On Data-related And Methodological Challenges in Analysis of Structures From Population-based MRIs: An Obstructive Sleep Apnea Application

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Introduction

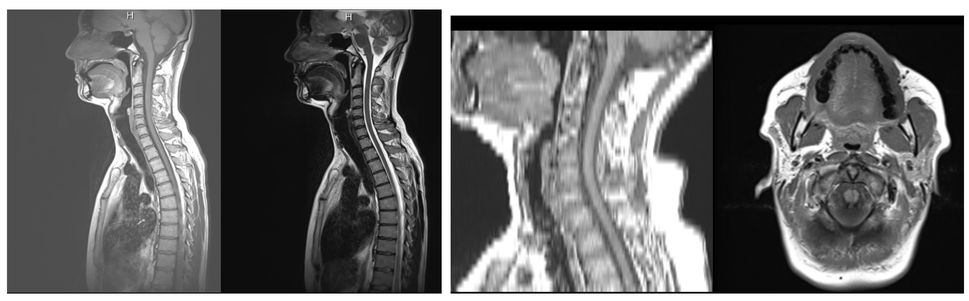
- Obstructive sleep apnea syndrome (OSAS) [1] is a sleep disorder affecting $2-7\%$ of middle-aged population.
- Recurrent episodes of partial and complete airway obstructions during sleep.
- The causes and factors are not fully understood.
- Project: Investigation of anatomical risk factors of OSAS from magnetic resonance imaging (MRI) in the general population (DFG Project IV 161/4-1).
- Objectives: (1) automated segmentation and measurements of pharynx, tongue, parapharyngeal fat pads, and soft palate; (2) statistical analysis of new generated data with sleep variables.

Discussion . . .

. . . of challenges during data selection, development of the automated pipeline, and its application to numerous appropriate datasets.

Epidemiological MRI Data

- Only few European cohort studies have MR and sleep data available.
- **Study of Health in Pomerania** (SHIP) [2]
- No specially dedicated MR sequence for our purposes, but the organs of interest are imaged in other sequences
- Mid-sagittal T1-weighted and T2-Weighted TSE (turbo spin echo) sequences registered by acquisition with resolution: $1.116 \times 1.116 \times 4.4\ mm^3$. Spatial resolution: 448×448, and the number of slices varied from 15 to 19.
- Axial T1-weighted TSE neck sequence ($1.0 \times 0.8 \times 4.0\ mm^3$), Spatial resolution: $256 \times 256 \times 40$

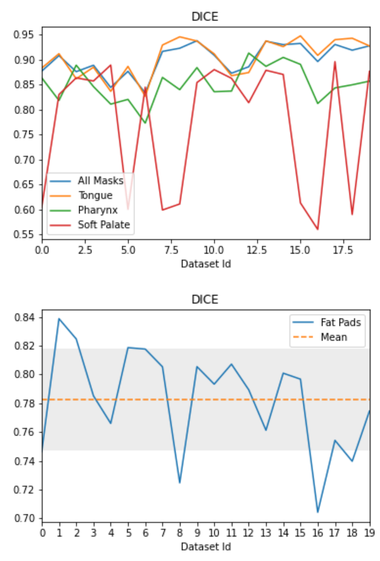


Challenges and Strategies

- **Low data resolution**. Segmentation is challenging even for a human observer.
  - Strategy: **Measure Intra-Observer Variability**.
- **Small ROI classes**. Classes are imbalanced.
  - Strategy: **Use prior anatomical knowledge to exclude unnecessary data**.
- **Anisotropic voxels**.
  - Strategy: **Try 2D and 3D Network architectures for segmentation**. U-Net, different loss functions.

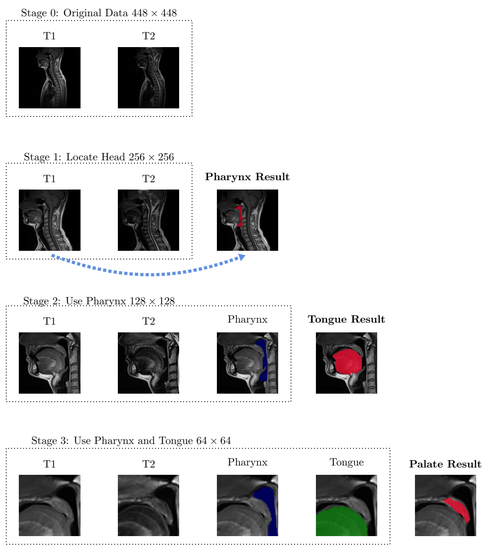
Intra-observer Variability

- A double reading of 20 datasets within one month interval;
- Random order; not allowed to view the results of the first reading
- The averaged Dice values: 0.865 ± 0.035, 0.904 ± 0.04, 0.776 ± 0.13, 0.783 ± 0.03 for pharynx, tongue, soft palate, and fat pads, respectively.
- That is the aim for the automated detector.



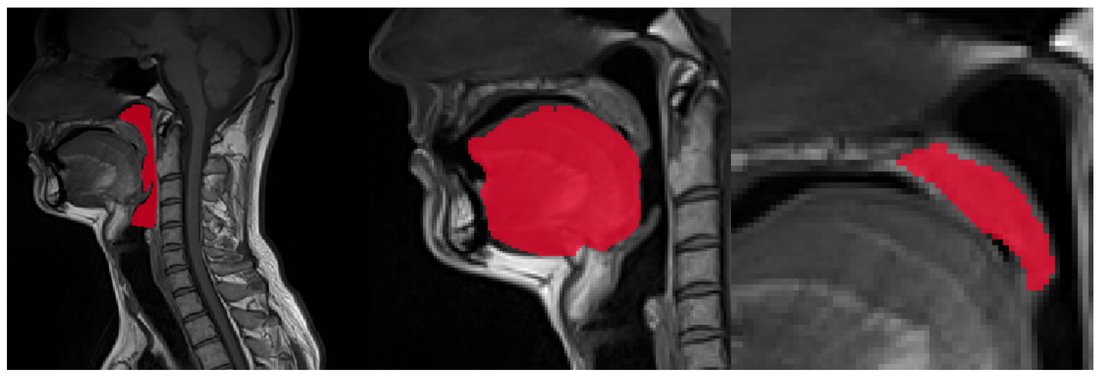
Methods I

- A cascaded framework for processing [3]
- Localization of the oral cavity region and efficient segmentation of pharynx, tongue, and soft palate;
- 2D UNet-like Networks on each segmentation stage;
- Structures from previous stages serve as physiological landmarks for region of interest detection on the current stage.
- Pharynx is segmented in T1-weighted MRI sequence;
- Tongue and Soft palate are found in T1- and T2-weighted data



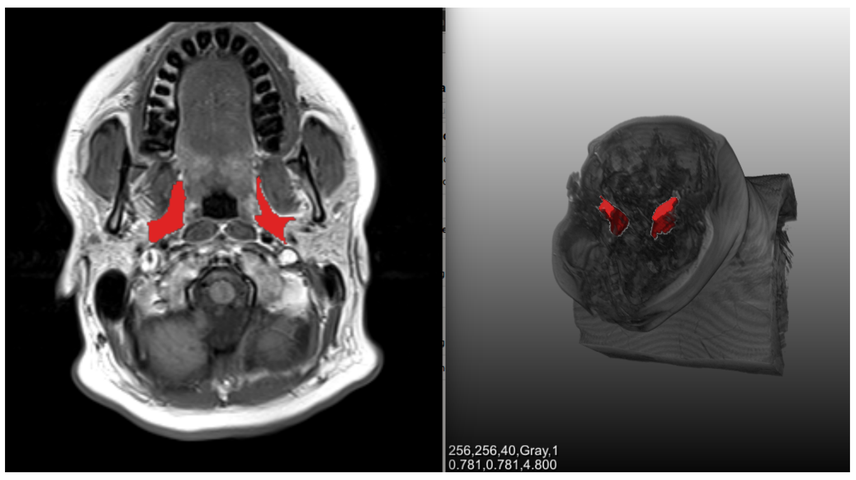
Results I

- Segmentation accuracy using 2D networks in the range of intra-observer variability in all levels: Dice of 0.89 ± 0.03, 0.87 ± 0.02, 0.79 ± 0.08 for tongue, pharynx, and soft palate tissues, respectively.
- Example cropping and correspondent segmentation results are shown below.



Methods and Results II: Fat Pads

- Parapharyngeal fat pads are two symmetrical visually bright structures, laterally located to pharynx;
- No specific shape
- Similar strategy to elimination of irrelevant regions
- Comparison of 2D and 3D networks
- The most successful network produced results with Dice $\approx 78\%$.
- Example 2D and 3D views with overlaid segmentation results are shown below.



Conclusions and Work-In-Progress

- The deep segmentation framework was applied to all available datasets;
- The proposed strategies were efficient and lead to accurate results;
- Consistency with intra-observer variability;
- From the segmented masks new variables including volumes, cross-sectional areas and between-organ distances were computed;
- The statistical analysis is currently performed.

References

[1] K A Franklin and E Lindberg. Obstructive sleep apnea is a common disorder in the population a review on the epidemiology of sleep apnea. *Journal of thoracic disease*, 7(8):1311, 2015.

[2] U John et al. Study of health in pomerania (ship): a health examination survey in an east German region: objectives and design. *Sozial-und Präventivmedizin*, 46(3):186–194, 2001.

[3] Tatyana Ivanovska, Amro Daboul, Oleksandr Kalentev, Norbert Hosten, Reiner Biffar, Henry Völzke, and Florentin Wörgötter. A deep cascaded segmentation of obstructive sleep apnea-relevant organs from sagittal spine mri. *International Journal of Computer Assisted Radiology and Surgery*, 16(4):579–588, 2021.