Acoustic Signal as a Carrier of Information on Breathing Sleep Disorders

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Abstract

The statement that an acoustic signal can be a good tool for assessing breathing during sleep is not revealing and certainly raises no doubts. Based on the experience of technical diagnostics, one can formulate the hypothesis about the suitability of sounds accompanying breathing to infer any specific disorders. The verification of this hypothesis was supported by a research experiment combining the experience of doctors and engineers. The obtained results was used to create the simple application for the initial diagnosis of respiratory problems while sleeping at home. Assuming the minimization of the use of an advanced mathematical apparatus, features that are the symptoms of basic respiratory disorders have been extracted from the signal. Thanks to this approach, the developed tool not only informs about the disorder, but also signals the potential cause of the problem. Thus, the inference procedure that is the basis of a useful application can also support doctors at the stage of preclinical diagnosis.

Keywords: acoustic signal, diagnosis of sleep breathing disorders

1. Introduction

Despite the increasing awareness, the problem of snoring is still largely treated as an “aesthetic” problem. In many cases this is indeed the case, however, snoring may be the result of serious breathing disorders [1, 2]. A good source of information about breathing problems occurring during sleep is an acoustic signal [3-6]. On the market there are many applications which record snoring. Most of them focus only on informing the user that the one “snore” and in some cases awake his/her in order to reduce the occurrence of annoying acoustic effects. Few applications indicate a potential disease aspect. The authors attempted to create an inference procedure for application which diagnoses sleep breathing disorders. The application is intended to inform the user about a medical problem and indicate the type of disorder.

2. Research experiment

The presentation of the procedure underlying the diagnostic application required the acquisition of representative samples of snoring associated with the patient's airway condition. To this end, a broad research experiment was carried out to build a database of signals representative of various disease stages. During the experiment, acoustic signals of patients referred for surgery were recorded. Acoustic recordings were carried out in the operating room, and patients were pharmacologically dormant. The measuring microphone was placed directly above the patient. Acoustic recordings of over 100 patients were obtained through the experiment. An example of registration is shown in Figure 1.

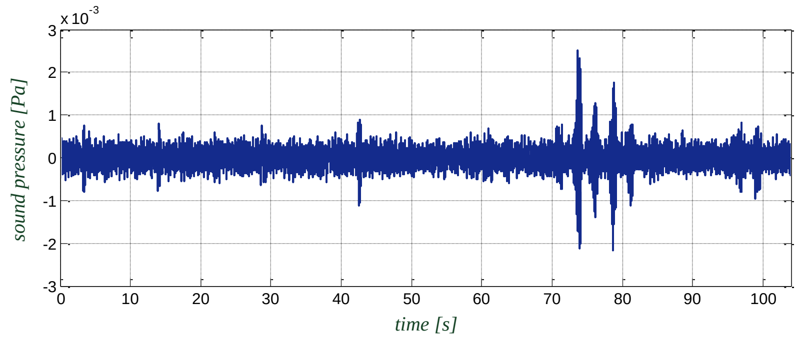

Figure 1. An example of changes in sound pressure during sleep breathing disorders

Recorded time courses contain a number of sounds and information not related to breathing. The fact that the recording of acoustic signals was carried out in pre-operative conditions meant that in addition, signals generated by operating medical equipment or conversations of medical staff were recorded.

3. Separation of useful information

For the purposes of analyzing the collected research material, information related to the analyzed disorders had to be separated from the general information. The frequency range in which information about breathing disorders is visible has been determined by analysis. Filtering frequencies out of range does not affect the correct conclusion of breathing disorders. The result of the filtration is shown in Figure 2. The development of a filtration procedure using a well-defined band containing information on breathing disorders allows to minimize the impact of external disturbances, not only generated by medical equipment. This conclusion was also confirmed on the basis of signals recorded at home.

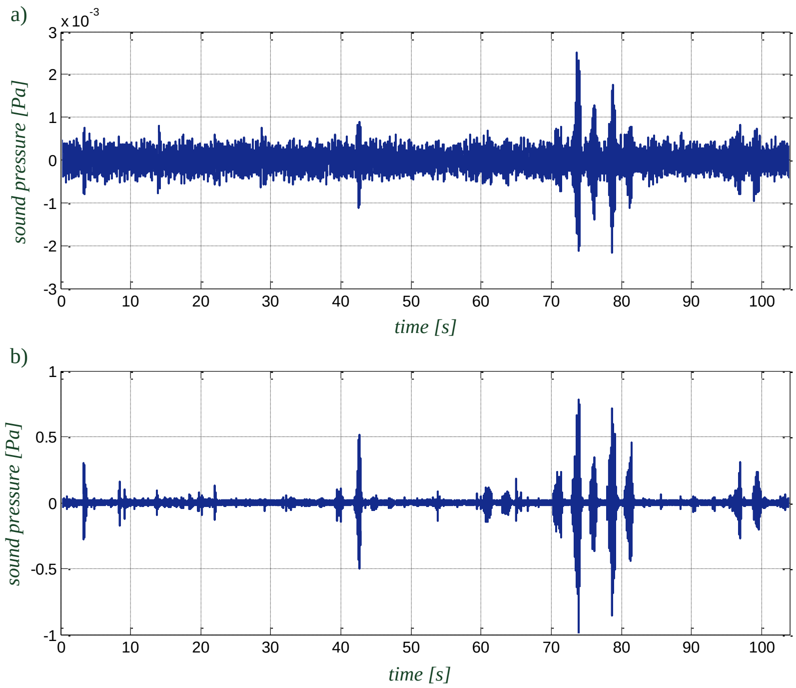

Figure 2. Recorded sound pressure waveforms:
a) original signal, b) signal after applying bandpass filtering

The signals prepared in this way could be further processed. The basic assumption was to create an inference procedure for an uncomplicated and universal application that allows for making a preclinical diagnosis at home using classic mobile devices. This forced minimizing the collected data. While collecting data from several hours of registration is not a problem, analyzing this data can be difficult, if at all possible. In this situation, it was decided to minimize the input data already at the registration stage. It was assumed that only data that contains as much information about breathing disorders as possible will be saved. It was therefore necessary to precisely determine the beginnings of subsequent registrations. For this purpose, simple indicators were calculated that would allow determining the threshold for triggering data recording. Finally, the effective value calculated in time intervals from ¼ second was selected. Figure 3 shows the rms value over a specific time period for the original signal (Fig. 3a) and the signal after applying bandpass filtration (Fig. 3b).

It seems that generally small, in terms of energy, external interference should not significantly affect the inference. Even if in total they constituted a significant part of the signal energy, it would be possible to apply appropriate procedures eliminating their adverse effect on the basic diagnostic information. Unfortunately, this makes it very difficult to determine the explicit starting point for registration (Fig. 3a).

a)

b)

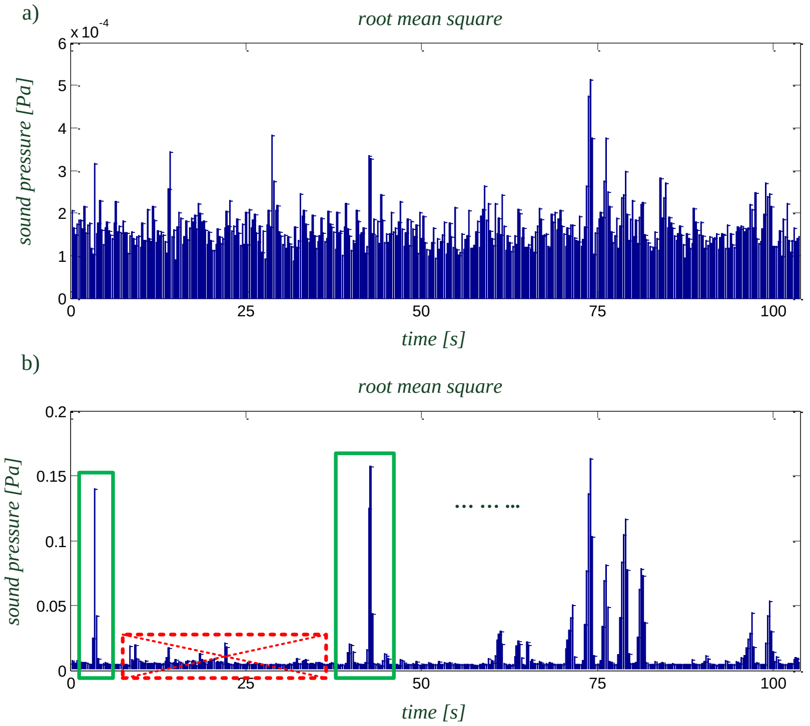

Figure 3. RMS waveforms calculated in ¼ second time intervals:
a) original signal, b) signal after applying bandpass filtration

The use of bandpass filtration has allowed not only to precisely determine the start of registration, thereby limiting the input data, but also to select data relevant for inference. Finally, it was determined that a further 3-fold background exceeding by 20% by the effective value integrated in ¼ second intervals would initiate the recording of a 60-second fragment.

4. Proposal of a diagnostic indicators

In [7] has been shown that detailed analysis of the spectral images of structures allows precise and unambiguous identification of respiratory disorders of sleep phase. The assumption of using the inference procedure at home, using universal mobile devices, forced the minimization of the mathematical apparatus used. Unfortunately, in this case classical Fourier analysis is not enough. Based on FFT, it is possible to indicate the dominant problem, but without detailed inference. Therefore, it was finally decided to simultaneously analyze in the field of time and frequency. An example of the result is shown in Figure 4.

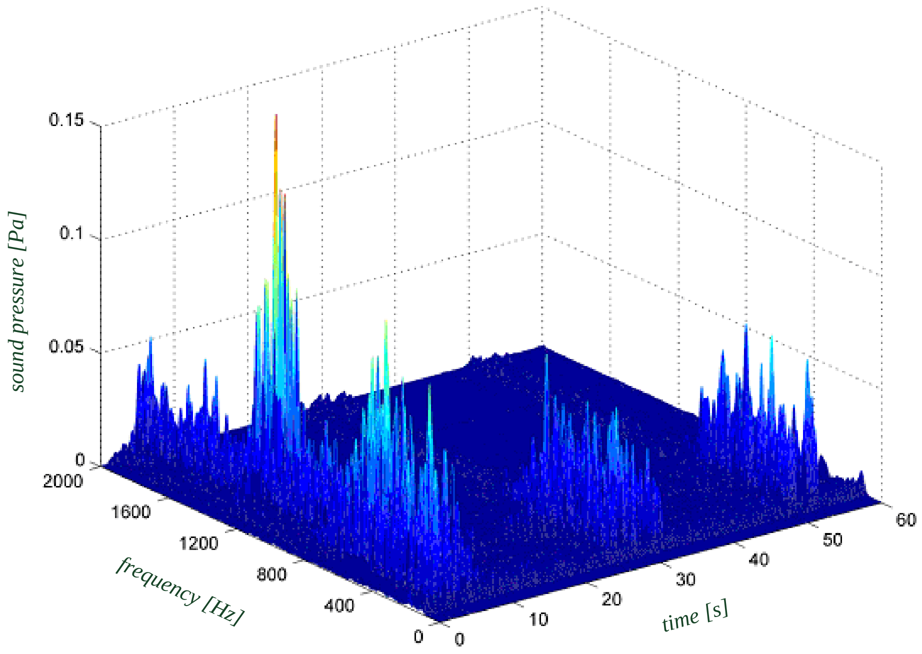

Figure 4. Instantaneous spectrum of the sample registration

Comparing the instantaneous spectra of different patients, similarities in structure were noted for patients who were medically diagnosed with similar respiratory problems; significant differences in spectrum structures were also found for various diseases. On this basis, the hypothesis was formulated that it is possible to build a database of measures allowing not only to determine whether a person requires the intervention of a doctor, but also to pre-select the disease. Simultaneous analysis in the time and frequency domains allowed for a broader structure assessment and specific indication of the problem. Ultimately, it should also be able to estimate the duration of the disorder, thereby determining the intensity of a particular breathing abnormality. Focusing on isolating the symptoms of basic respiratory disorders during sleep, a measure in the form of effective value of instantaneous spectra calculated in 500 Hz bands was proposed (Fig. 5).

Patients whose acoustic registrations were analyzed were previously comprehensively diagnosed in clinical settings. Detailed information about the diseases will confront the causes of the occurring disorders with the diagnostic measures obtained and will enable the assignment of measurements to a specific breathing disorder.

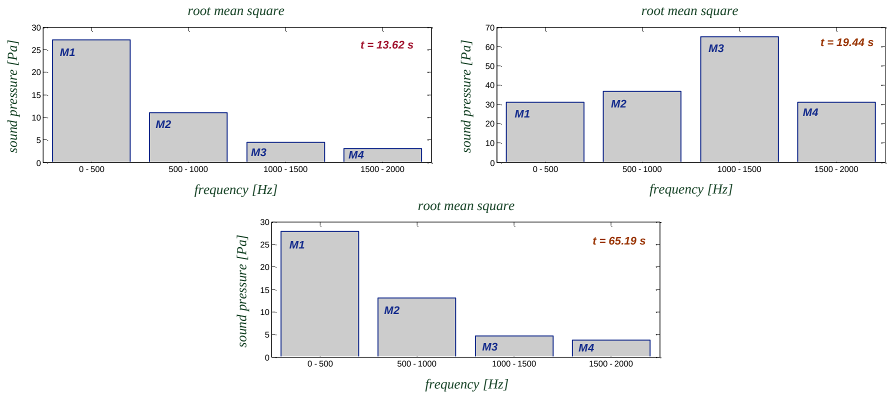

Figure 5. Examples of measures extracted from the instantaneous spectra

5. Conclusions

The results achieved during the work on the subject allowed to proceed to the development of an application for preclinical assessment of sleep breathing disorders based on an acoustic signal. Implementation of the application on mobile devices will allow patients to get a preliminary diagnosis about the potential health hazards and guidance of the possible desirability of detailed clinical diagnostics.

The experience to date creates premises for the possibility of using the developed methodology in the direction of the development of tools supporting ENT doctors in the process of diagnosing sleep breathing disorders, and even in choosing the appropriate, the most effective treatment.

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