Snoring Detection Based on A Stretchable Strain Sensor

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1 Introduction

2 Strain sensor

3 Snoring detection

4 Future work

1 ▶ Introduction- risks of snoring

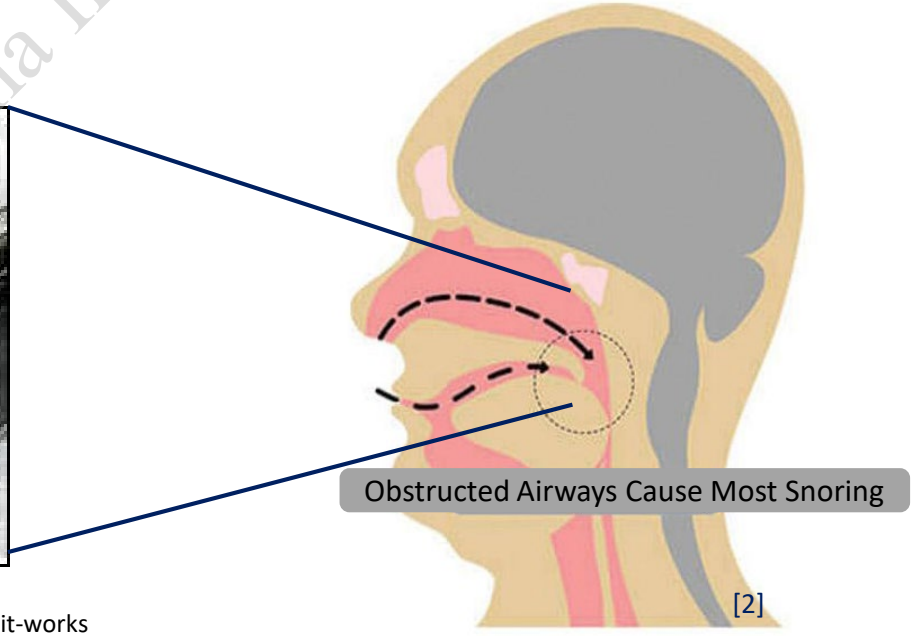
Influence on daily lives

- sleep deprivation;
- daytime drowsiness;
- irritability;
- lack of focus;
- decreased libido;
- ……

Risks of suffering from diseases

- 67% greater chance of suffering from stroke
- 34% increased risk of having heart attack

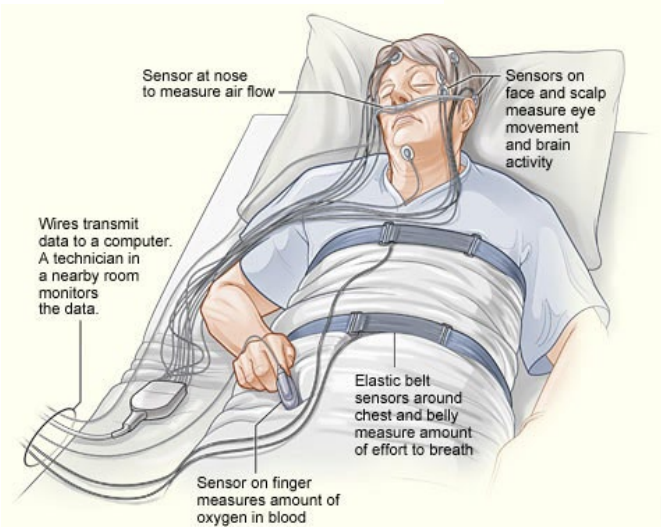

[1]



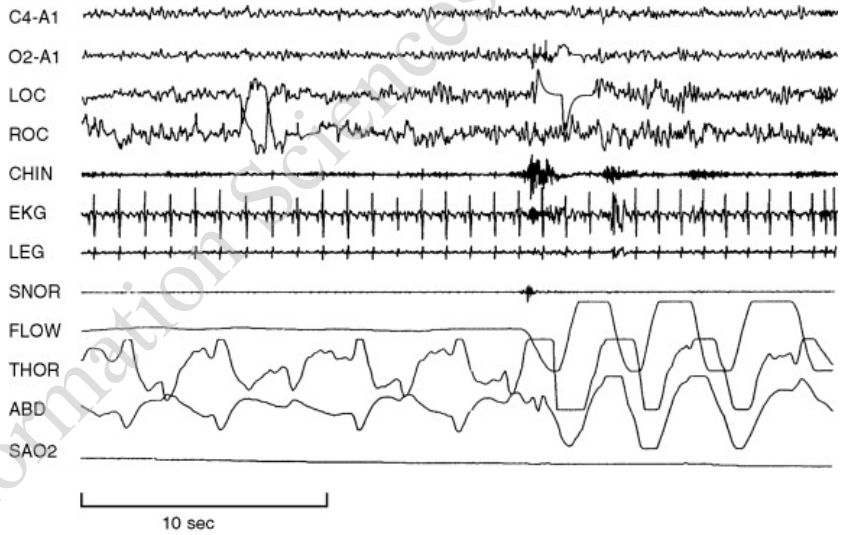
Source: [1] http://news.bbc.co.uk/2/hi/health/7272651.stm
Source: [2] https://goodmorningsnoresolution.com/pages/how-it-works

1 ▶ Introduction- detection methods

Polysomnography (PSG)



[1]



[2]

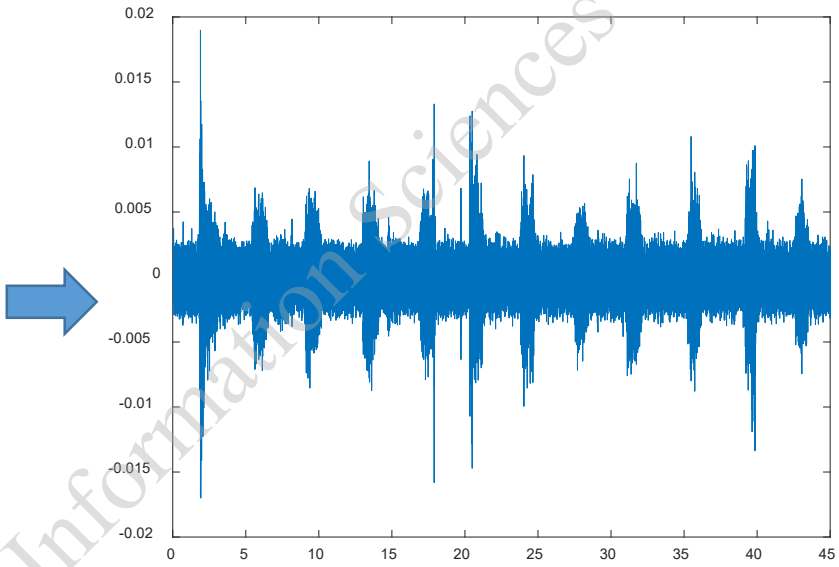
Characteristics of polysomnography

- A standard method of monitoring the sleeping quality in the literature;
- Acquire various signals (EEG, EMG, ECG, EOG, Respiration condition);
- Require the experts among analysis of the measurement result;
- Expensive, not suitable for snores to use at home.

Source: [1] https://www.sleep-apnea-guide.com/polysomnogram.html
Source: [2] https://www.sciencedirect.com/topics/neuroscience/polysomnography

1 Introduction- detection methods

Audio sensor



Characteristics of using audio data for snoring detection

- Low price and small volume;
- Prone to be affected by the environment noise;
- the machine-learning-based detection method requires a large amount of computation resources.

Source: [1] https://www.tri-anim.com/snore-microphone-wire-length-7-ft-pharm-32112-3826.aspx

1 Introduction- detection methods

Piezoelectric vibration sensor

- Signal strength depends on whether the piezoelectric sensor is tightly attached to the snorer's skin.

Nasal cannula

- bring discomfort to the snorers;
- easily affected by nasal blockage, mouth breathing and the movement of the cannula in the nares.

Is there a natural and friendly way to detect snoring and avoid issues mentioned before?

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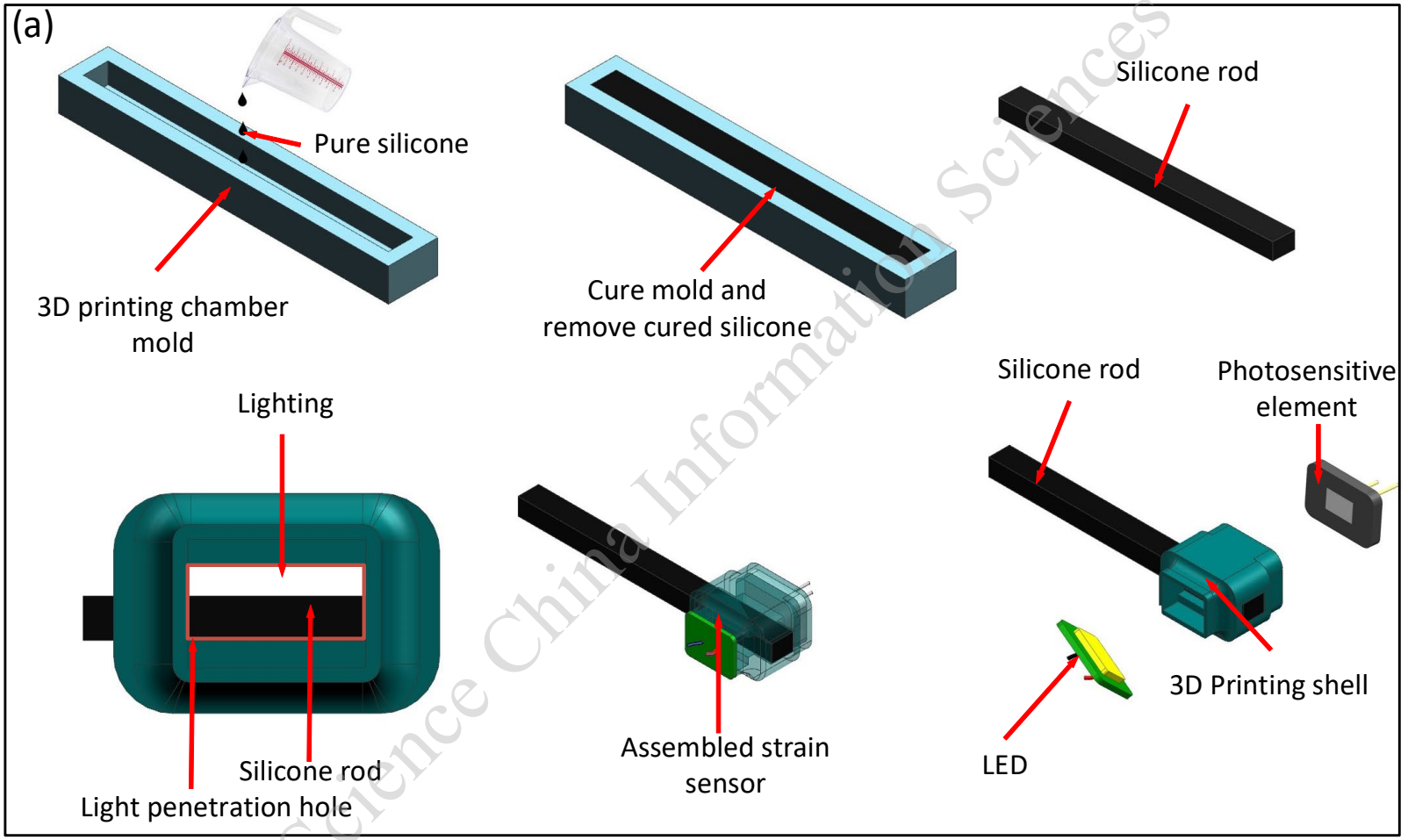
2 **Strain sensor**

3 Snoring detection

4 Future work

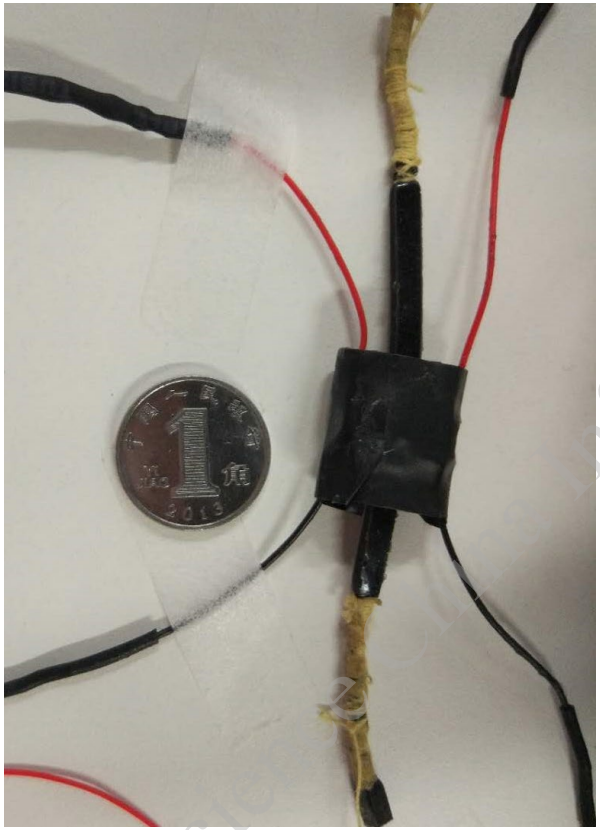
2 ▶ Strain sensor: assemble processing



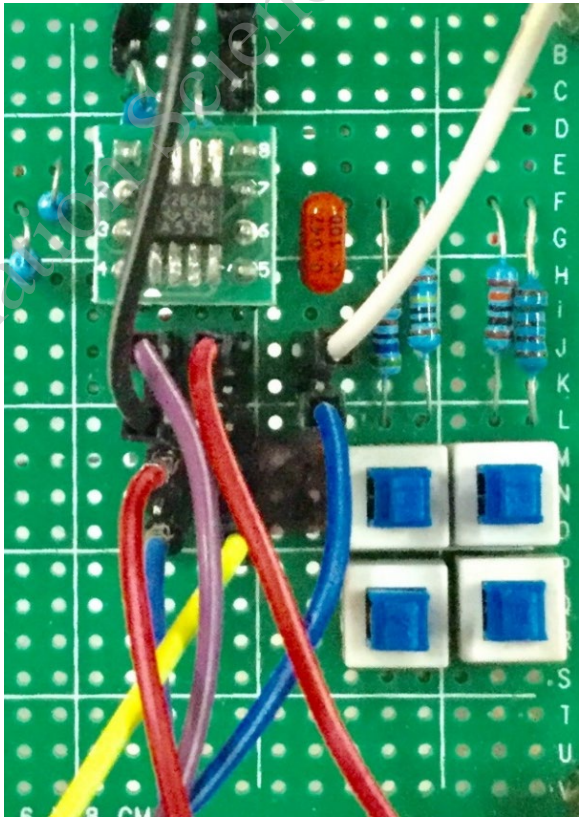
Fabrication process of stretchable strain sensor.

2 Strain sensor: assemble processing

Strain sensor



Measurement circuit



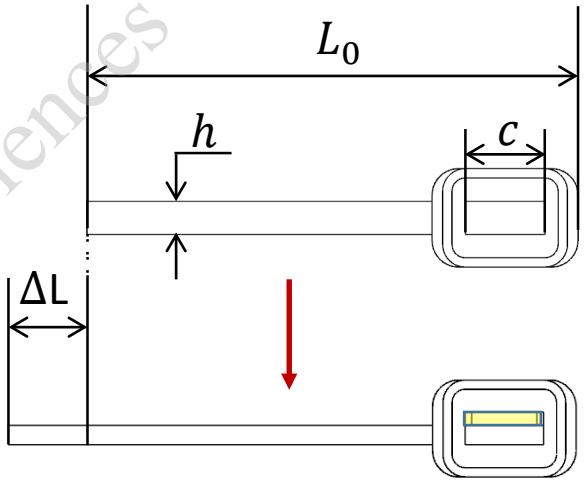
The sensor is low-cost, light and portable, and can be use at home.

2 Strain sensor: principle

- **Light intensity received by silicon photocells**

$$E_l = Echv\frac{\Delta L}{L_0}$$

Where E is the light intensity emitted by the LED, and $v$is the Poisson's ratio of the rubber;



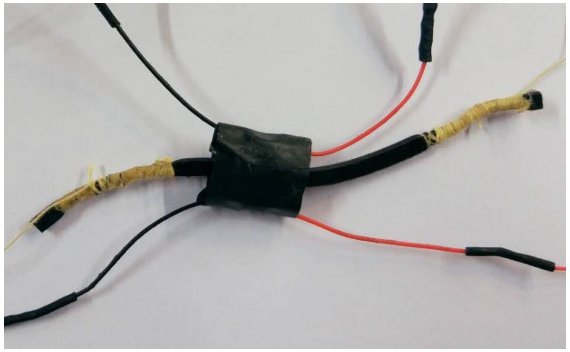
- **Sensor output voltage**

$$\Delta U = K_d K_i R_c Echv\frac{\Delta L}{L_0}$$

Where K_d is the amplification factor of the amplifier, R_c is the series resistance of the circuit, and $K_i$is the slope of the current generated by the silicon photocell and the intensity of the received light.

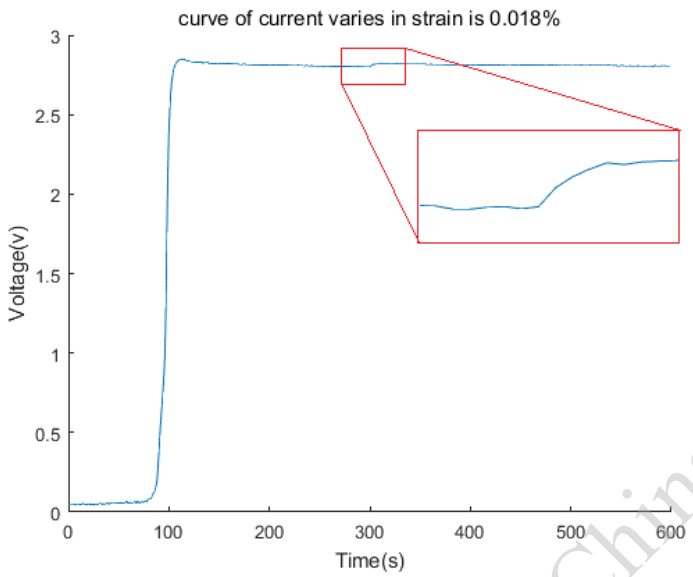
- **Sensor sensitivity**

$$GF = \frac{\Delta U}{\Delta L/L_0} = K_d K_i R_c Echv$$



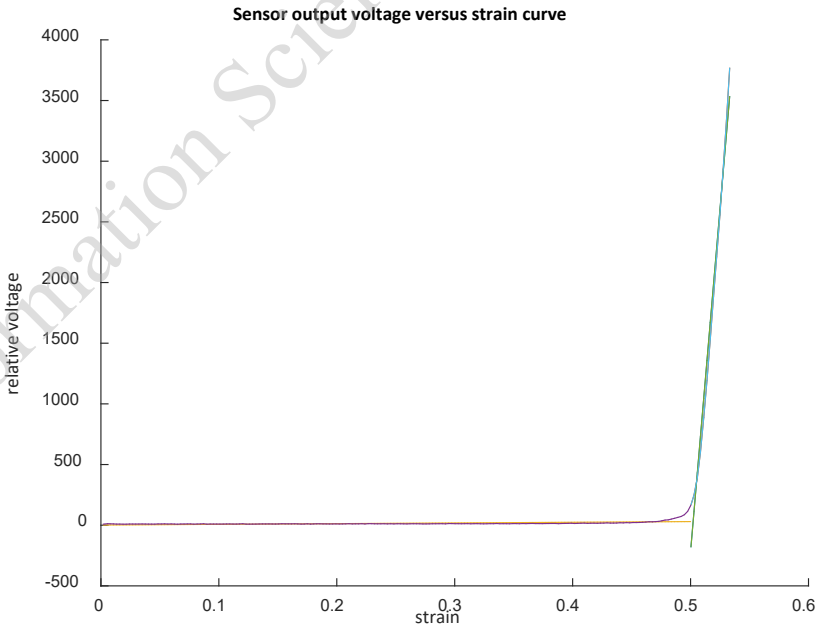
2 Strain sensor: performance test

Resolution test curve



Strain resolution is less than 0.018%

Gauge factor test curve



gauge factor is up to 683.31

Strain sensor has a high accuracy and a good linearity.

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3 Snoring detection: algorithm

Snoring detection principle

■ **Amplitude-based detection principle:**

(1) Determine the amplitude threshold A_{light} to distinguish in normal sleeping or not ;

(2) Determine the fluctuation lasting time T_{last} to distinguish in Short-term actions or continuous actions;

(3) Determine the amplitude threshold A_{snore} to distinguish in snoring or deep breathing.

■ **Slope-based detection principle:**

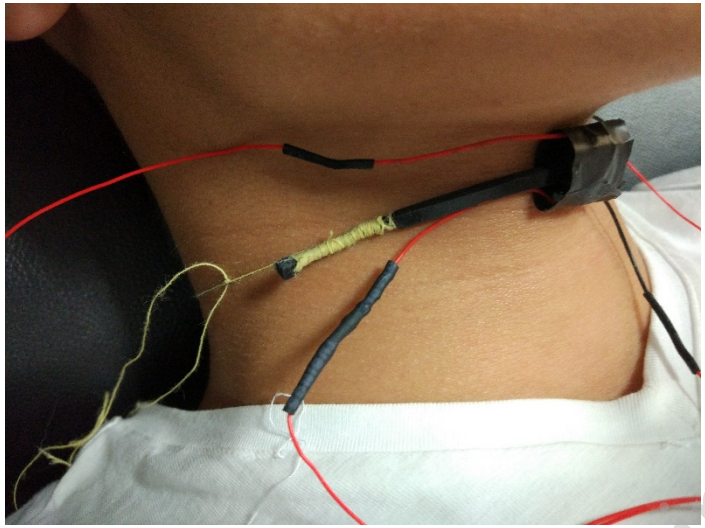
Determine the slope $P_{\max}$ and $P_{\min}$ to distinguish in snoring or not ;

Algorithm 1 Sleeping action recognize

```
while (1) do
    t = 0, a = 0, p = 0;
    obtain 10 cycles of fluctuating data D;
    unbiased processing of fluctuating data D − E(D);
    search the local maximum values D_m and local minimum values D_n;
    while i < 10 do
        calculate the time difference between two adjacent extremum points T(i) = t(D_m(i)) − t(D_m(i − 1));
        calculate the relative amplitude of each cycle A(i) = D_m(i) − D_n(i);
        calculate the slope of signal rising edge P(i) = (D_m(i) − D_n(i)) / (t(D_m(i)) − t(D_n(i)));
        if A(i) > A_light then
            if A(i) > A_snore then
                a = a + 1;
            end if
            if A(i) − A(i − 1) < 0.5 × A(i) then
                t = t + 1;
            else
                output t and t = 0;
            end if
            if P(i) > P_min and P(i) < P_max then
                p = p + 1;
            end if
        end if
    end while
    if a > A_snore and max(t) > T_last and p > 5 then
        snoring happened during sleeping.
    end if
end while
```

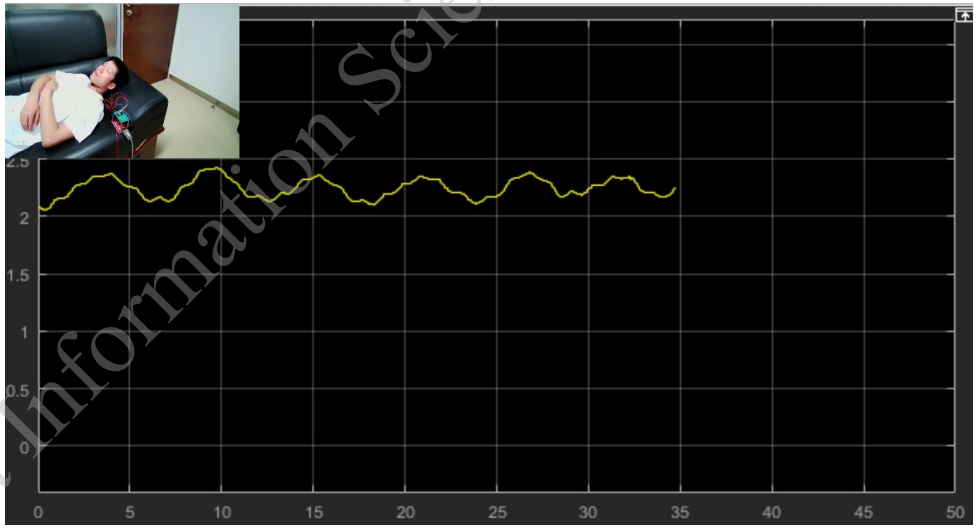
3 Snoring detection: experiments

Fixing the strain sensor



In the experiment, the sensor is attached to the neck with a rope.

Record sleeping data

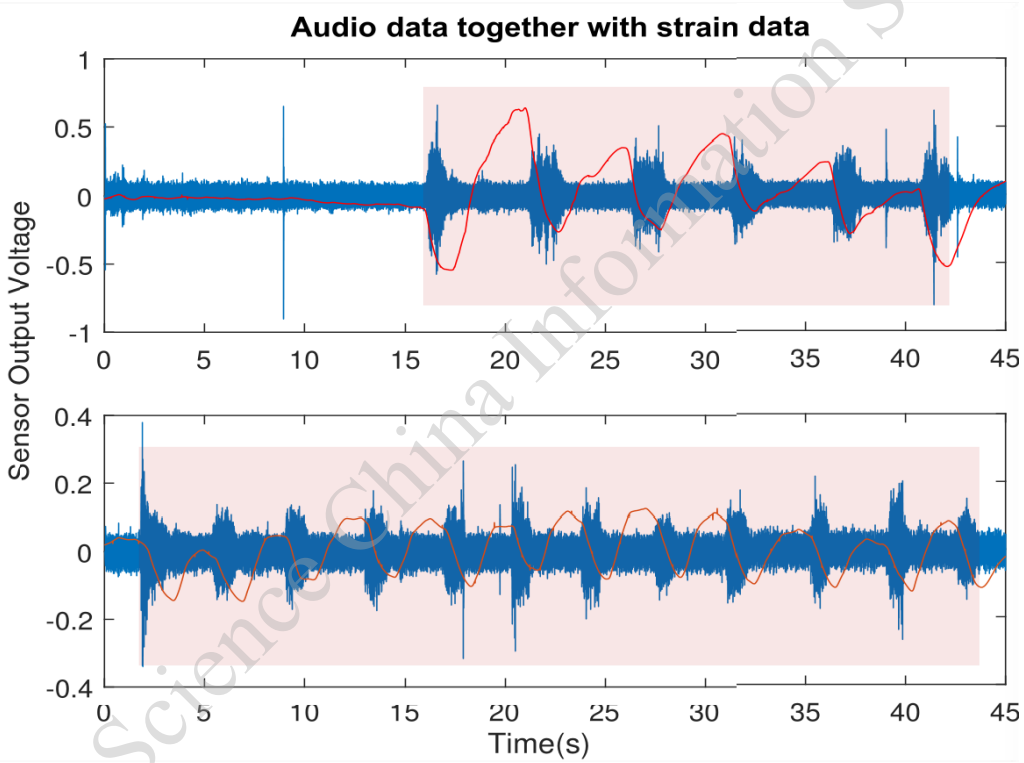


The behavior of subjects is recorded with the sleeping data simultaneously.

Five subjects are employed to test the proposed snoring detection method.

3 Snoring detection: result

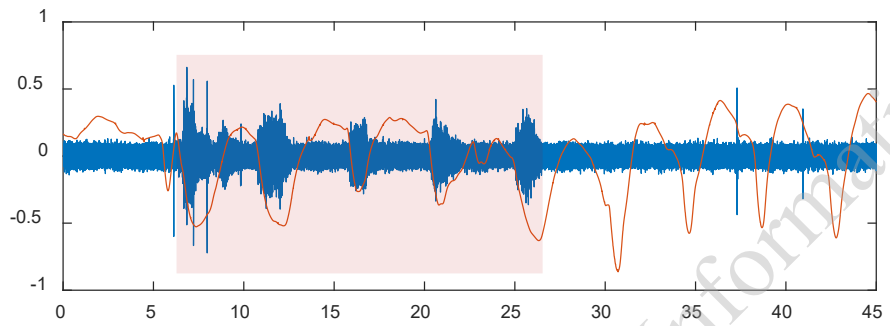
- Audio data and strain sensor data are recorded when snoring occurs during sleeping.



It can be observed that strain sensor is sensitive to snoring.

3 Snoring detection: result

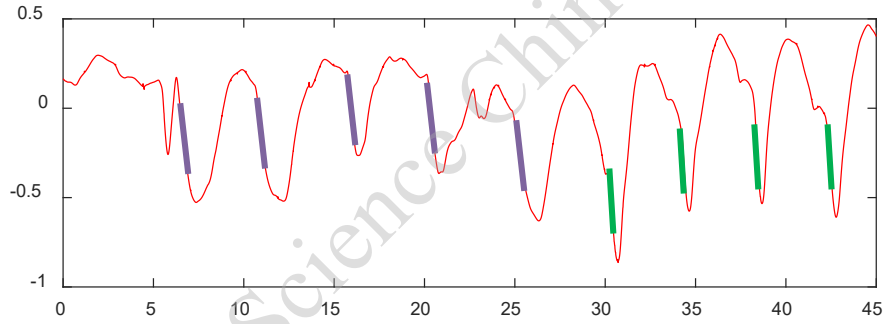
- Audio data and strain sensor data is recorded when snoring and swallowing occur during sleeping.



Snoring occur

Strain sensor data

Audio data



Strain sensor data

Swallowing occur

Snoring occur

Detecting snoring through slope of sleeping data

3 Snoring detection: conclusion

- This MOOP proposes a new method to detect snoring based on a self-developed stretchable strain sensor.

Conclusions

- **This proposed detection method can avoid the influence of environment noise during the detecting process;**
- **This sensor only applies light stress to the snorer's skin and obtains a satisfactory detection result;**
- **This detection device is small, light and cheaper, it can be used by snorers at home;**
- **The algorithm of detecting snoring/non-snoring actions was proposed and verified by experiments.**

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4 **Future work**

4 Future work

- Develop a more convenient way to wear strain sensor;
- Machine learning methods can be used to detect the snoring, swallowing and turning over actions and therefore monitor the sleeping quality;
- Other interesting applications based on the self-developed strain sensor are to be investigated.

Thanks for your attention