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

Tatyana Ivanovska1, Amro Daboul2, Oleksandr Kalentev4
1Department for Computational Neuroscience, Georg-August University Göttingen; 2Technical University of Applied Sciences Amberg-Weiden; 3University Medicine Greifswald; 4University of Greifswald (Alumni)

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 x 1.116 x 4.4 mm³. Spatial resolution: 448 x 448, and the number of slices varied from 15 to 19.
- Axial T1-weighted TSE neck sequence (1.0 x 0.8 x 4.0 mm³), Spatial resolution: 256 x 256 x 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

Methods I

- A cascaded framework for processing [3]
- Localization of the oral cavity region and efficient segmentation of pharynx, tongue, and soft palate;
- 2D U-Net-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.

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 x 1.116 x 4.4 mm³. Spatial resolution: 448 x 448, and the number of slices varied from 15 to 19.
- Axial T1-weighted TSE neck sequence (1.0 x 0.8 x 4.0 mm³), Spatial resolution: 256 x 256 x 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 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 ≈ 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