Real-time Breath Monitoring through Smart Fashion

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Introduction

Breathing rate (BR) is a vital physiological parameter that plays a critical role in various clinical applications, including illness monitoring and predicting potentially life-threatening events like cardiorespiratory arrest. Continuous detection of breathing signals is also essential in anaesthesia, apnea evaluation, hyperventilation and radiotherapy for lung tumour treatment. With the growing need for more efficient and interactive health management systems, there is a demand for wearable technologies that allow people to monitor their health status more effectively and receive timely medical assistance. This can be achieved by smart fashion implemented in breath monitoring.

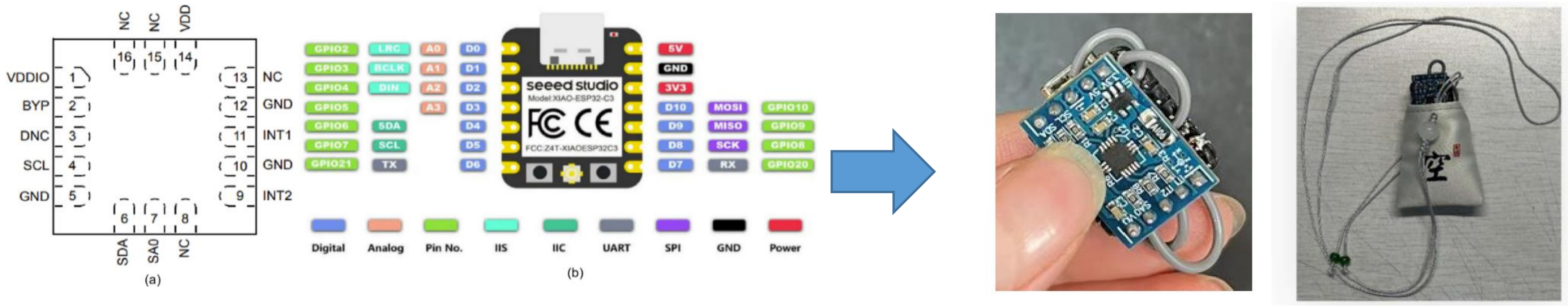
Breath Monitoring
- Non-contact Methods: Suitable for burn patients
- Contact Methods: Suitable for daily life (accelerometer)

Smart Fashion
- Smart Clothes: Tights to ensure accuracy; Less comfort
- Smart Jewellery: Portable, small, high-level user experience

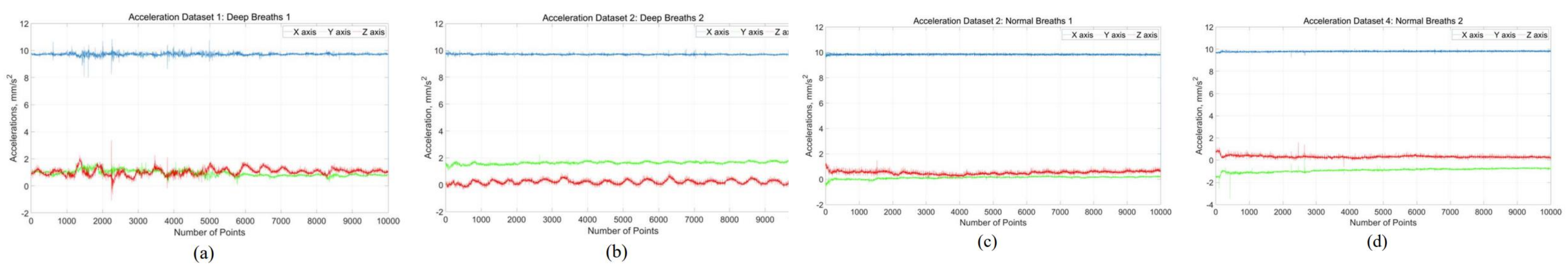
Proposed: **Breath-monitoring Smart Necklace through Accelerometer**

Methodology & Results

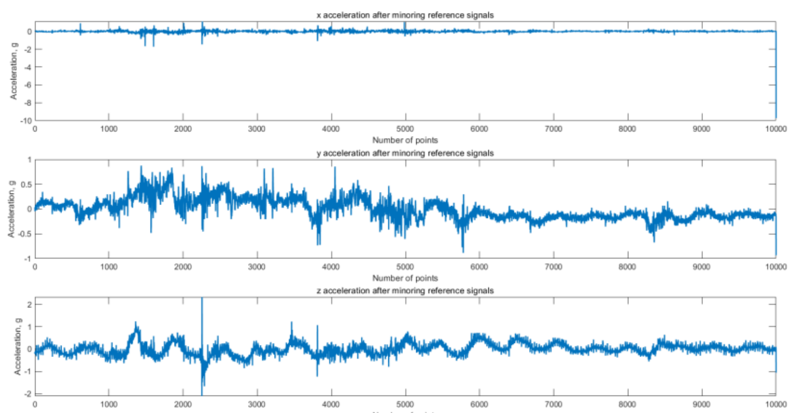
1. **Hardware Construction (Prototype)** The breath-monitoring smart necklace was composed of an MMA8451 accelerometer and a Seeed Studio XIAO ESP32C3 microcontroller.



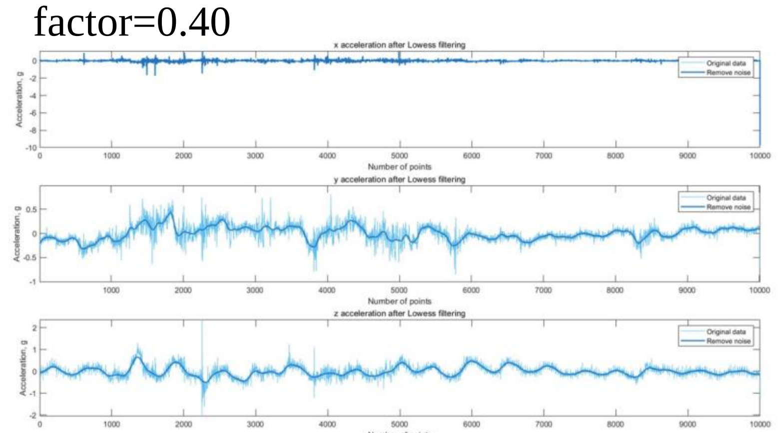
2. **Data Collection** Two deep breath datasets and two normal breath datasets were collected when a user was sitting still for 1.5 minutes. One of the deep breath datasets was taken as the sample to develop an acceleration-to-breath algorithm with others for validation.



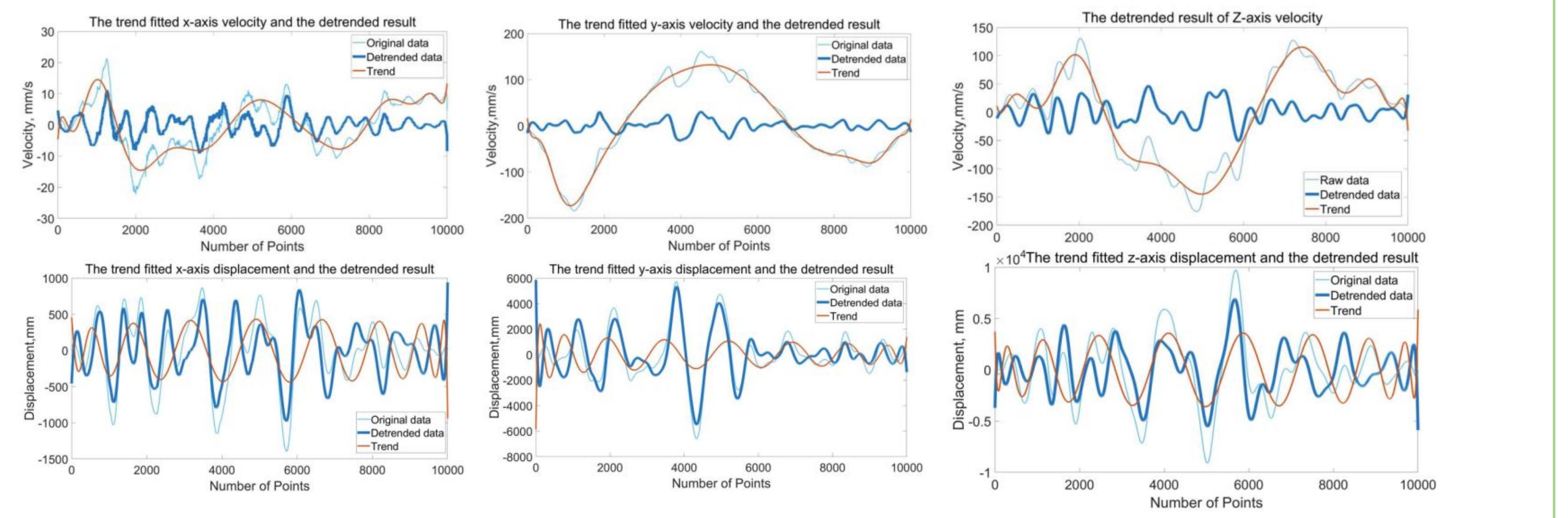
3. **Preprocessing: De-averaging** The reference signals were designed to make the mean values of each axis to be 0.



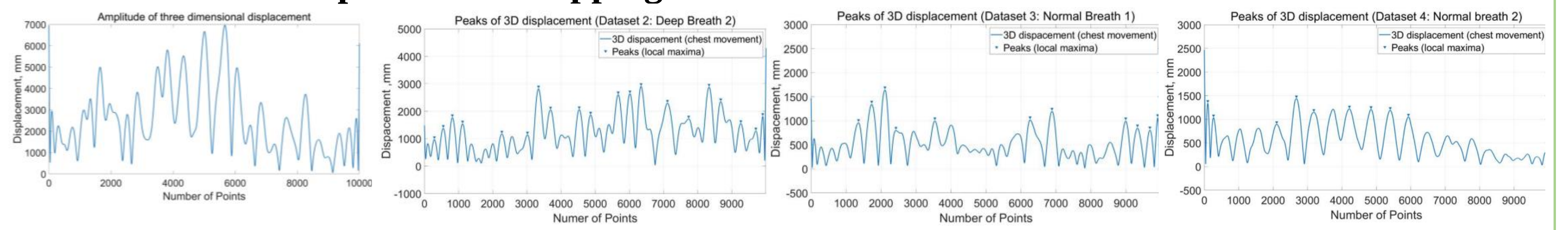
4. **Preprocessing: Filtering** Lowess filtering method with smooth factor=0.40



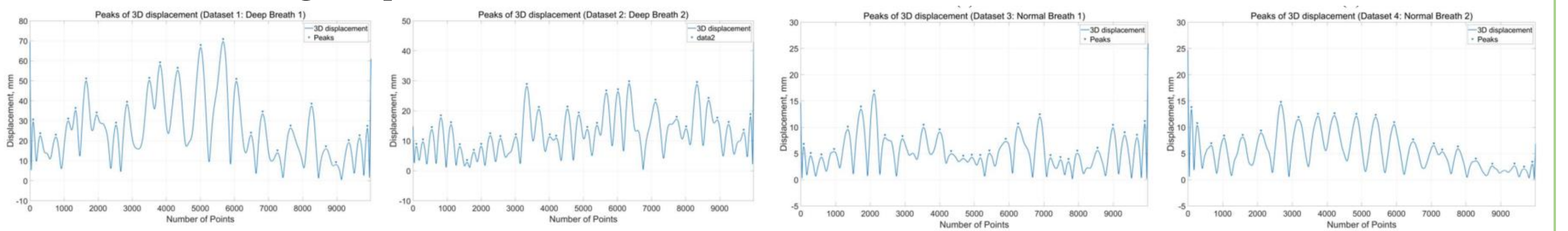
5. **Preprocessing: Detrending** This method was conducted to avoid cumulative errors when converting accelerations to displacements by applying trapezoid integral twice. It was achieved by first fitting the trend of the raw data and then removing the fitted trend from the original data.



6. **Acceleration-Displacement Mapping: Vector Sums for three-dimensional movement**



7. **Adaptive Peak Detection Method** Function *findpeaks()* was utilized to find peaks of the 3D displacements and the peaks can be referred to as the number of breaths. The improvement can be realized by first multiplying 10^{-2} to the collected acceleration data and then eliminating the prominence that can be rounded to 0.



8. **Results: BR calculation** According to $BR = \frac{Number\ of\ breaths\ (Number\ of\ peaks)}{time}$, the results of BR detected were **17, 21, 19, and 15bpm** (breaths per minute) for four datasets respectively.

9. **Email Notification** A warning email will be sent if the BR is over 26 bpm (Hyperventilation) or the intervals between two neighboring peaks are larger than 10 seconds (Apnea).

10. **Two Criteria Evaluation**

Criterion 1: The deviation between processed BRs and ground-truth BRs.
- **Before improvements:** the overall deviation is 43%
- **After improvements:** decreased to 35%

Criterion 2: The deviation between processed BRs and the theoretical range of normal BRs.
- **Before improvements:** 50% of datasets are within the range of normal breathing with 2 other datasets deviated by 42% and 50%.
- **After improvements:** 75% of datasets match the range of normal breathing with only 1 dataset deviated by 5%.

Conclusion

The whole process of this project is concluded in this figure. Results shown that the accuracy of this smart necklace is about 65% for criterion 1 and 75% for criterion 2. Future work should aim to improve accuracy in terms of types of devices and signal processing methods.