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

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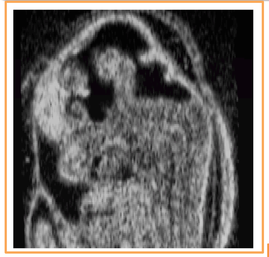
Motivation and Challenges



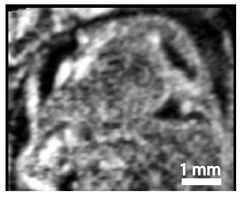
Data 1

Motivation

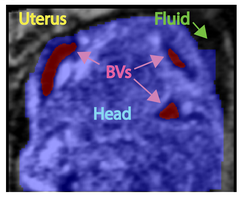
- Volumetric analysis of brain ventricles (BVs) can help detect neurological disorders.
- Mouse embryos are a very useful model for these studies.
- High frequency ultrasound (>20MHz, HFU), which is real-time and noninvasive, is gaining a wider acceptance in imaging mouse embryos. An automated segmentation algorithm for 3D HFU image would permit fast and efficient embryo staging and detection of brain phenotypes.

Challenges

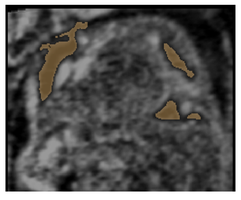
- **Segmentation:** Boundaries between BVs and the amniotic fluid regions may be missing because of the loss of ultrasound signal. The contrast between the head and uterus may be insufficient to detect the boundary between them.
- **Shape characterization:** BVs have complicated shapes. Quantities computed from the entire region (e.g. the BVs volume relative to the head volume) are not sufficient to differentiate embryos at different ages and detect mutants.



HFU image

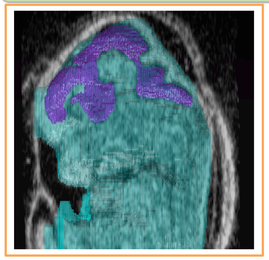


Manual segmentation

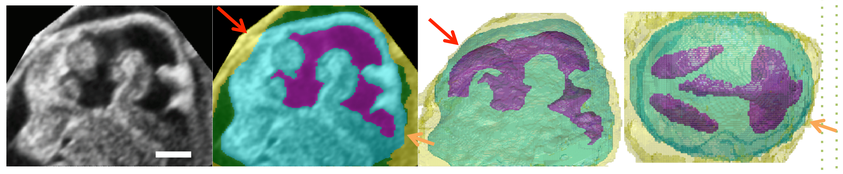


Result of region growing

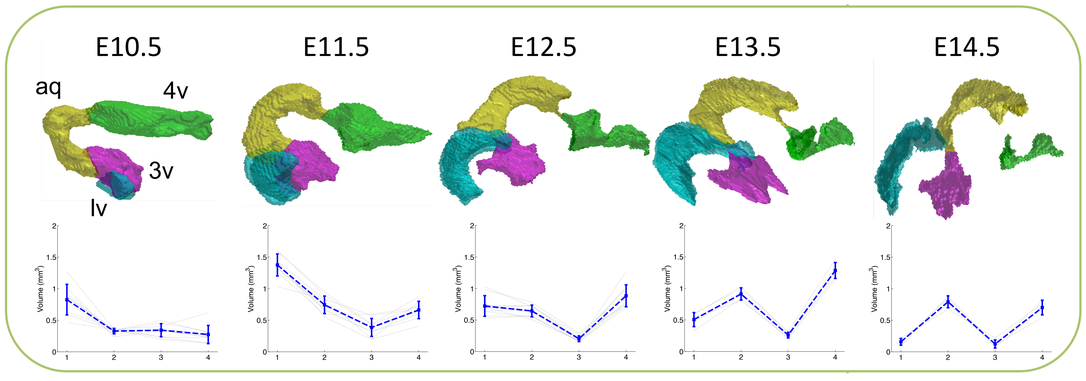
I. BVs and Head Segmentation



- 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.

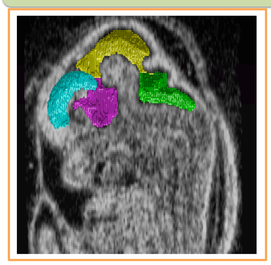


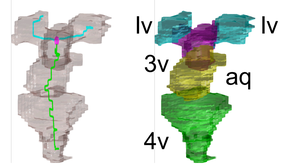
[1] J. W. Kuo, J. Mamou, O. Aristizabal, X. Zhao, J. Ketterling, and Y. Wang, "Nested Graph Cut for Automatic Segmentation of High-frequency Ultrasound Images of the Mouse Embryo," Transactions on Medical Imaging, 2015.



Decomposition results and mean volume vectors in all gestation stages.

II. Brain Ventricle Decomposition



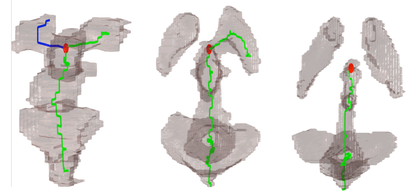


Y-skeleton and the components of BVs. Y-skeleton contains one main skeleton (green), two lateral skeletons (cyan), and one central node (red).

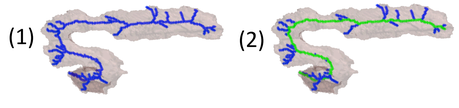
- BVs are described using a Y-skeleton and the volume profile along the skeleton.

Retrieve Y-skeleton

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

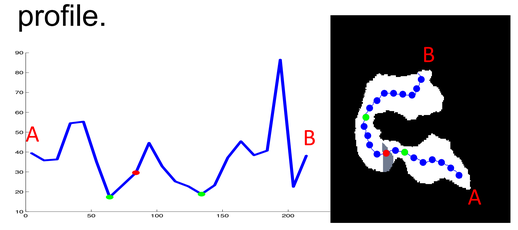


Condition a Condition b Condition c (3)



Decomposition

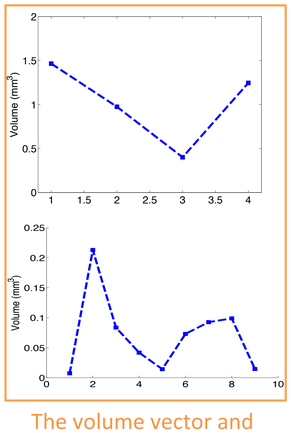
1. Obtain the volume profile of the sub-region defined by the Voronoi partition based on the sample points along the skeleton.
2. Find the boundary between components based on the volume profile.



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.

	E10.5	E11.5	E12.5	E13.5	E14.5
Total image number	9	9	13	5	4
False staging by **volume vector**	1-E11.5	1-E12.5	1-E11.5 1-E13.5	0	0



The volume vector and volume profile of Data 1.

IV. Detect Mutant by Volume Profile

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