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Automatic Snoring Detection from Nasal Pressure Data*

Hyo-Ki Lee, Jeon Lee, Hojoong Kim and Kyoung-Joung Lee

***Abstract*—This study presents a method for automatic snoring detection from a nasal pressure data. First, a spectrogram analysis was performed in order to obtain information about the spectral characteristic of nasal pressure data. The automatic method is based on a simple signal filtering and short-time energy technique. Fifteen patients were participated in order to evaluation the performance of the proposed method. Results are compared with manually labeled snoring events by watching video records. The sensitivity and positive predictivity value were 93.73% and 93.70%, respectively. The results in this study could provide sleep experts with the method to objectively monitor sleep-disordered breathing in CPAP system or PSG study.**

I. Introduction

Automatic snoring detection is a significant issue in multiple clinical realms for diagnosis or evaluation of sleep-disordered breathing (SDB) [1]. Snoring may lead to transient sleep disturbance bring on excessive daytime sleepiness, social disharmony and car accidents and then it causes a poor life-quality [2]–[4]. The patients with habitual snoring may require treatment such as continuous positive airway pressure (CPAP).

Most methods for automatic snoring detection are depended upon acoustical analysis of snoring sound acquired from a microphone placed on the neck or above the head [1]–[3], [5]. However, these methods require acquisition of high-quality snoring sound data and then processing of high-capacity data. Also, the microphone is limited in monitoring of respiratory variation during inspiration and expiration. Thus, the microphone-based methods are inappropriate for applying to a CPAP system.

A nasal pressure sensor is used for monitoring respiratory variation in polysomnogram (PSG) analysis and in CPAP patients. In several studies, the SDB was successfully detected using the nasal pressure sensor [6]–[7]. However, it cannot be provided with the results for automatic snoring detection.

The main purpose of this study is to provide a simple and real-time technique for automatic snoring detection from the nasal pressure data. For this purpose, simple signal processing and short-time energy technique were employed. Our basic premise was that the snoring detection from the nasal pressure data would be comparable to manually labeled snoring. If this assumption holds true, the proposed method can be useful in the CPAP system or PSG study.

II. Materials & Measurements

A. Study populations

Fifteen patients (four females) going through full-night PSG study at the Samsung Medical Center (Seoul, Korea) gave written consent to participate. The anthropometric detailed information is summarized in Table I.

B. Data Acquisition & Selection

Data were acquired from the nasal pressure sensor attached to the subject in full-night PSG study. The data were captured at a sampling rate of 200 Hz and 16-bit resolution. The snoring was manually labeled by auditory inspection of the spectrogram and by watching video records. RemLogic (Embla Systems Inc., US) software program was used for recording all PSG data and labeling the snoring events. Matlab (The Mathworks Inc., US) was used for analyzing and processing the recorded data.

III. Analysis of Nasal Pressure Data

The nasal pressure data reflects the fluctuations in pressure caused by inspiratory and expiratory effort. The unfiltered raw pressure data contains very rapid oscillation when snoring occurs and this phenomenon can be found through the frequency analysis. To analyze the spectral density over time

TABLE I. Participants' Anthropometric Data

Data set (AHI)	Participants (females/males)	Age (years) [range]	BMI (kg/m^2) [range]	AHI [range]
Mild (5~15)	4 (1/3)	43.5±17.3 [22–58]	24.7±2.8 [21.8–27.5]	7.9±1.6 [5.7–9.4]
Moderate (15~30)	6 (2/4)	56.2±10.5 [45–72]	25.9±3.5 [22.3–31.1]	22.5±2.8 [19.4–27.4]
Severe (30~)	5 (1/4)	53.0±12.1 [33–64]	28.3±3.3 [23.9–32.0]	46.8±12.6 [32.6–66.9]

BMI: body mass index, AHI: apnea-hypopnea index

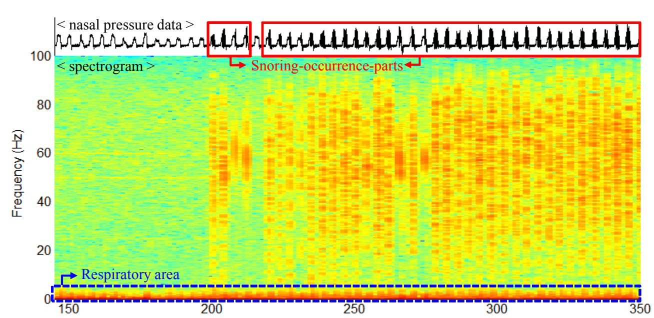

Figure 1. Raw nasal pressure data and its spectrogram.

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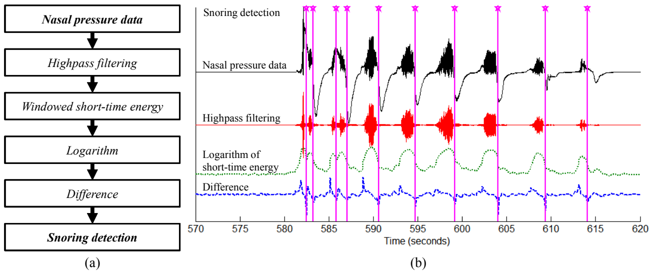

Figure 2. Schematic of proposed method for automatic snoring detection.

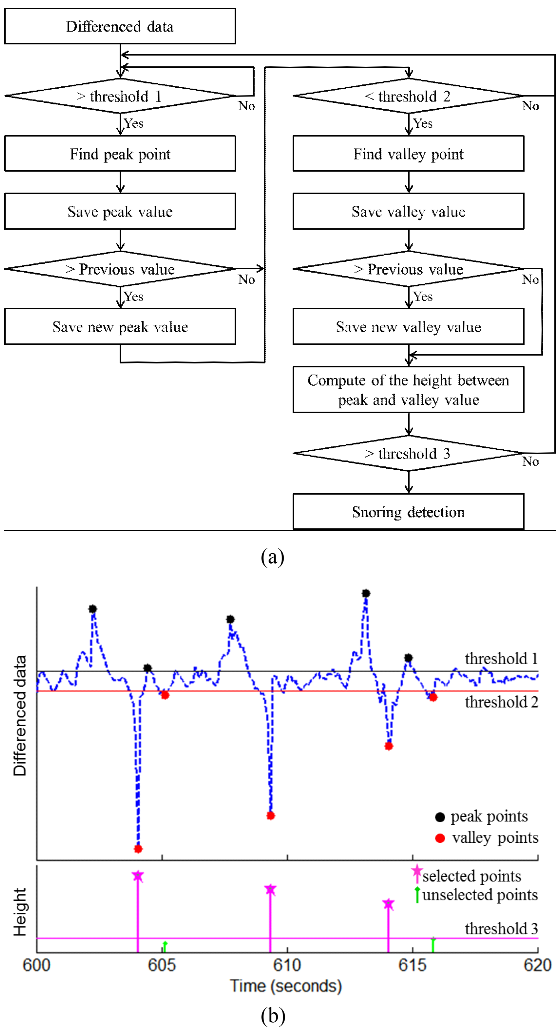

Figure 3. (a) Block diagram for snoring detection from differenced data. (b) Example of snoring detection using three thresholds (the data in Fig. 2(b) were used).

of data, the spectrogram analysis was investigated. Fig. 1 presents an example of raw nasal pressure data and its spectrogram. The dashed (blue) box indicates the frequency bands of respiration. A solid (red) box indicates the parts of the snoring occurrence. The spectrogram shows that the snoring has various frequency bands over 10 Hz. These frequency bands of snoring are overlapped with those of other noises. These characteristics vary depending on patients. Thus a snoring detection method with no regard to the specific frequency bands was proposed in this study.

IV. Automatic Snoring Detection

A schematic of the method for automatic snoring detection has been shown in Fig. 2. Detailed procedure of the method is described below.

A. Highpass filtering

The fundamental frequency range of snoring in nasal pressure data is over 10 Hz (Fig. 1). Thus, the data were processed with the highpass filter at a cutoff frequency of 10 Hz to remove low frequency component associated with respiratory effort (red line in Fig. 2). In this study, the values of data were rescaled in the range of -100 to 100 from a range of 0 to 2^{16}-1 for computational convenience.

B. Short-time energy and logarithm

The short-time energy (STE) reflects amplitude variation of data and is simply computed as in (1).

$$E_t = \sum_{m=0}^{N-1} x'^2[m]w[t-m] \qquad (1)$$

where x' is filtered data, w is the sliding window function with 101 window lengths (approximately 0.5 seconds), t is time index and N is the length of the window. The STE was computed every 10 samples (0.05 seconds). Then, the STE values were rescaled by logarithm function in order to determine suitable settings for the threshold values for snoring detection (dotted green line in Fig. 2).

C. Difference

The logarithmic STE data was differenced by subtracting the data point of previous time from that of present time for approximation of the first derivative (dashed blue line in Fig. 2). The difference was used for detection of end-point of each snoring event.

D. Snoring detection

Fig.3 highlights the detailed procedure for snoring detection from the differenced data. First of all, a peak point should be detected by threshold 1. Then a valley point should be detected by threshold 2. When the valley point was decided, the height between the peak and valley point is computed. If the height is over threshold 3, then the point was selected as snoring. Otherwise, the point was not selected. This procedure is repeated. In this study, three thresholds were experimentally decided as 0.15, –0.30 and 1.0, respectively.

V. Results

The performance of the method was evaluated by examining the sensitivity and positive predictivity value (PPV). The sensitivity indicated that real events have been correctly extracted. The PPV denotes that extracted events are correct. Their definitions are expressed as follows:

$$\text{Sensitivity (\%)} = \frac{\text{TP}}{\text{TP+FN}} \times 100 \qquad (2)$$

$$\text{Positive predictivity value (\%)} = \frac{\text{TP}}{\text{TP+FP}} \times 100 \qquad (3)$$

where TP indicates a true positive, FN stands for a false negative and FP represents a false positive. To evaluate the method, half an hour of data containing frequent snoring was arbitrarily selected from fifteen full-night recordings.

Table II presents the performance of the proposed method for snoring detection. The numbers of snoring events of mild, moderate and severe AHI groups are 1393, 1879 and 1683 respectively. The overall sensitivity and PPV were 93.73% and 93.70%, respectively.

VI. Discussion and Conclusion

In this study, a method for automatic snoring detection using data acquired from a nasal pressure sensor was proposed and evaluated. In PSG study or the CPAP system, the nasal pressure sensor is used for monitoring respiratory variation during inspiration and expiration. In case of PSG studies, the microphone placed on the neck or above the head was used for automatic snoring detection. However, the methods of these studies require acquisition of high-quality snoring sound signals and processing of high-capacity data. Moreover, the microphone is inappropriate for applying to CPAP system because it should be additionally mounted in that system.

The results revealed that the sensitivity and positive predictivity value were more than 90% each in all three severity AHI groups. These results suggest that the proposed method is useful to precisely detect snoring events using the nasal pressure sensor regardless of patient's AHI.

To the best of our knowledge, the automatic method using the nasal pressure data for snoring detection has not been reported in the literature. The proposed method is simple and is not needed additionally sensor such as microphone. Also, this automatic method permits real-time data processing and cost-effectiveness. The results in this study could provide sleep experts with the method to objectively monitor sleep-disordered breathing in CPAP system or PSG study.

TABLE II. Performance Results for Automatic Snoring Detection Using a Nasal Pressure Data

Data set (AHI)	TP	FN	FP	Sensitivity (%)	PPV (%)
Mild (5~15)	1337	58	117	95.84	91.95
Moderate (15~30)	1738	141	76	92.50	95.81
Severe (30~)	1571	112	119	93.35	92.96
Total	4646	311	312	93.73	93.70

TP: true positive, FN: false negative, FP: false positive, PPV: positive predictivity value

This study invites further research with a larger sample size in patient population since three thresholds used in this study may have an effect on the results. Although the results of the proposed method showed good performance, further research is needed to optimize three thresholds which in turn enhance the ability to detect snoring with greater precision.

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