

## Olfactory bulb (OB) pipeline documentation

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Date: December 13 2023

Version: 1.0

In this document you will find all required information to start using the data generated from the Rhineland Study olfactory bulb (OB) MRI pipeline.

## 1 Methods

### 1.1 Segmentation pipeline

All OB MRI structural information is extracted from the predicted segmentation maps generated from the in-house pipeline developed by Estrada et al. (1). The in-house pipeline is a fully automated deep learning pipeline to accurately segment OB tissue on high-resolution T2-weighted (T2w) whole-brain MRI. Overall, the deep learning pipeline consists of three stages:

1. **Localization** of a region of interest (ROI) containing the OBs of both hemispheres using a semantic segmentation approach by implementing *FastSurferCNN* (2); we use the centroid of the predicted region as a center point for cropping a localized volume.
2. **Segmentation** of OB tissue within the localized volume through four *AttFastSurferCNN* - a novel deep learning architecture with a self-attention mechanism (3) to improve modeling of contextual information - with different training condition (four data-splits and data initialization).
3. **Ensemble** stage where the previously generated label maps are averaged and view-aggregated to form a consensual final segmentation.

### 1.2 T2-weighted sequences

The T2w sequences used in the study are as follow:

- MRI scans from the Rhineland Study were collected at two different sites both with identical 3T Siemens MAGNETOM Prisma MRI scanners (Siemens Healthcare, Erlangen, Germany) equipped with 64-channel head-neck coils. The 0.8 mm isotropic T2-weighted 3D Turbo-Spin-Echo (TSE) sequence uses variable flip angles (4) as well as elliptical sampling (5) and parallel imaging (PI) (6) for faster imaging. Up to now, there have been three modifications ( $T2w^{b-d}$ ) to the original protocol ( $T2w^a$ ). Common sequence parameters are as follows: repetition time (TR) = 2800 ms, echo time (TE) = 4405 ms, matrix size =  $320 \times 320 \times 224$ . The following parameters differ between protocols: phase-encoding direction: a, c, d: Anterior > Posterior; b: Right > Left, PI acceleration factor: a-b: 3x1; c: 2x1, d: 1x2 with one CAIPIRINHA shift (7), PI reference scan: a-b: integrated; c-d: external, acquisition time: a: 3:57 min, b: 4:30 min, c-d: 4:47 min. Note, care was taken to preserve the image contrast between all four versions.

## 2 How to cite

If you use the OB MRI data please cite :

- Santiago Estrada, Ran Lu, Kersten Diers, Weiye Zeng, Philipp Ehse, Tony Stöcker, Monique M. B. Breteler, Martin Reuter, Automated olfactory bulb segmentation on high resolution T2-weighted MRI, NeuroImage, Volume 242, 2021, 118464, ISSN 1053-8119, <https://doi.org/10.1016/j.neuroimage.2021.118464>.

**Citation example:** Olfactory bulb tissue features were obtained using the post-processing pipeline proposed by Estrada et al. (1) on T2-weighted whole-brain MRI.

## 3 Variables

The pipeline variables summary are presented on Table 1 .

Table 1: OB Variables Summary

Variable ID	Name	Description
<b>*_OB.Volume.mm3</b>	Olfactory bulb volume (Left, Right or Total)	Volume estimates of the olfactory bulb. UNIT: Cubic millimeters
<b>*_OB.NVoxels</b>	Olfactory bulb number of voxels (Left, Right or Total)	Number of segmentend voxels of the olfactory bulb.
<b>*_OB.normMean</b>	Olfactory bulb intensity normMean (Left, Right or Total)	Intensity normMean of the olfactory bulb region.
<b>*_OB.normMin</b>	Olfactory bulb intensity normMin (Left, Right or Total)	Intensity normMin of the olfactory bulb region.
<b>*_OB.normMax</b>	Olfactory bulb intensity normMax (Left, Right or Total)	Intensity normMax of the olfactory bulb region.
<b>*_OB.Entropy</b>	Olfactory bulb prediction entropy (Left, Right or Total)	Entropy of the olfactory bulb predictions between the 12 ensemble models.
<b>*_OB.CV</b>	Olfactory bulb volumes estimates coefficient of variation (Left, Right or Total)	Coefficient of variation of the olfactory bulb volume estimates between the 12 ensemble models.
<b>*_OB.CM</b>	Olfactory bulb center of mass (Left, Right or Total)	Center of mass of the olfactory bulb in array space from the generated segmentation map.
<b>loc_cm</b>	Localization network center of mass	Center of mass of the olfactory bulb predicted by the localization network in array space.
<b>seg_cm</b>	Segmentation center of mass	Center of mass of the olfactory bulb extracted by the generated segmentation in array space.
<b>dist.mm</b>	Distance between the loc_cm and seg_cm	Distance between the generated center of mass UNIT: millimeters .
<b>mse.px</b>	Mean square error between the loc_cm and seg_cm	Mean square error between the generated center of mass.
<b>ROI.NVoxels</b>	Number of voxels of the forebrain ROI	Number of voxels of a the forebrain region containing the OB from the localization network .
<b>in_image</b>	T2 input image	the T2-weighted MRI used as input to the pipeline.
<b>Flags</b>	Olfactory bulb pipeline flags	Pipeline warning flags.

## References

- [1] S. Estrada, R. Lu, K. Diers, W. Zeng, P. Ehse, T. Stöcker, M. M. Breteler, M. Reuter, Automated olfactory bulb segmentation on high resolutional t2-weighted mri, *NeuroImage* (2021) 118464.
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- [3] H. Zhang, I. Goodfellow, D. Metaxas, A. Odena, Self-attention generative adversarial networks, in: International conference on machine learning, PMLR, 2019, pp. 7354–7363.
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