

KinRes: Depth Sensor Noise Reduction in Contactless Respiratory Monitoring

INTRODUCTION

KinRes is a novel reliable solution to extract contactless respiratory signal via an IR-3D Depth sensor (Microsoft Kinect v2) on human subjects interacting with a computer. To do so, we need to analyze how the human respiratory system works. When a subject is inhaling, the rib cage moves upwards and outwards, and the air is drawn into the lungs. In this case, the chest is getting closer to the sensor, and when exhaling the reverse procedure occurs and the chest would go downwards and backward, and it is getting further from the sensor.

PROBLEM STATEMENT

3D Depth sensor in Microsoft Kinect v2 is sensitive to the noises, which are generated by:

- 1) the subject's movements (Figure 1);
- 2) data acquisition in a high-frequency sampling rate;
- 3) sensor limitations and errors.

A high quality noise-free signal is essential to measure the respiratory peaks & troughs accurately.

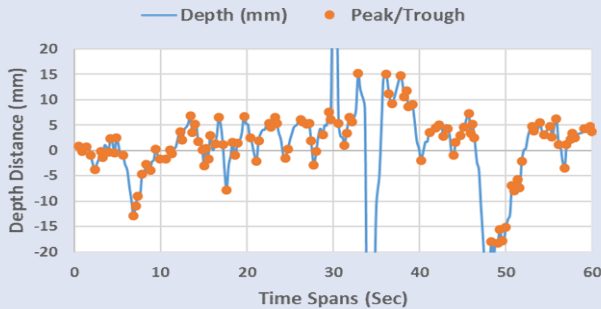


Figure 1. Moving backward and forward interference in respiration monitoring with incorrectly calculated peaks and troughs due to the signal noise.

RESULTS

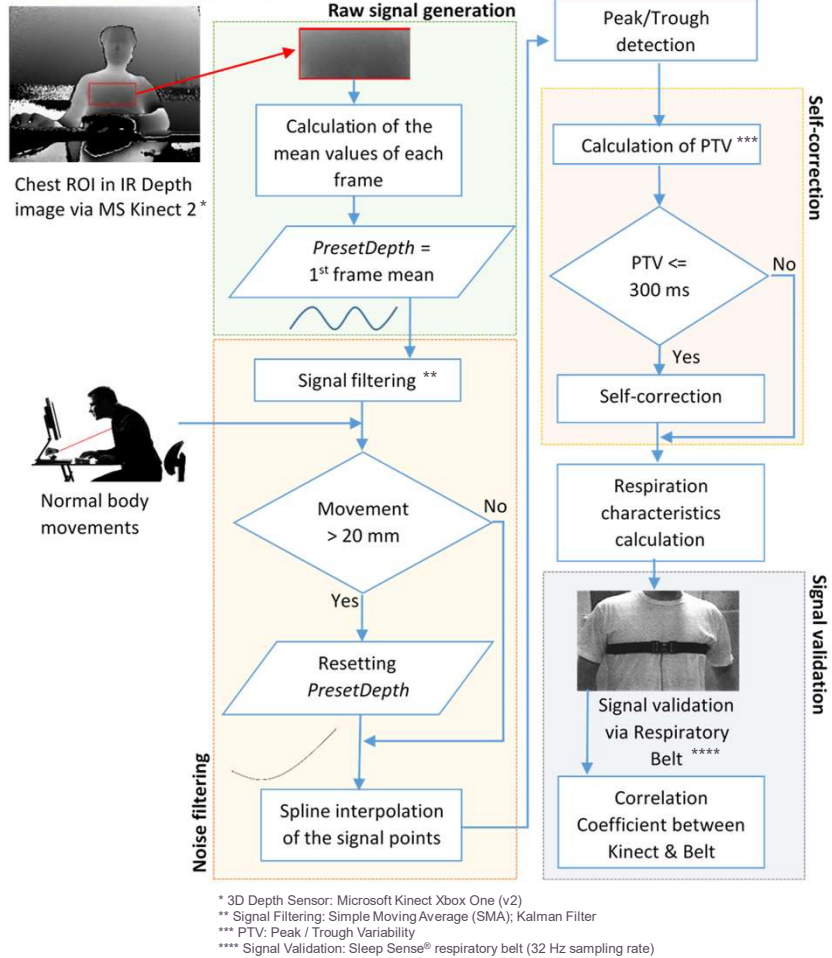
KinRes signal (Kinect 2 distance: 1 meter) (Figure 2) was validated against the Sleep Sense[®] respiratory belt at 32 Hz. 24 signals with minimum length of one minute from 12 male subjects (Mean age = 27.58; SD = 2.84) were captured. Each subject was recorded in two modes: 1) Static/Still: with no significant body movements; 2) Active: with normal body movements while interacting with a PC.

The best achieved correlation coefficient of *KinRes* with the Kalman filter on interacting/moving subjects was 0.8637. In overall, the mean correlation coefficient value of 0.9094 of Kalman filter in both modes outperformed SMA (refer to Table 1). Utilized filters improved the accuracy of the system by more than 24% in active mode, compared to the raw depth signal.

| Filtering | Static | Active |
|-----------|---------------|---------------|
| No-filter | 0.8724 | 0.6195 |
| SMA | 0.9565 | 0.8411 |
| Kalman | 0.9551 | 0.8637 |

Table 1. Correlation Coefficient results of two modes of signals (static/still; active/normal) from *KinRes* against respiratory belt (**Bold**: higher values)

METHODOLOGY



PEAK / TROUGH SELF-CORRECTION

KinRes can measure the respiratory characteristics precisely by employing Peak-Trough Variability (PTV) in a smart greedy algorithm for self-correction. PTV is the time difference between two sequential detected peak and trough.

- 1 $PT \in [peaks/troughs \text{ collection}]$
- 2 **for every** PT_n **in** PT **do**
- 3 **if** $PTV(PT_n, PT_{n-1}) \leq 300 \text{ ms}$ **then**
- 4 **if** $f''(PT_n) < 0$ **then**
- 5 **Remove** $\rightarrow \min(PT_n, PT_{n-1}) \in PT$
- 6 **end if**
- 7 **if** $f''(PT_n) > 0$ **then**
- 8 **Remove** $\rightarrow \max(PT_n, PT_{n-1}) \in PT$
- 9 **end if**
- 10 **end if**
- 11 **end for**

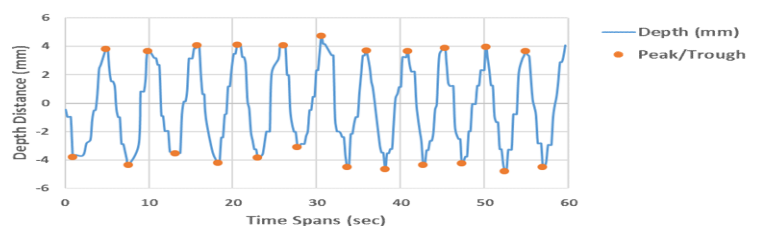


Figure 2. Respiratory signal after noise reduction with correctly detected peaks/troughs