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A Fully Automatic Pipeline for Estimation of Putamen and Caudate Volume

Introduction

The caudate and putamen are subcortical structures sensitive to progression of Huntington's Disease (HD). The volume and volume change in these regions has been used as a marker of potential treatment within clinical trials.

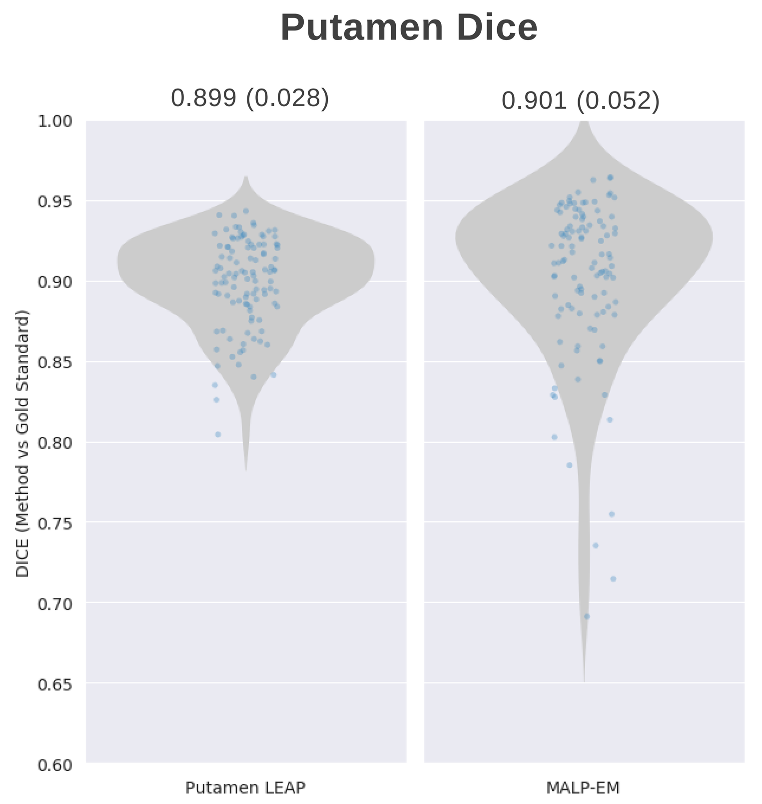
Manual segmentations of these structures is considered the “Gold Standard”, however this is a time-consuming, expensive and laborious process which is subject to inter- and intra-rater variance making manual segmentation prohibitive for large clinical trials.

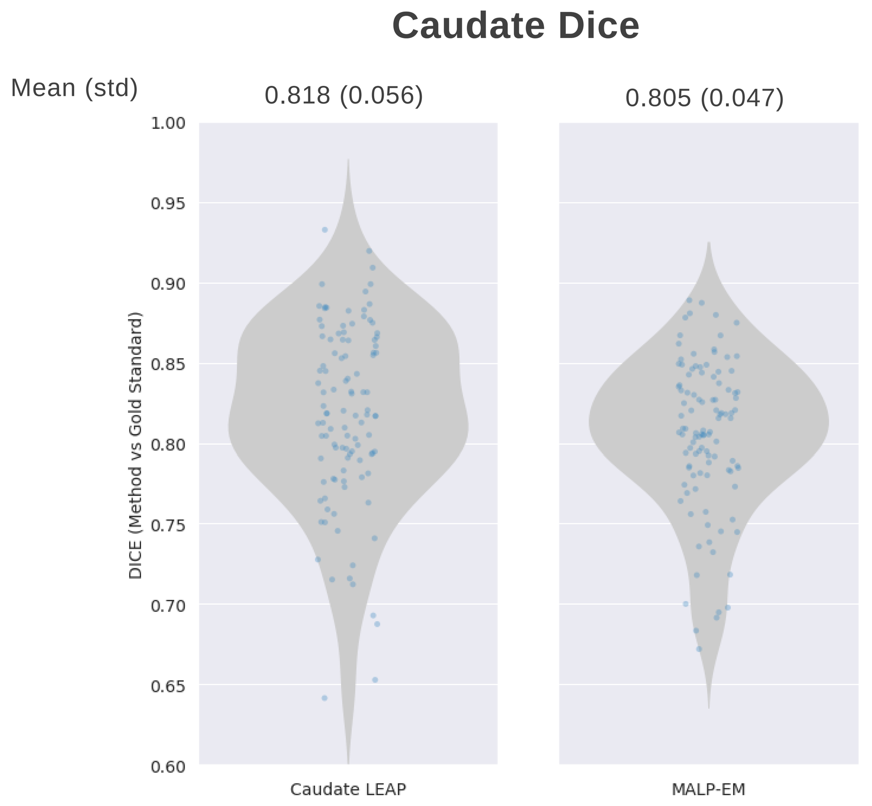
Here we present a fully-automatic pipeline for consistent segmentation of the caudate and putamen, removing human variance in segmentation and providing a scalable solution for segmentation in clinical trials reporting high consistency with manual segmentation.

Results

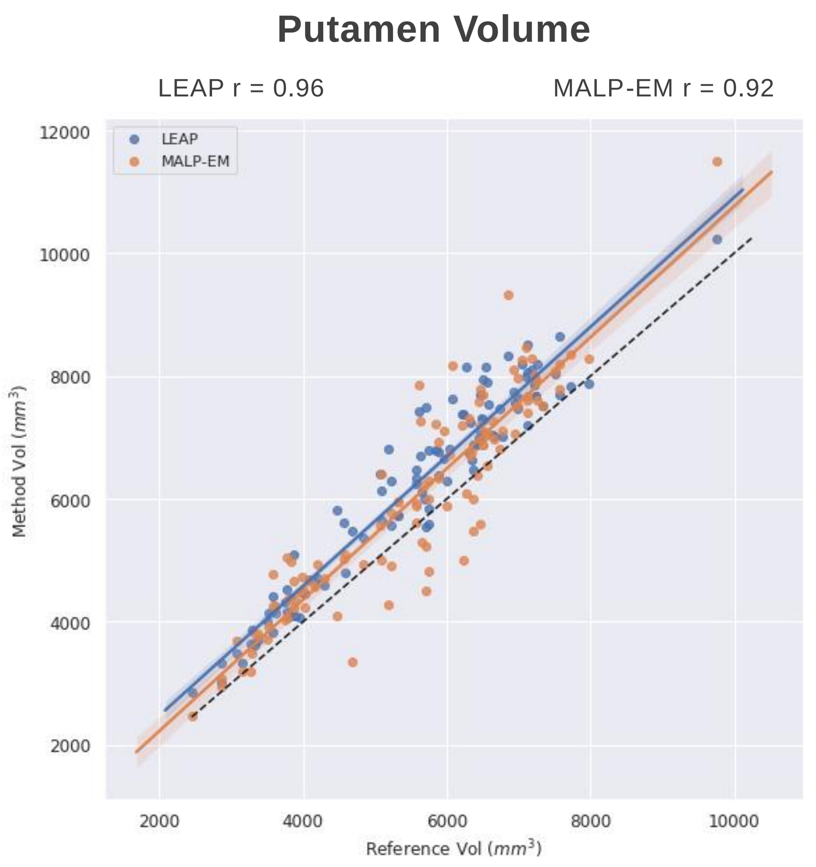
For 100 T1W images from a HD cohort, gold-standard semi-automatic segmentations for the caudate and putamen were compared with the proposed LEAP method and MALPEM [2], a fully automatic whole-brain parcellation method.

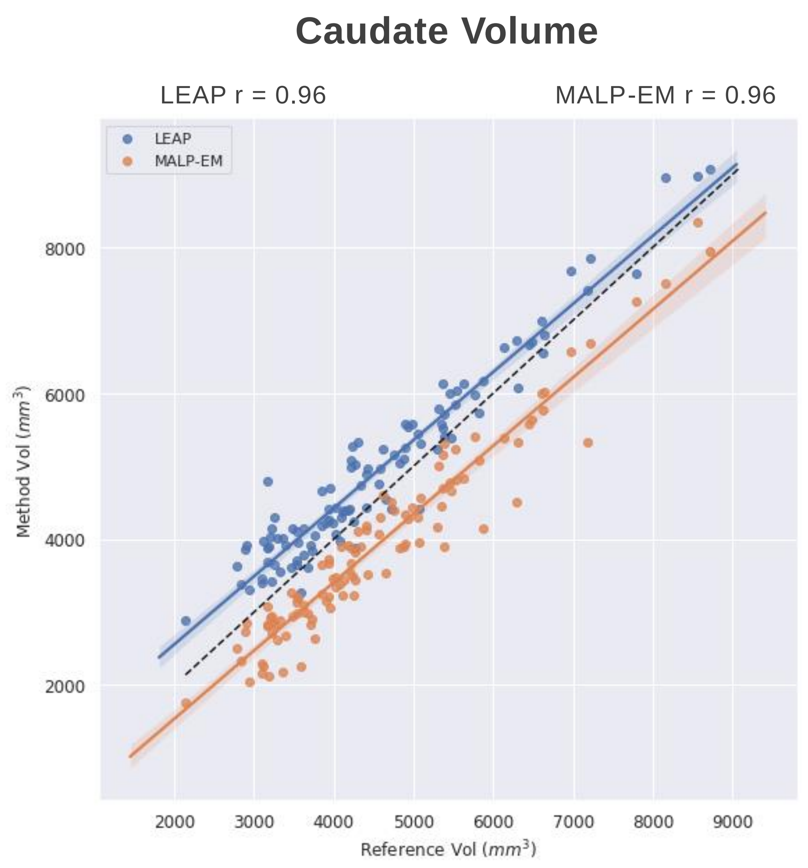
Spatial overlap (DICE) scores between reference segmentations and the automatically generated segmentations for both the caudate and putamen show comparable results for the MALPEM and LEAP methods, with both methods reporting a high degree of consistency (mean DICE > 0.8).





Putamen and caudate volumes estimated with MALPEM and LEAP reported a significant (p<0.001) correlation with the reference segmentation volume.





Visual quality assessment (QA) was performed on the automatically generated putamen and caudate segmentations for a subset of 50 images randomly selected from the test dataset. The rater was blinded to the method and the same high quality pass criteria applied to all segmentations viewed.

N = 50	Method	Putamen	Caudate
Pass %	LEAP	80%	88%
	MALPEM	20%	38%

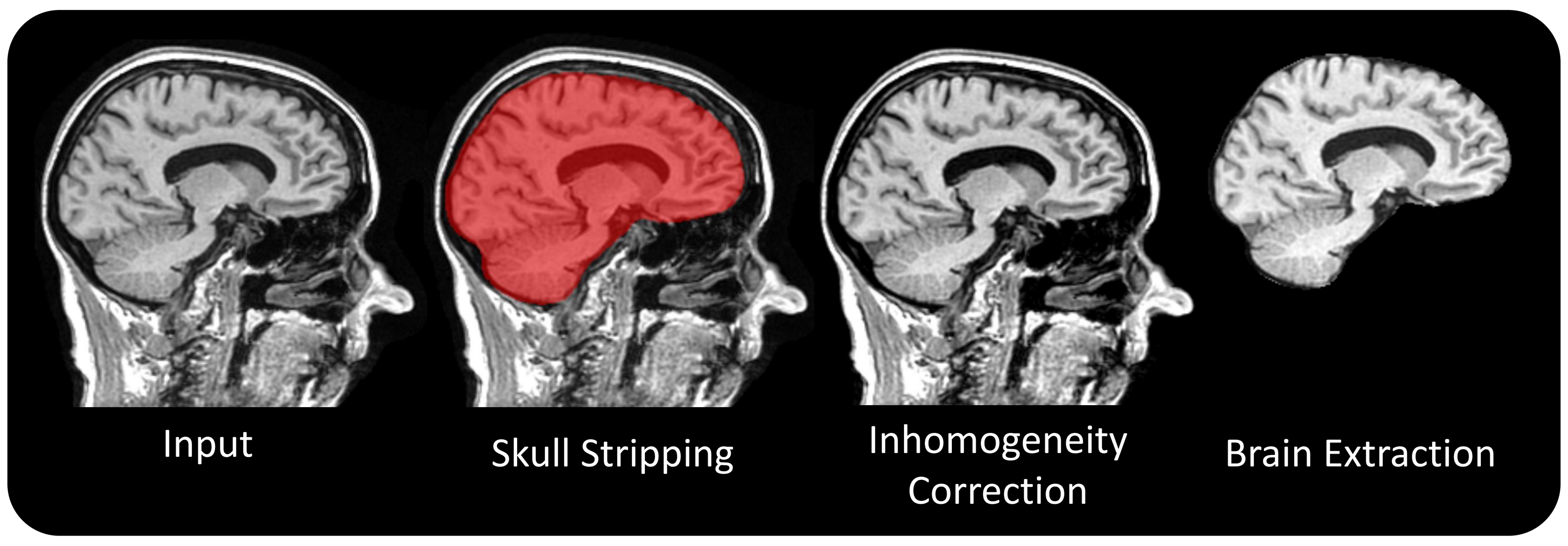
References

1. Wolz, R., Aljabar, P., Hajnal, J.V., Hammers, A., Rueckert, D. and Alzheimer's Disease Neuroimaging Initiative, 2010. LEAP: learning embeddings for atlas propagation. *NeuroImage*, *49*(2), pp.1316-1325.
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.

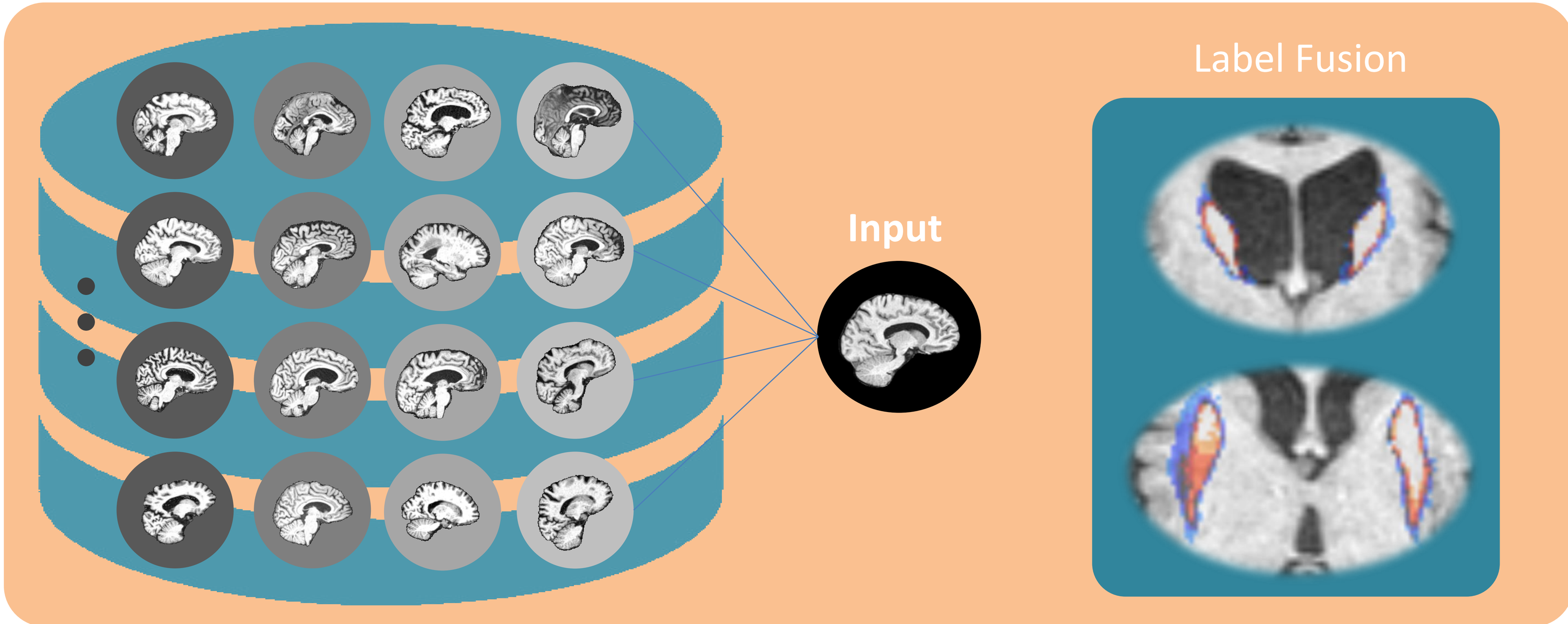
Methodology

We employ LEAP [1] a fully automatic, multi-atlas approach for regional segmentation to generate two pipelines for parcellation of 1) the putamen and 2) the caudate.

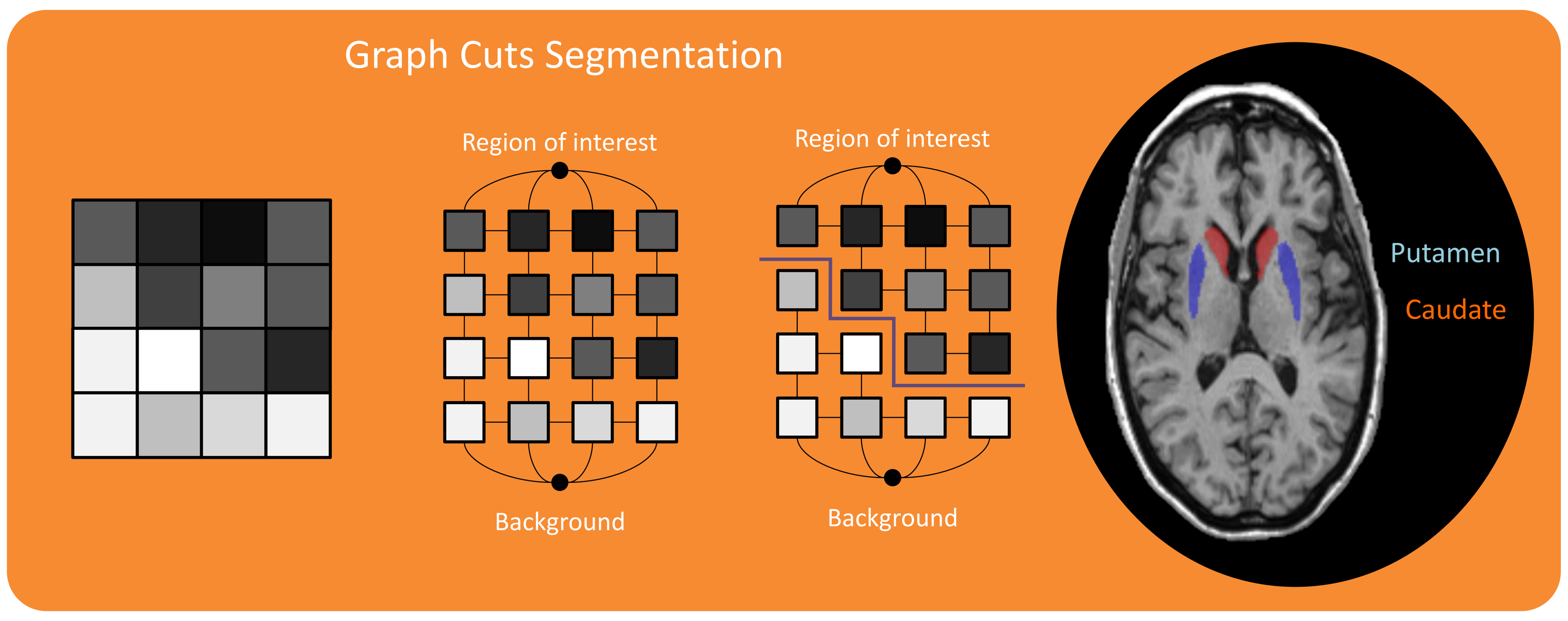
In this approach an input T1W image is pre-processed with brain extraction and inhomogeneity correction.



The pre-processed image is compared to a reference database of T1W images with existing gold-standard segmentations. The closest 10 reference images, selected in manifold space, are registered to the input image and reference segmentations fused to create an initial probabilistic atlas for the target region.



Here a reference database was generated from semi-automatic caudate and putamen segmentations in ADNI reference images. The initial label fusion segmentations generated from this reference database are subsequently refined with a graphs-cut segmentation, where graph-cuts parameters were refined using a grid search and optimised against images with a gold standard. This resulted in a final refined segmentation of the target region.



Conclusions

We have demonstrated the application of LEAP to generate fully automatic segmentations of the caudate and putamen allowing for scalable volumetrics in a clinical trial setting, removing the variance and cost associated with manual segmentation.

The LEAP pipeline performed well when compared to gold-standard segmentations and MALPEM, a fully automatic alternative parcellation technique, optimised for whole brain segmentation. LEAP was found to report greater rates of acceptable high quality data when assessed visually compared to MALPEM; demonstrating the advantage of such a regionally optimised segmentation technique, especially for regions with challenging bounds such as the putamen, which reported a low QA pass rate.

This pipeline could be potentially further improved with the refinement of the reference database to include gold standard segmentations from a HD population.