BREATHING SOUND DETECTOR AS A MEANS TO IDENTIFY POSSIBLE APNEIC PERIODS FROM TRACHEAL SOUND RECORDINGS

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INTRODUCTION

Tracheal sound represents an easily acquired signal, particularly popular in the evolution of smartphone-based systems for Sleep Apnea Syndrome (SAS) diagnosis. The syndrome is characterized by partial or complete breath cessation for at least 10 s.

The major issues that emerge in the endeavor to develop home-based systems for SAS diagnosis are:

1. The **inter-patient variability** of the breathing sound signal.
2. The **intra-patient variability** of the breathing sound characteristics affected by factors such as the body position during sleep.
3. The **intra-night variability of the Apnea Hypopnea Index (AHI)**, defined as the average count of apnea/hypopnea events per hour of sleep.
4. The recent tendency towards the **specifically delineated in time apneic/hypopneic events** rather than extracting a general characterization of the patient with respect to the syndrome's severity.

IN THIS STUDY

We developed a complex breathing detector system relying on four sound features:

1. The **signal power**
2. The **Tsallis entropy**
3. The **Shannon information** — Complexity metrics
4. The **zero-crossing ratio**

to perform detection of all apnea/hypopnea periods from the tracheal sound signal.

THE DATASET

The data were collected by 178 patients undergoing a poly-somnography (PSG) study in the Sleep Laboratory of Sismanoglio General Hospital of Athens with simultaneous recording of tracheal sound by a high quality contact microphone (electret, 900 Ω impedance, sampling frequency 48 kHz, spectral response range: 350 Hz – 8 kHz).
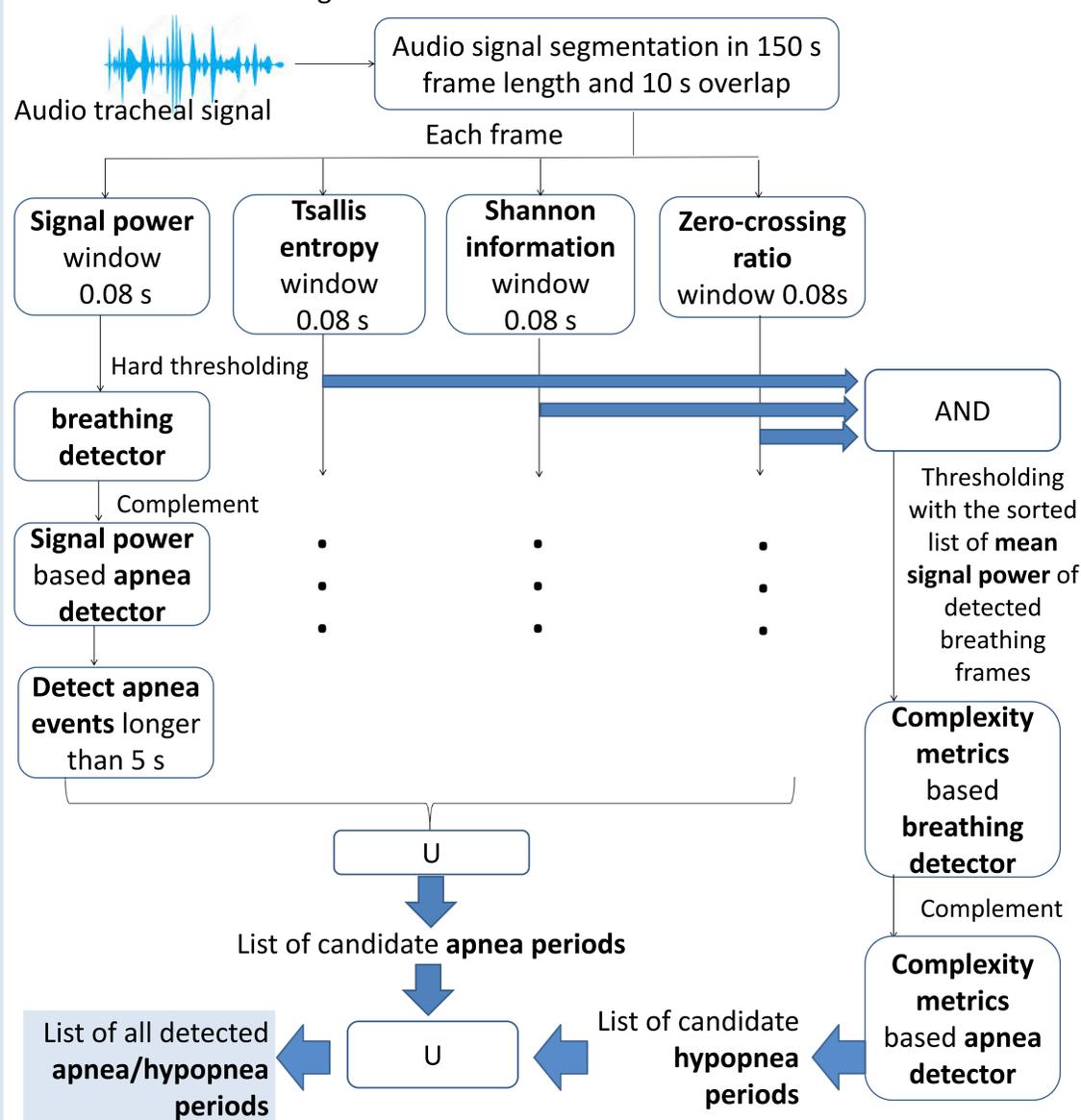
Gender (Number of patients and %)	Male: 136 (76.4 %)	Female: 42 (23.6 %)	Total: 178 (100 %)	
Mean age and age range (years)	Male: 58 (23-83)	Female: 58 (34-76)	Total: 58 (23-83)	
SAS severity diagnosis (number of patients and %)	Normal: 3 (1.7 %)	Mild: 1 (0.6 %)	Moderate: 14 (7.9 %)	Severe: 160(89.8 %)

Table 1. Anthropometric factors and final diagnosis of all patients participating of the dataset.

After interpretation of the PSG signals we extracted **40800 apnea/hypopnea events in the entire dataset**.

THE APNEA DETECOR'S ARCHITECTURE

The developed detector of apnea comprises 5 independent apnea detectors. The first 4 aiming at apnea periods detection are based on signal power and 3 complexity metrics: the Tsallis entropy, the Shannon information and the zero-crossing ratio. The 5th detector combines the the 3 complexity metrics-based breathing detectorswith logical AND and applies a series of thresholds extracted by the mean signal power of each detected breathing frame.

Audio tracheal signal → Audio signal segmentation in 150 s frame length and 10 s overlap

Each frame

Signal power window 0.08 s | Tsallis entropy window 0.08 s | Shannon information window 0.08 s | Zero-crossing ratio window 0.08s

Hard thresholding

breathing detector

Complement

Signal power based **apnea detector**

Detect apnea events longer than 5 s

AND

Thresholding with the sorted list of **mean signal power** of detected breathing frames

Complexity metrics based **breathing detector**

Complement

Complexity metrics based **apnea detector**

U → List of candidate **apnea periods**

List of candidate **hypopnea periods**

U

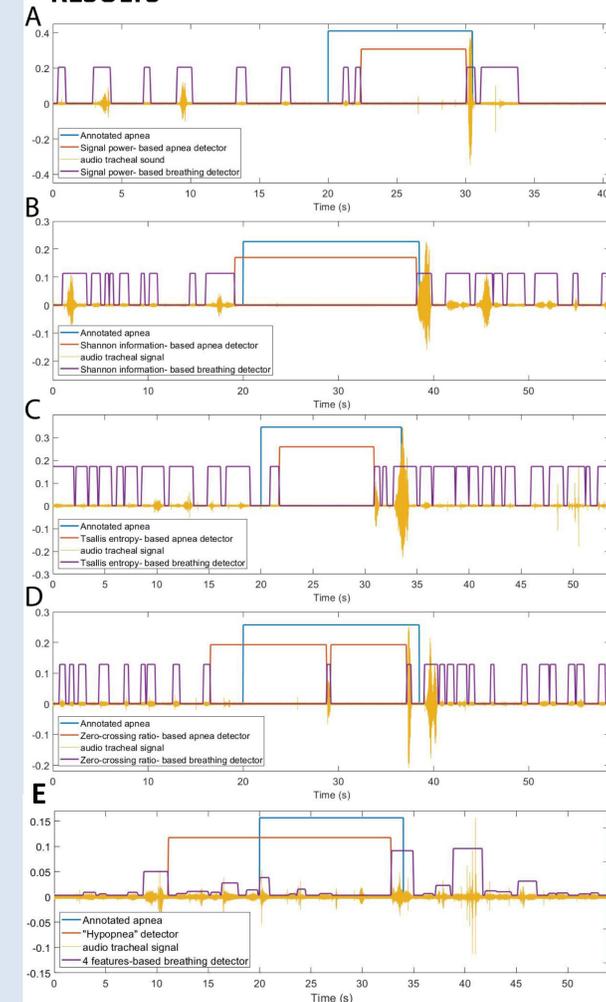List of all detected **apnea/hypopnea periods**

RESULTS

Figure1. (A-D) Examples of audio excerpts from different patients subjected to 4 features extraction and the corresponding breathing and apnea detectors. The y axis values correspond to tracheal sound amplitude while for all detectors the amplitude is equal to 1, though presented at different levels for easier interpretation. (E)Equivalently for the "hypopnea detector".

The system is capable to detect 32824 out of 40800 apnea events by inspecting the end of each detected period and provided this is located closer than 10 s to an annotated episode. **The sensitivity of the system is 80.45 % proving the dominance of the followed sound pattern in apnea events.**

	Sensitivity	Precision
Signal power- based detector	52.64 %	51.61 %
Shannon information- based detector	35.02 %	40.19 %
Tsallis entropy- based detector	36.87 %	42.31 %
Zero-crossing ratio – based detector	37.59 %	46.85 %
"hypopnea" detector	53.20 %	35.99 %

Table 2. Sensitivity and precision per patient provided by each separate detector.

The detected apneas were grouped so that all detected periods whose ends were closer than 6.5 s were considered as one. **The precision of the system per patient presents a maximum value of 80 % and a mean value of 33 %. Thus, further investigation or classification of the detected episodes is imperative to achieve high accuracy.**