An Implementation of Snoring Detection in Real-time by Time Analysis

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***Abstract*—Snoring is not only health problem for snorers but also great thread for partners life. In this project, we suggest a method by analyzing real-time audio data from a smart phones microphone which could successfully identify the snoring sound and take actions such as vibration, alarm etc. to notify the snorer to adjust himself/herself. Two features from sound data which are energy and zero-crossing rate applied to detect snoring. By experimenting with sound data from freesound.org, were able to set thresholds for figuring out regular snoring patterns.**

I. Introduction

Normal people spend one third of their life in sleep, and it is estimated that approximately 30% to 50% of the US population snore at one time or another, some significantly. Snoring causes a few problems including marital discord, sleep disturbances and waking episodes which is caused by one's own snoring [1]. In some serious condition, apnea which is a potentially life-threatening disease developed from simple snoring. Thus, we're looking for a method to use cell phones to do real-time analysis at night and give proper responses to the snorer in order to alert the person. In this way, we could train the user to stop snoring.

In this paper, an android app is built for this purpose. The app contains three main components which are sound capturing module, analysis module and action module. In sound capturing module, we used raw data from microphone input. After microphone collected large enough data, they were sent analysis module. The analysis module extracted two key features which are energy and zero crossing rate in order to identify the snoring. After snoring sound was confirmed, action module responded with pre-recorded alarm.

II. Related Work

A. Snoring Detection Methods

Numerous researchers are interested in snoring signal features and detection. Back in 1996, Fiz tried to figure out the difference in snoring sound among simple snoring patients and obstructive sleep apnea patients [2]. Their research demonstrated significant difference in sound power spectrum of snoring sound between subjects with simple snoring and obstructive sleep apnoea which means that it should be possible to identify different snoring patterns. In 2006, Duckitt [3] suggested using Hidden Markov Models(HMMs) as basic elements to model different type of sound. In [3], the authors made overnight audio recordings for six subjects, and analyze the data afterwards. This approach is not perfect since feedback can not be provided when the subject is snoring. Cheng [4] implemented a portable device to detect sleep apnea syndrome. The device is made up of recorder, LCD screen, microphone etc. which all can be found in a normal cell phone. [5] also introduced a method to detect snoring by time and frequency analysis. The method is used in our project, but adjustments need to be made since snoring sound is normally in low frequency area [6] [7]. Thus, we'd analyze frequency lower than 500 HZ instead of 0-7500 HZ range.

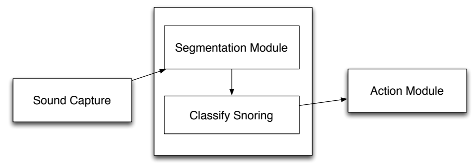

Fig. 1: Overview of Modules

B. Awakening Methods

What is the proper way to wake a person up? Thomas's research shows that voice alarm was quite effective for younger age groups but not for older adults [8].The paper [8] also mentioned the mother's message including the child's name several times is quite effective when waking the kid's up. It lays the foundation for us to use human voice, especial a snorer's name as alarm. In Bruck's experiment, it shows male's voice is more effective than a female's voice [9]. For short arousal while sleeping, people will have short term memory lost, so it is hard to people to notice how many times they woke up [10]. This helps us to let the app alert with certain duration.

III. Architecture

A. System Design

Figure 1 demonstrates the overall structure. In order to do real-time analysis and give correspond alarm actions, the project uses a pipeline structure which contains *Sound Capture*, *Sound Analysis* and *Action Module*. In *Sound Analysis* step, the sound raw data has to be sliced and processed first, then by calculating the energy and zero-crossing rate to classify the sound type which is a binary decision. The pre-recorded alarm in *Action Module* is activated

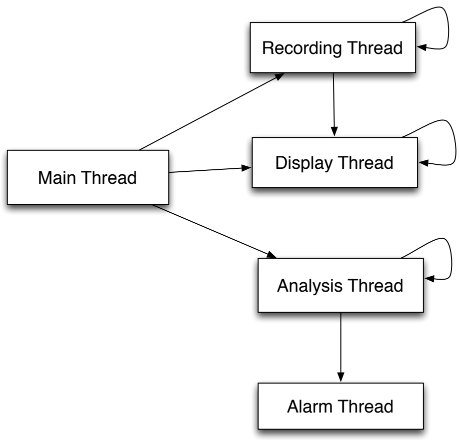

Fig. 2: Overview of the App

once the system confirms the user is snoring. The decision of alarm is made by the count of detected snoring m.

This system is multi-threaded and consists of five main threads. As shown in Figure 2, the five threads are Main thread, Recording thread, Display thread, Analysis thread and Alarm thread.

Main thread
: Main thread is in charge of main Graph User Interface display and invoking other threads including Recording, Analysis and Display thread. In other word, this is the parent thread of the whole system. Since in Android system, children threads are not able to modify user interface, so we create many handlers in main thread in order to control functions like message display and alarm output.

Recording thread
: Called by main thread. Recording thread keeps recording the sound while user is sleeping. This is a child thread that running all the time. We use Android system method AudioRecord to implement the recording function.

Display thread
: Called by Recording thread. Display thread keep drawing and refreshing the oscilloscope stimulation function which recording thread is running.

Analysis thread
: Called by main thread. Analysis thread calls the sound analysis function to judge if the input sound is snoring or not.

Alarm thread
: Called by analysis thread. Alarm thread output the alarm sound when snoring being detected.

B. *Sound Analysis*

IV. Results

The app supports Android 2.3.3(API Level 10) or later. It is tested in Samsung Galaxy s3.

As shown in Figure 6.The user needs to record his voice as an alarm first. User's name is recommended to record as the alarming message. After tapping on start, the app enters into detection mode. If snoring is detected m times($m = 2$), the alarm will be triggered. If the user continues to snore, he will be alarmed again. The process won't stop detecting until morning once the user chooses to stop the app.

In this project, 8 audio samples are collected from freesound.org. Each of them contains a type of male snoring sound. Thanks to freesound.org and people who like to upload personal snoring sound, we're able to get various types of snoring which helps us to develop the app.

By using our analysis method, all 8 audio samples with 78 snoring episodes are detected in MatLab. Figure 3 shows that ZCR and energy have quite clear patterns in simple snoring. In the snoring part, ZCR is relatively high and energy stays between certain limited range which characterize the snoring. In Figure 4, snoring sound is merged with breath. As we can see, the real snoring sound have wider peak, so the classification result could be based on the continues positive count. If more than m times slice of data is classified as positive snoring, it will be count as the snoring. In frequency domain as shown in Figure 5, the difference between snoring and breath is mainly in low frequency part. After dividing the bands into several sub-bands, we could get 10 features vectors for each frame. The amplitudes distribution in Figure 5 shows that we could use the frequency features of sound to improve classification. Using principle components analysis, two main features contributes most of the snoring characteristics.

In Matlab, the algorithm performs quite good since all the samples's snoring sound is detected. However, playing the samples in laptop output, the amount of detected snoring sound is significantly less.

In noisy environment such as discussion area of the library, restaurants etc., snoring sound almost can not be detected while in relatively quite environment like home, snoring sound could be detected sometimes.

V. Conclusion

An Android app used for snoring detection is built. It read raw audio data from a smart phone's microphone, and data is sliced into small segments to calculate zero crossing rate and energy. By using thresholds experimented from MatLab, the app is able to classify snoring sound and give proper alarm responses to the user. The app is tested in both noisy and quite environment in order to figure out the performance. The experiments shows that the app works good in quite environment and triggers alarms. Future work needs to be done to improve the accuracy of snoring detection.

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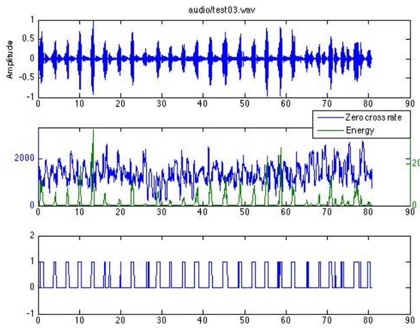

Fig. 3: Simple Snoring Results

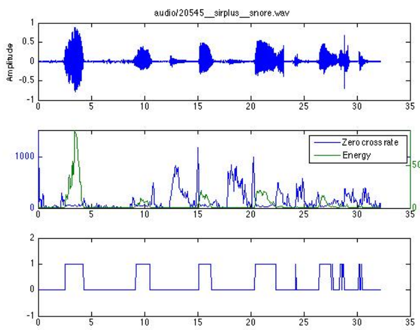

Fig. 4: Snoring with Breath Results

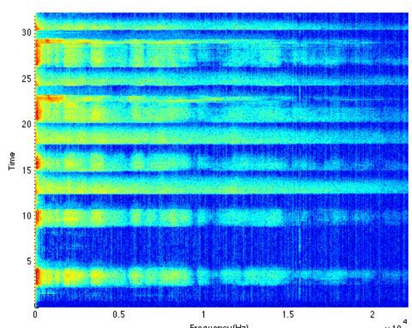

Fig. 5: Spectrogram of Snoring with Breath

develop such an interesting app from scratch. Tremendous suggestions were given by Doctor Jason Leign and Doctor Robert Kenyon. The authors also would like to thank the open source community. Without them, the project couldn't be finished in time.

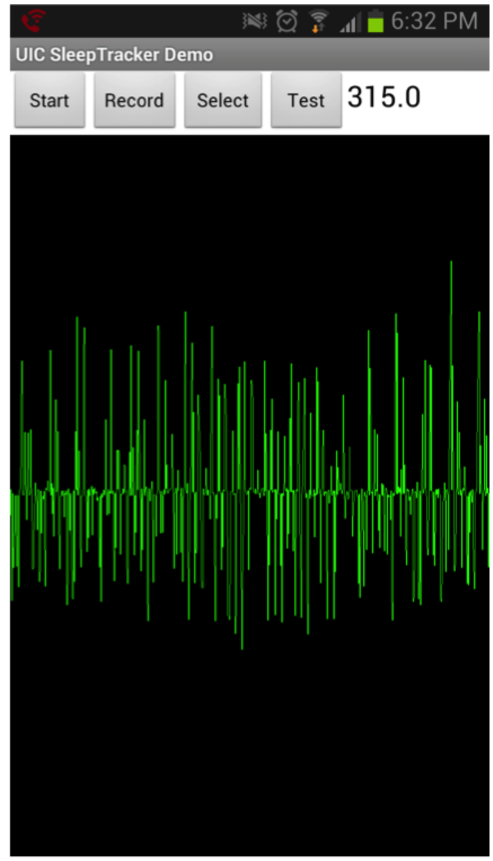

Fig. 6: Screenshot of Android App

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