Non-contact home health monitoring based on low-cost high-performance accelerometers

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Introduction

This poster reports the initial study of non-contact home health monitoring based on custom-designed low-cost ultrasensitive accelerometers. These sensors were developed based on a unique cascaded asymmetric-gapped cantilever structure and achieved a resolution orders of magnitude better than those in smart phones and other wearable devices.

Sensor Development

The ultra-sensitive accelerometer is based on an asymmetric-gapped cantilever structure, as schematically shown in Fig. 1 (a). The top beam formed by a piezoelectric sensing layer is separated from the bottom mechanical beam by a gap, which can significantly increase the sensitivity compared with the traditional accelerometer with same dimensions.

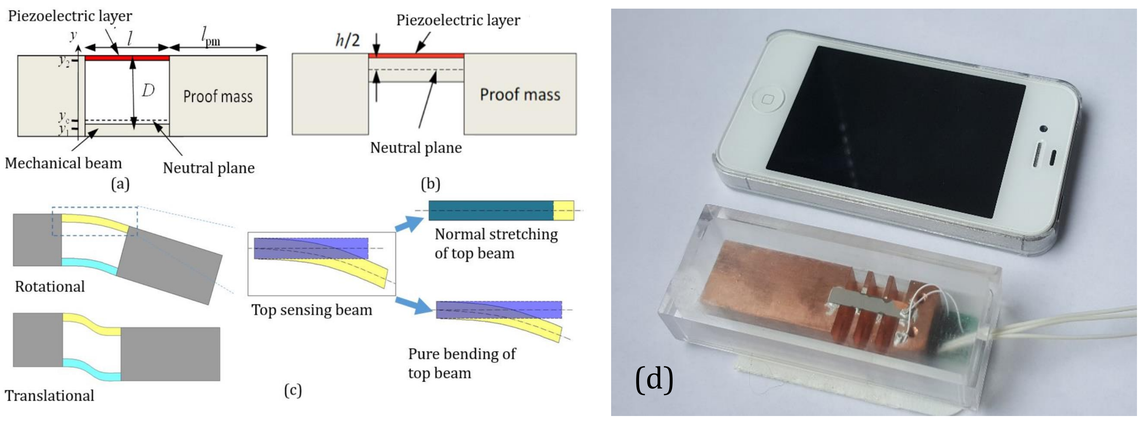

Fig. 1 (a) structure of accelerometer based on asymmetric-gapped cantilever; (b) structure of a conventional accelerometer; (c) decomposition of the bending of asymmetric-gapped cantilever; (d) an ultrasensitive accelerometer in comparison with an iPhone 4 smart phone.

The deflection of the asymmetric-gapped cantilever under acceleration can be decomposed into rotational and translational bending as shown in Fig. 1 (c). What is effective in generating output voltage is only the energy stored in the top sensing layer in the form of normal strain; therefore, in order to get optimal energy efficiency, a careful designing in the beam structure is needed.

BCG Recording

The newly developed sensor has been demonstrated for detecting Ballisocardiogram (BCG) on beds. The sensor was conveniently attached to the front frame of a bed in order to measures BCG in *x* direction, i.e., the head-to-toe direction. A group of recordings is shown in Fig. 2 (all presented data are bandpass filtered from 0.2Hz to 20Hz).

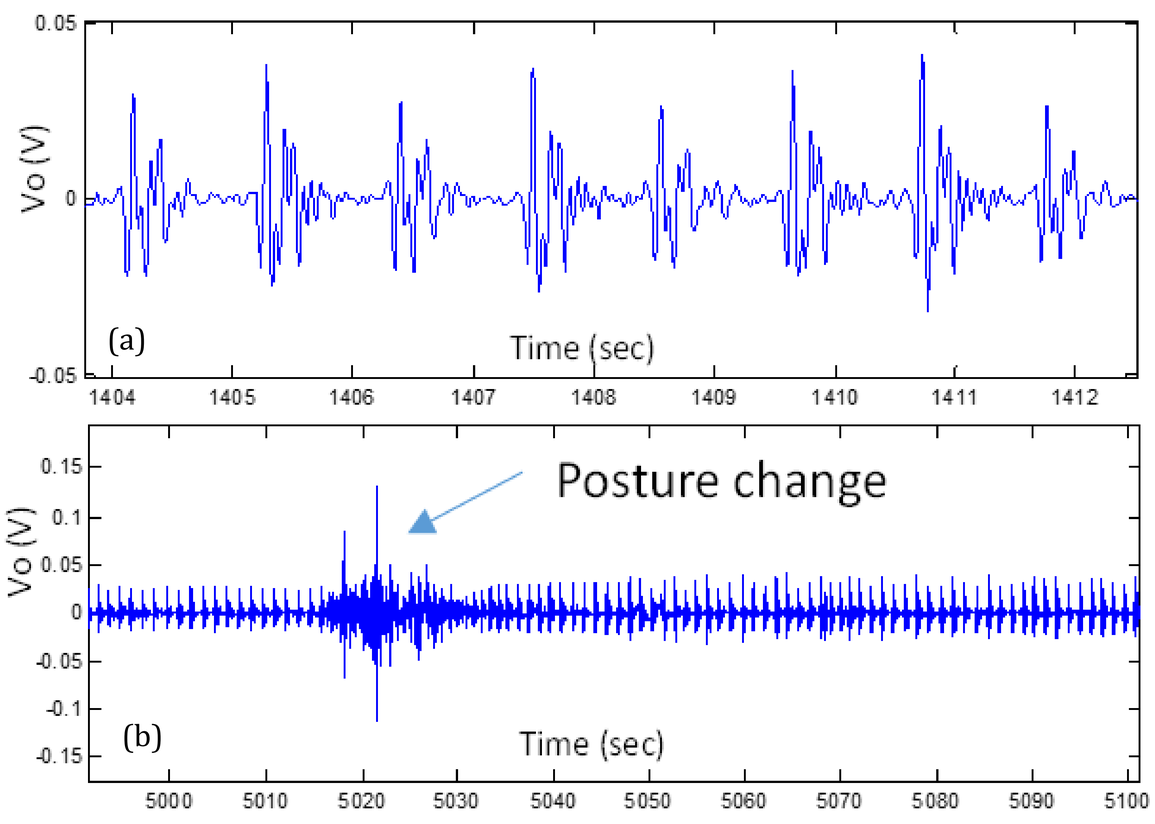

Fig. 2 (a) Enlarged view of BCG pulses; (b) large spikes caused by body movement.

It can also be observed from Fig. 2 that, the amplitude of BCG pulses is not constant. This is mainly because of the modulation of respiration. A more obvious result is presented in Fig. 3; the respiration information such as rate and magnitude can be derived from the BCG waveforms.

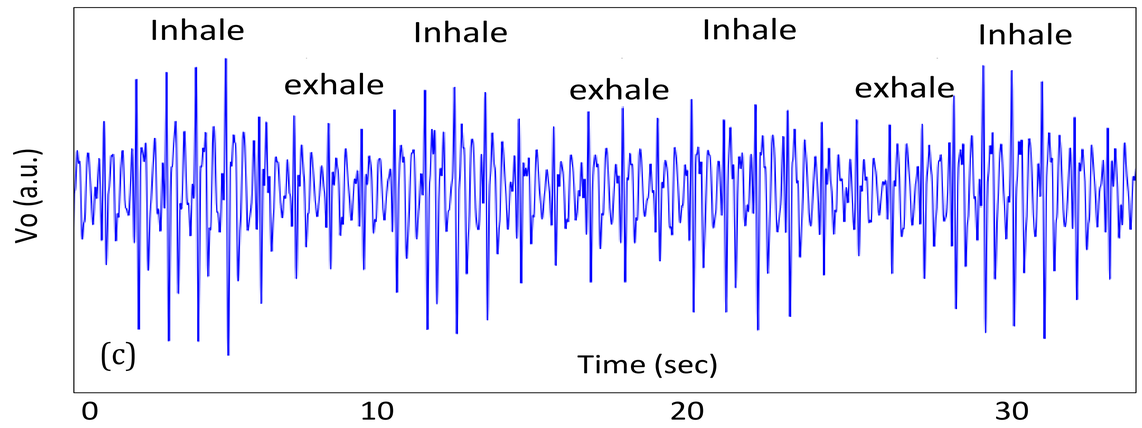

Fig. 3 Modulation of BCG signal by respiration

3D BCG

It is feasible to extract posture signatures from two main groups of 3-D BCG parameters: (1)the morphology, amplitude change of individual components; (2)phase and amplitude ratio among 3 BCG components.

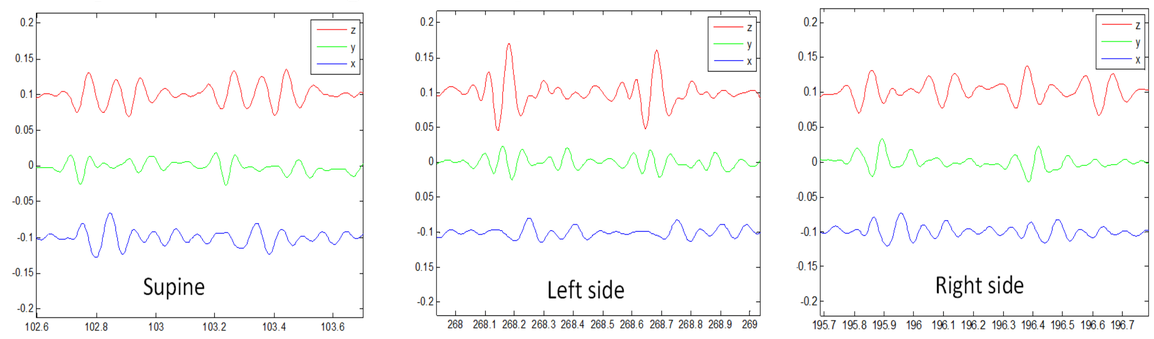

Fig. 3 3-D BCG of a healthy volunteer in three different sleeping postures (Voltage-time plot; *x* and *z* components are shifted vertically for clarity).

Challenges

A commonly encountered issue in real world is the multi-occupancy issue, i.e., the accelerometer will record BCG signals from both or all occupants, if two or more subjects are present simultaneously. Separation of individual signals is a classic but challenging problem.

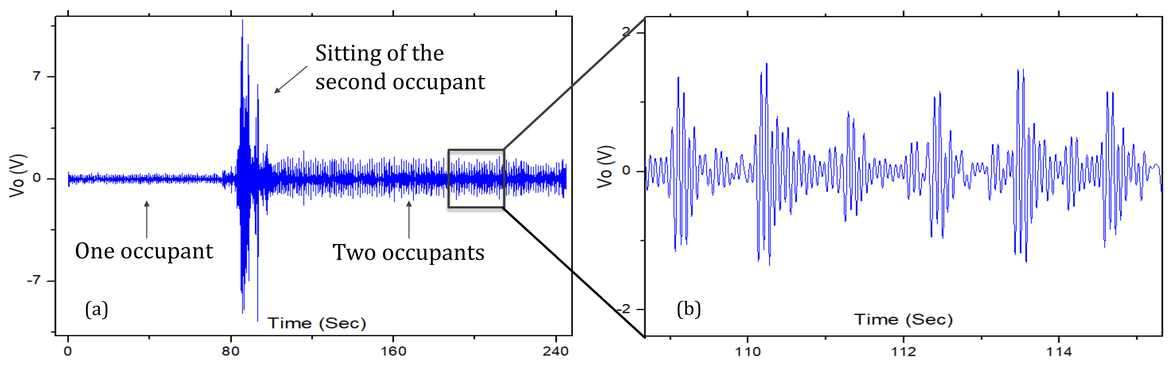

Fig. 4 (a) change of the BCG recording of one occupant to two occupants; (b) BCG signal recorded from two occupants in one bed simultaneously

The environmental background noise is also a concern; in some buildings, such as hospitals, the environment vibration could overwhelm the BCG signal.

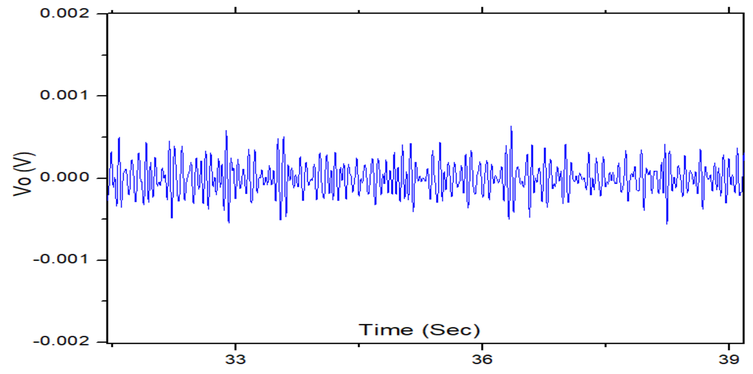

Fig. 5 BCG signal acquired on a hospital bed

References

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