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Multirate Processing for Removal of Ventilator Artefact in Oesophageal PPG Signals

K Shafqat[1], P A Kyriacou[1], R M Langford[2] and D P Jones[3]
[1]School of Engineering and Mathematical Sciences, City University, London EC1V 0HB UK
[2]Anaesthetic Laboratory & Department, St.Bartholomew's Hospital, London EC1A 7BE, UK
[3]Medical Electronics & Physics, Department of Engineering, Queen Mary University of London, London E1 4NS, UK

Background and purpose

The human oesophagus has been shown to be an alternative site for monitoring arterial blood oxygen saturation (SpO_2) by pulse oximetry in cardiothoracic patients [1 2]. Despite the convincing evidence for it's use as an alternative site for measuring SpO_2, it was only feasible to measure SpO_2 in the middle to upper oesophagus since the ac photoplethysmographic (PPG) signals from the lower oesophagus were frequently corrupted by an artefact, synchronous with the period of the ventilator. The magnitude of this artefact varied from patient to patient and it also depended on the depth of the measurement site. In the middle and lower part of the oesophagus (20 cm and more from the incisors), where the ac PPG signals were of significantly larger amplitude, the magnitude of the artefact was often more than that of the ac PPG signal making the estimate of SpO_2 impossible. This restricted the use of the lower oesophagus for continuous measurement of SpO_2. In the present work a filter was designed using the Multirate Processing (MRP) technique for the reduction of the ventilator artefact [3].

Method

The ventilator artefact has a fundamental frequency component at about 0.2 Hz whereas the fundamental frequency component of the ac PPG signal in adults will be between 1 and 2 Hz. An FIR filter design was preferred over the IIR technique because of its linear phase characteristics. A narrow transition width of 0.1 Hz was chosen so that the maximum number of artefact harmonics can be suppressed. The filter was developed under *Matlab* environment. The PPG signals were sampled at a rate of 100 Hz. At this sampling rate an FIR filter designed using the Equiripple method with attenuation of 80 dB in the stopbands and 0.5 dB ripple in the passband will be of order 2775 and will be very difficult to implement in software for real time processing. For this reason the MRP technique which is capable of reducing the order of the filter down to 695 was used [3]. A 10^{th} order bandpass IIR Butterworth filter with similar specifications was also designed to compare its performance with the results obtained by MRP. Recorded PPG data from ten health patients, undergoing elective surgery, were analysed.

Results

Figure 1 shows the result of processing a typical corrupted red oesophageal PPG signal by both MRP and the Butterworth IIR filter. The MRP technique has performed better than the IIR filter not only in reducing the artefact but also in preserving the morphology of the signal. Figure 2 shows the spectrum of the corrupted and the MRP filtered signal.

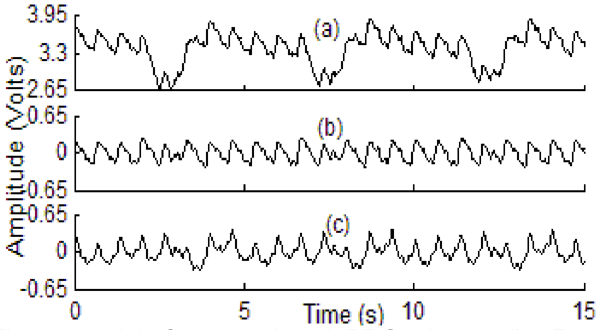

Figure 1: (a) Corrupted red PPG signal, (b) Result from MRP and (c) Result from Butterworth filter.

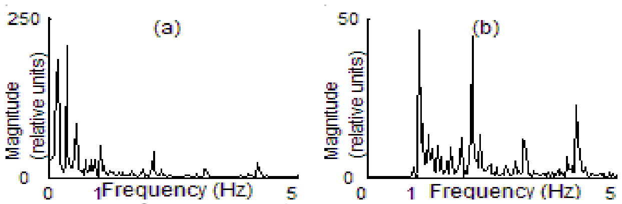

Figure 2: Spectrum of the (a) corrupted red PPG signal, (b) MRP filtered red PPG signal.

A signal-to-noise ratio (SNR) improvement, calculated from the difference in ratio of signal and artefact components before and after processing, of about 60 dB was achieved on average for both red and infrared PPG signals.

Conclusions

This study has demonstrated that a sharp cut-off FIR filter can be used to reduce the ventilator artefact in the oesophageal PPG signal. This will allow the estimation of SpO_2 in the lower parts of the oesophagus as well as the upper. These initial findings are encouraging. However more clinical studies are required to see the effectiveness of such processing in allowing SpO_2 estimation from the lower parts of the oesophagus.

References

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