Breath sound analysis of sleep apnea syndrome using cluster model

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Abstract. Sleep apnea syndrome (SAS) is a contemporary disease, with few subjective symptoms. For this reason, many people with SAS have not received a medical examination. In this paper, the possibility of a person with a high probability of having SAS in the near future (Pre-SAS) is determined from only the sound of the subject’s breathing during sleep. The sound is extracted and the breathing pattern and its tendency analysed using the cluster method. Compared to the conventional SAS process for diagnosis in medical institutions, the method proposed in this paper is very simple and easy.

1. Introduction
Sleep apnea syndrome (SAS) is one of the modern illnesses, and not only is the affected patient treated, but many people are suspected of having SAS, but they often do not feel the need for treatment [1]. In addition, it takes time and effort for the subject to diagnose SAS, and the current SAS diagnosis has to diagnose data other than breath sounds during sleep for 6 to 8 hours. For this reason, many researchers are studying speech analysis in SAS. However, breathing sounds during sleep are very long and uneven. For this reason, there are a method in which a person cuts out the SAS sound analysis part in advance and analyses it in detail, and a method in which trends are analysed from the whole by machine learning.

In this paper, we efficiently cut out the part to be analysed from the entire long-term breathing sound recorded by the IC recorder. Then, a simple diagnosis of SAS was performed using cluster analysis. This proposal was a very simple method and the time required for analysis was very short. The SAS discrimination rate based on this proposal was 100%. This proposal would be useful for SAS medical support tools.

2. SAS diagnosis and problems in medical institutions

2.1. Current SAS diagnosis method
Current SAS diagnosis method take time and effort for both subjects and analysts to receive a SAS diagnosis at a medical institution [2]. First, subjects suspected of having SAS go to a medical institution to undergo prior measurements. There are two methods. One is for the patient to rent a simple portable device from the hospital, take it home overnight, return it, and the data is analysed [3]. The patient then visits the medical institution again to receive the diagnosis. Second, the subject stays overnight in a medical facility and undergoes a polygraph examination overnight [3]. In this case as well, measuring devices are installed on the body. Like the first method, it is necessary to come to the hospital for the results at a later date. At the medical institution, specialists comprehensively check the data obtained from subjects. They require about 6 hours per subject for this task. The doctor then diagnoses SAS based
on the results submitted by the specialist. Fig. 1 shows the current SAS diagnosis method. As shown in this figure, there are so many steps.

![Diagram of current SAS diagnosis steps]

**Figure 1** Current SAS diagnosis steps

### 2.2. The problems in medical institutions of SAS diagnosis method
In general, people are not able to sleep well when they are different from sleep conditions, and breathing sounds during sleep are also different [4]. For example, hospitals and unfamiliar hotel futons and pillows. The sounds and lights of the doors that nurses open when they visit hospital rooms. And sounds from outside the building and from the next room. Wearing a measurement device for SAS diagnosis is no exception. The current SAS diagnosis is a simple test: renting a measurement device from a hospital and recording measurement data, and a main test: an inspection that is hospitalized overnight and recording measurement data. For the reasons described above, these methods have a problem that accurate data cannot be measured from the subject.

### 2.3. Measurement data for SAS diagnosis
The measured data by these diagnoses measured from the subject at the medical institution does not include breathing sounds during sleep. There are several possible reasons, but the main reason is that it is difficult to analyse long-term sounds. However, there are many cases where it was noticed that a person was suffering from SAS by listening to the breathing sound during sleep.

### 2.4. SAS sound and its researches
However, SAS sounds during sleep are characteristic, such as abnormal sleep sounds during sleep: snoring and repeated apnea [4]. Many SAS people have started to receive treatment because their family members and friends pointed out these abnormal sleep sounds. There have been many previous studies...
on SAS sounds. Many of them analysed the sound waveform narrowly, using Fourier transform, wavelet transform [5], or analysed the tendency of SAS sound widely using machine learning [6].

There are studies to analyse SAS sound waveforms, both in a narrow area and in wide area. The reason is that sleep time is as long as 6 to 8 hours, and the sound is uneven, which makes analysis difficult. In narrow-area analysis, a characteristic SAS sound portion is artificially cut out and analysed. Wide-area analysis studies the characteristic SAS sound waveform as a result of analysis. With the widespread use of smartphones, simple SAS diagnostic apps have been released, but these measure the state in which there is no breathing sound, which might indicate the person has stopped breathing.

2.5. Our proposed method
We propose a method for diagnosing the possibility of SAS and pre-SAS by a simple method using multivariate analysis of only the breathing sound during sleep. In our proposed method, a breathing sound is recorded during sleep using a simple voice recorder and the subject can perform a simple diagnosis of SAS from the recorded data. The subject has no stress to wear the device and can take a normal sleep. Fig.2 shows the SAS diagnostic method we propose. As shown in this figure, it is very simple compared to Fig.1.

![Figure 2. Subject details and points for analysis](image-url)
3. Breathing sound during sleep used for analysis

3.1. Collect analysis data
In order to analyse the characteristic sounds of SAS, we collected respiratory sounds during sleep of SAS patients, Pre SAS people, and Non SAS people. In this paper, SAS, Pre SAS, and Non SAS are defined as follows. SAS is a person who currently suffers from SAS and is being treated at a medical institution. Pre SAS is a person who is not currently affected by SAS but is likely to become SAS in the near future. And Non SAS is not currently suffering from SAS, is unlikely to become SAS in the near future, and has no problems with health examinations. Regarding data collection, people with SAS have their data provided by a sleep medical institution in Toyohashi City, but Pre SAS and Non SAS are difficult to collect from medical institutions. I collected this data separately and had a specialist make a voice diagnosis.

3.2. Subject details
Table.1 shows the composition of the number of subjects we analysed. AHI in the table is the Apnea Hypopnea Index determined by the World Health Organization, and is an index for judging the severity of SAS symptoms [1]. There are three types of SAS, and all the subjects in this paper are obstructive SAS (OSAS): the main cause is that the tongue base and soft palate fall due to muscle relaxation during sleep and obstruct the airway.

| --- | AHI | No. of people |
| --- | --- | --- |
| Non SAS | 5<\text{AHI} | 4 |
| Mild | 5 \leq \text{AHI}<15 | 5 |
| Moderate | 5 \leq \text{AHI}<30 | 11 |
| Severe | 30 \leq \text{AHI} | 21 |
| --- | Total | 42 |

3.3. Points for analysis
The sound analysis will be described in the next chapter. Before that, we will define the sound used in this paper. What we analyse is the breathing sound of the subject during sleep, commonly referred to as snoring. Snoring is a collective term for abnormal breathing sounds during sleep and is medically distinct from SAS and snoring. However, the purpose of this study is not to distinguish between SAS and snoring, so in this paper we define the breathing sound during sleep obtained from these subjects as the breathing sound during sleep or breathing sound.

4. Subject details and points for analysis

4.1. SAS sound features
When comparing breath sounds during sleep between SAS and Non SAS, there are some notable differences. In this paper, we focus on two of them and analyse them.

- Features1. The sound pressure of SAS is larger than Non SAS.
- Features2. The respiratory rhythm of SAS is less constant than Non SAS.

An example of feature 1 is shown in FIG. 3. FIG.3 (A) shows example of SAS waveform sound, which is a 3-second breath sound during sleep. (B) shows the power spectrum of (A). The vertical axis is the energy dB of the audio component of each frequency, and the horizontal axis is the normalized
frequency. It can be seen that the area enclosed by the horizontal and vertical axes of SAS is larger than Non SAS. The features 2, Non SAS repeat the breath to be constant during sleep in the same manner as when awake, but, SAS is the cessation of breathing during sleep, and the breathing rhythm is not constant.

(A) Example of SAS waveform sound.

(B) Example of SAS waveform sound.

Figure 3. Example of SAS sound spectrum.

Figure 4. Example of Cluster analysis of SAS breath sounds.
4.2. Analysis method
From the above features 1 and 2, we thought that there would be a difference between SAS and Non SAS at the point where the sound pressure of breathing sound during sleep was high. Therefore, from the recorded breathing sounds during sleep, the top five points with high sound pressure for each subject were cut out. The sound to be cut out was 7 seconds before and after the high sound pressure. Then, each data was normalized based on the centre, and all data were clustered into 6 by k-means method [8] - [9].

4.3. Results
The results were good, and classified into 6 clusters of characteristic breathing patterns. Fig. 2 shows the most common pattern of patients with SAS. The horizontal axis is elapsed seconds, and the vertical axis is normalized sound pressure. In this pattern, the patient takes a large breath while stopping breathing and then stops breathing again. In the other five patterns, breathing patterns different from those of Non SAS were obtained. In addition, Pre SAS had the same result as SAS, and it was possible to distinguish between Non SAS and Pre SAS. Also, the analysis time was 10 to 15 minutes per person because the recorded part of the SAS sound was cut out semi-automatically rather than analysing all the recorded data of the subject. It was more efficient than the time required for conventional SAS diagnosis.

5. Conclusion
We cut out the breath sounds of SAS during sleep and performed cluster analysis based on them. The result was 100%. This proposed method has been shown to be useful for simple diagnosis of SAS. In the future, I would like to increase the number of subjects, examine the cluster method, and improve the accuracy.

6. References
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