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Using artificial intelligence for fast, reliable, and automatic segmentation of the thalamus

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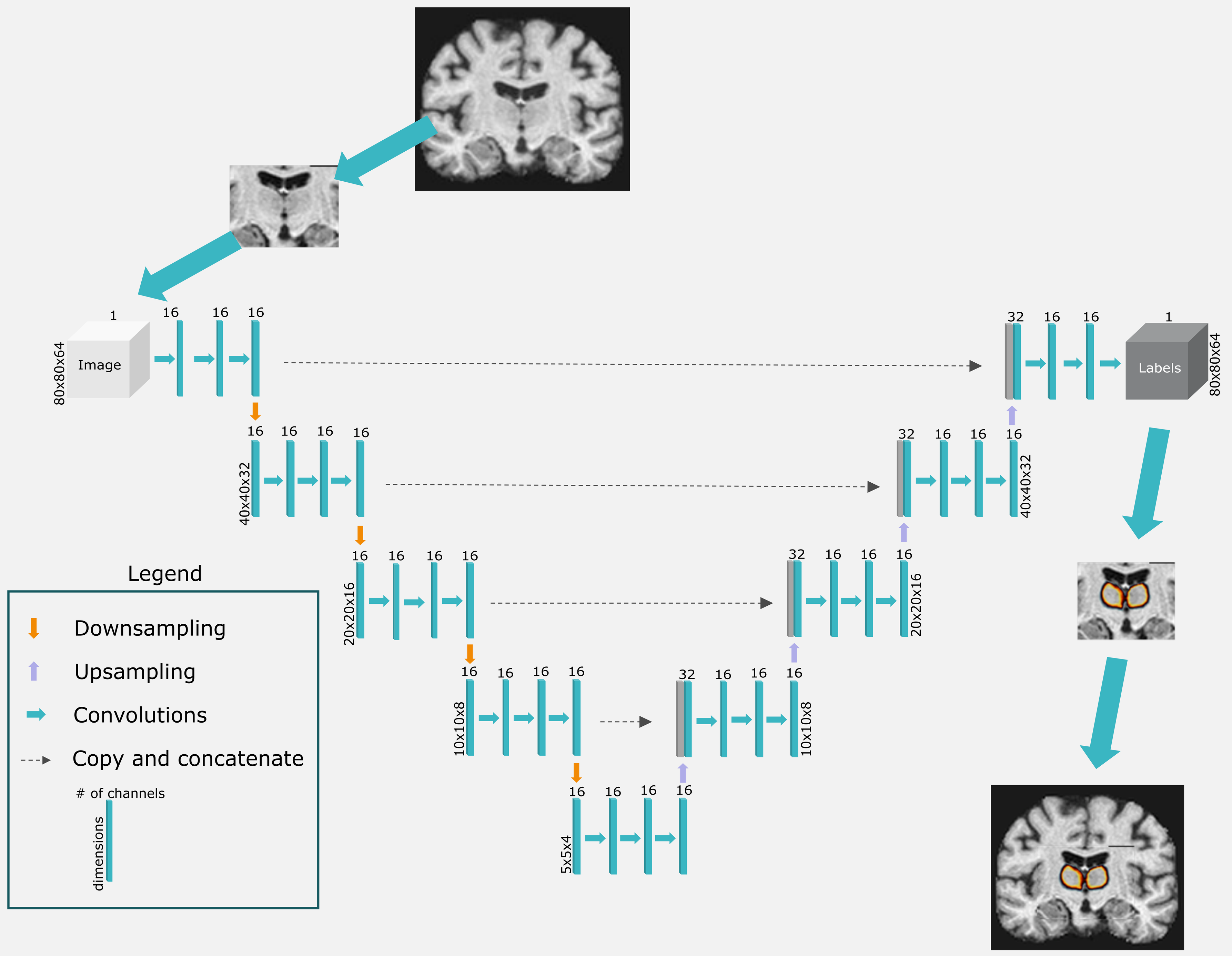
Motivation

- Changes in volume of the thalamus are used as biomarkers to track the development of Huntington's Disease (HD)
- Accurate volume calculations, obtained via segmentations, are of utmost clinical importance
- Thalamic region is particularly challenging for both manual and automated methodologies, due to unclear region boundaries

Neural network architecture

- ~218,000 trainable parameters
- Optimizer: Weighted Adam (Stochastic gradient descent)
- Loss function: Sum of Binary Cross-Entropy and Soft Dice



Methods

- Our neural network architecture features an analysis path, using 3D T1 MRI scans as an input, and a synthesis path, with the thalamus segmentation as an output (see bottom left box).
- AI was trained on 30 T1s from the OASIS dataset and their corresponding manually edited thalamus segmentations.
- Validation was done on various open-source datasets as well as in-house HD clinical trial data.
- We compared our AI against other widely used analysis tools, such as Freesurfer[3], volBrain[1], and MALP-EM[2].

Results

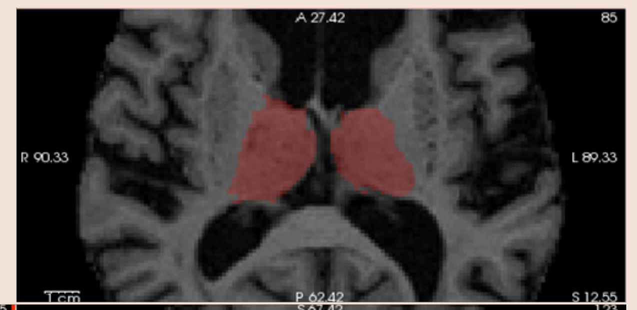
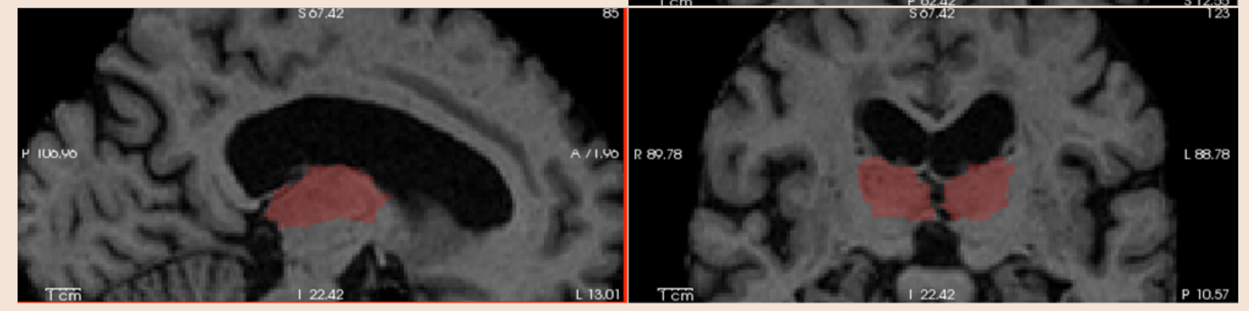
- Our AI segmentations are of superior quality throughout all datasets. They are most consistent, with smooth boundaries which overlaid the thalamus well. Furthermore, our segmentation can be processed in seconds, which is several orders of magnitude faster than the other methods.
- Freesurfer segmentations had rough boundaries, and were often too large, with the thalamus region-of-interest (ROI) spilling into neighbouring regions in both anterior and posterior directions. They also had examples whereby the ROI was excluding posterior regions of the thalamus.
- volBrain segmentations show better consistency, however, suffer from tight boundaries between the thalamus and the CSF, resulting in underestimation of the thalamus.
- MALP-EM segmentations were of fairly inconsistent quality between the datasets with a number of different types of errors, such as spillage and overestimation of the volume.

[1] Manjón, J.V. and Coupé, P., 2016. volBrain: an online MRI brain volumetry system. Frontiers in neuroinformatics, 10, p.30.
[2] Ledig, C., Heckemann, R.A., Hammers, A., Lopez, J.C., Newcombe, V.F., Makropoulos, A., Lötjönen, J., Menon, D.K. and Rueckert, D., 2015. Robust whole-brain segmentation: application to traumatic brain injury. Medical image analysis, 21(1), pp.40-58.
[3] Fischl, B., 2012. FreeSurfer. Neuroimage, 62(2), pp.774-781.

Algorithm Comparison

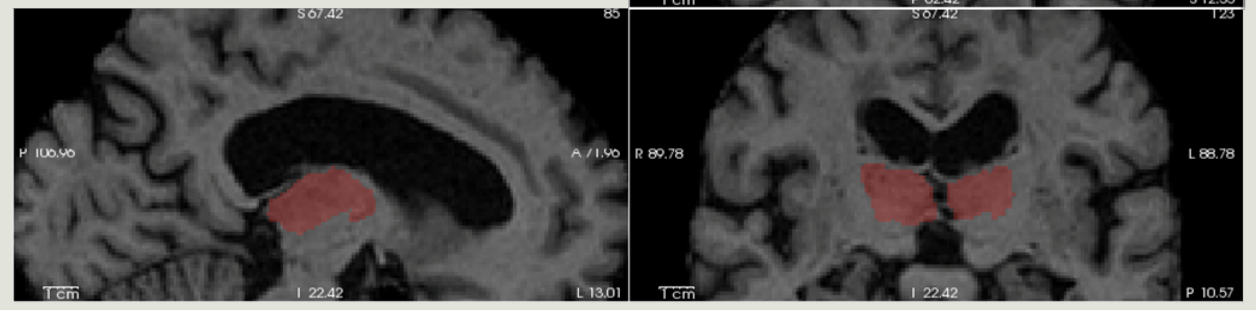
Freesurfer[3] (7.1)

- Jagged edges
- Spillage into other regions

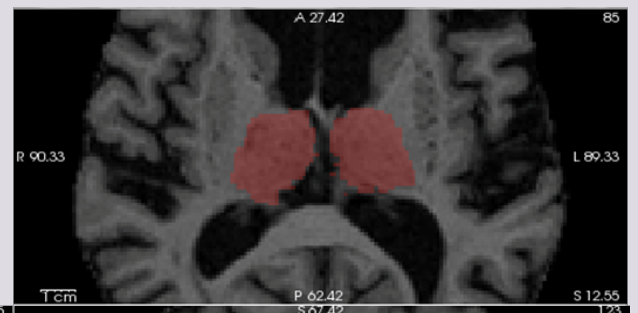
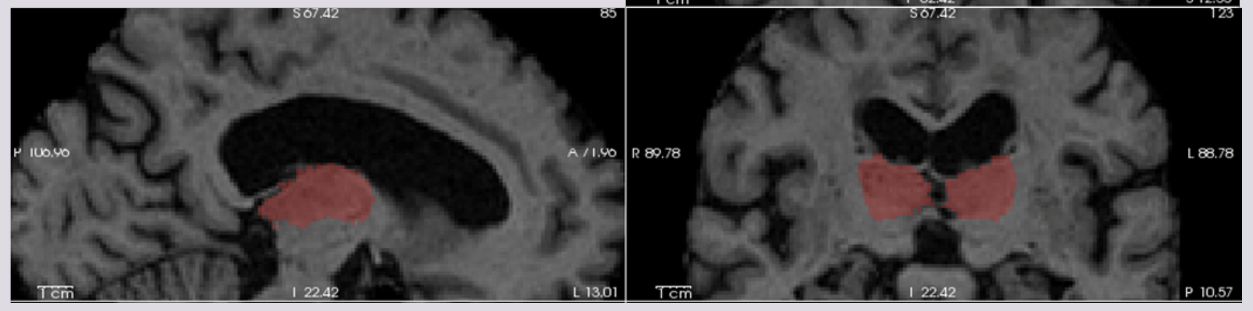
volBrain[1]

- Good white-matter boundary
- Underestimation
- Highest failure rate

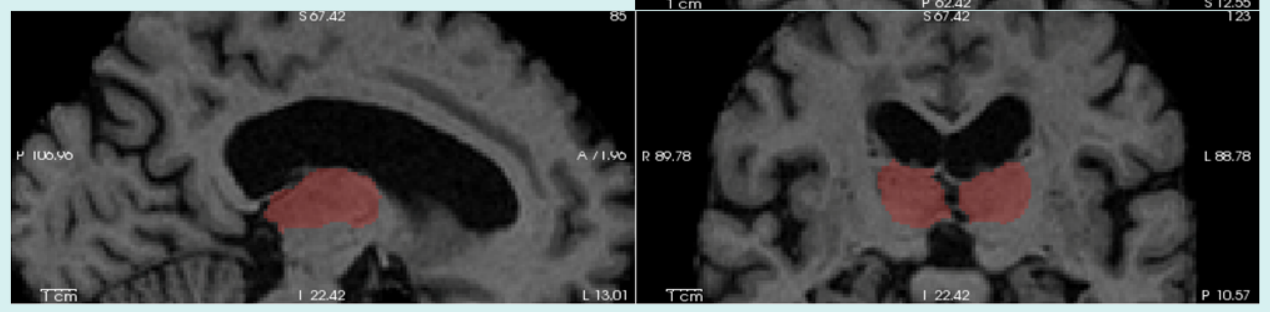
MALP-EM[2]

- Inconsistent quality
- Spillage into other regions
- Overestimation

Our AI

- Most consistent
- No failures

For comments, business proposals, collaborations and more, please contact us at ixico.com or send an email to the author: michael.reinwald@ixico.com