range around the boundary of 4v and aq.

The volume vector and volume profile of Data 1.