

Bayesian denoising framework of Phonocardiogram based on a new dynamical model

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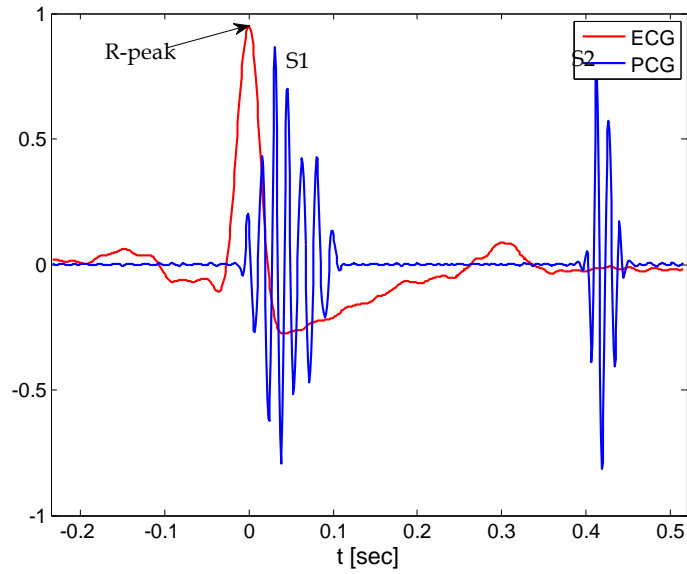


Figure 1: A phonocardiogram signal from a healthy person, including the first heart sound (S1) and the second heart sound (S2). The time is specified relative to the position of the R-peak in the Synchronous ECG.

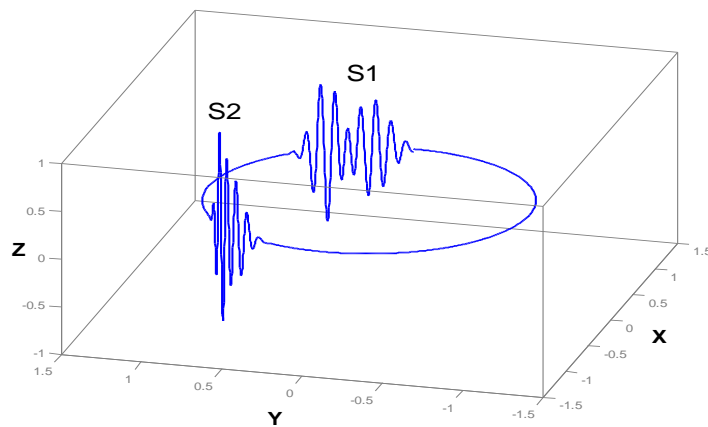


Figure 2: Typical trajectory generated by the dynamical model (11) in the 3-D space given by (x,y,z) . Each entire movement around this trajectory is equivalent to one heartbeat. The model parameters are selected based on a real PCG beat.

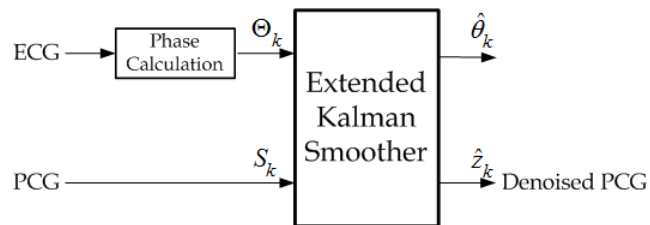


Figure 3: General block diagram of the proposed model-based Bayesian PCG denoising.

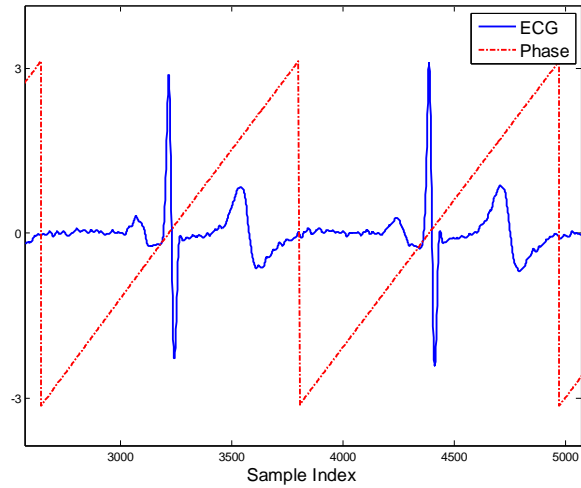


Figure 4: Phase Signal obtained from the synchronous ECG signal.

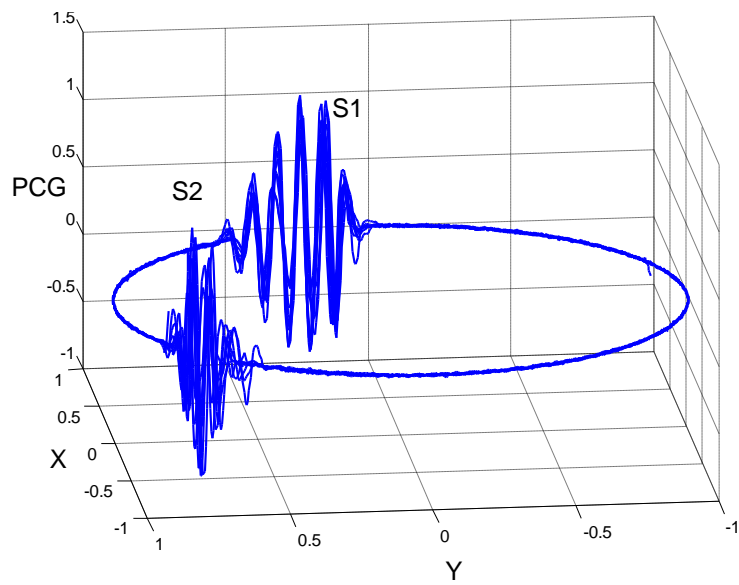


Figure 5: A PCG signal plotted in cylindrical coordinates with corresponding Phase signal.

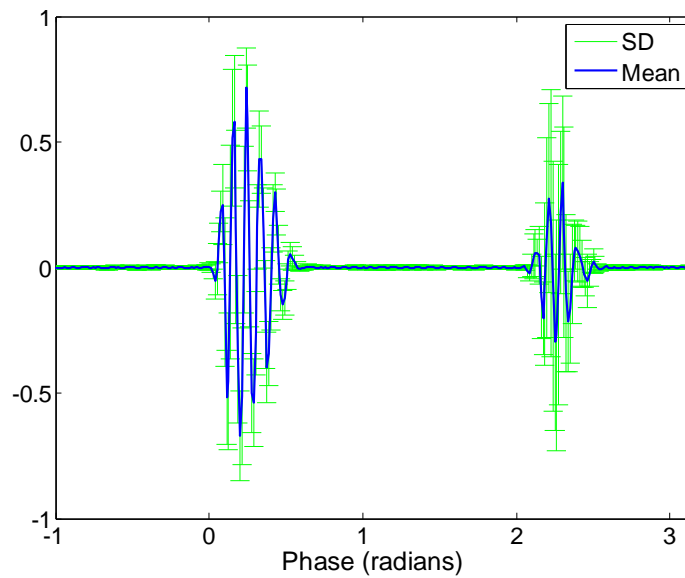


Figure 6: The mean and standard deviation-bar of a 10-beat-PCG signal. The standard deviation-bar features the beat to beat variations in a PCG signal.

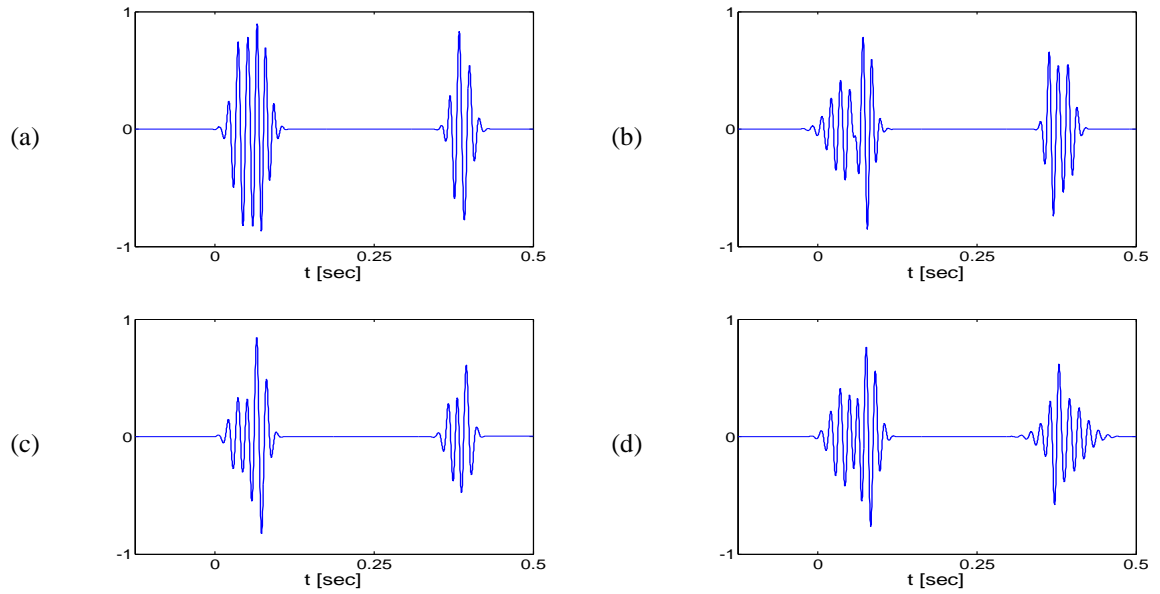


Figure 7: Synthetic PCG signals including two heart sounds, S1 and S2, generated by PCG dynamical model. Each heart sound waveform is generated by using two Gabor kernels whose parameters are listed by figure index (a), (b), (c) and (d) in Table 3. The heartbeat duration is assumed to be 1 sec and therefore the angular velocity ω would be equal to 2π . The origin of the time axis corresponds to the R-peak in the synchronous ECG signal.

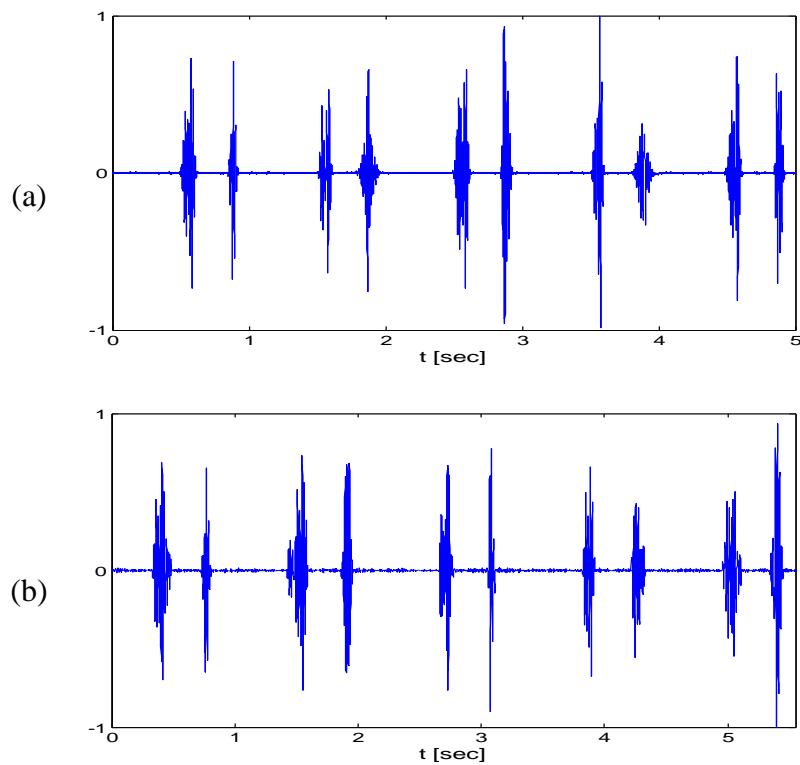


Figure 8: Comparison between (a) synthetic PCG with additive white Gaussian noise, and (b) real PCG from a healthy person.

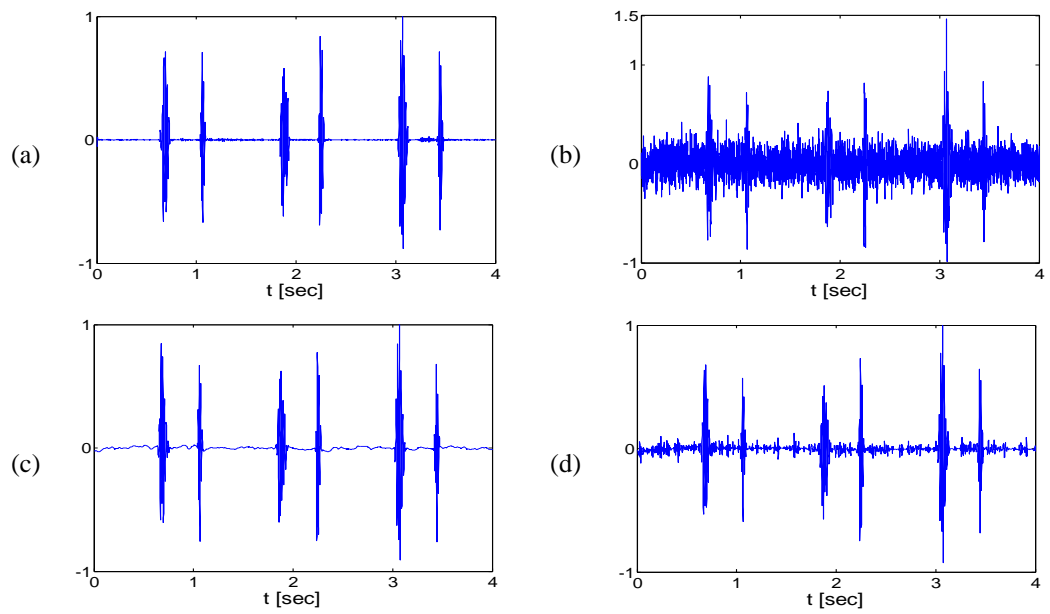


Figure 9: Typical Denoising results for an input signal of 0 dB. (a) original, (b) noisy, (c) EKS, and (d) WD.

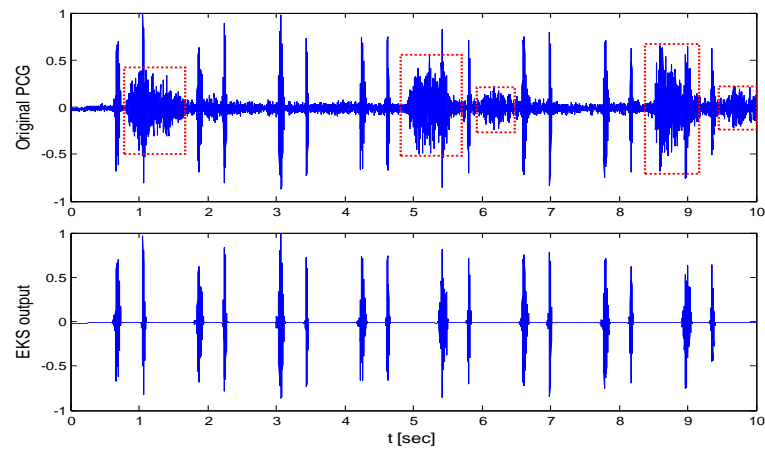


Figure 10: The result of removing breath sounds from PCG signal by the introduced EKS structure; Original PCG signal associated with breath sounds in dot-rectangular shapes (top), and output of the EKS structure (bottom). As it is clear, the breath sounds contaminating PCG signal are completely removed.

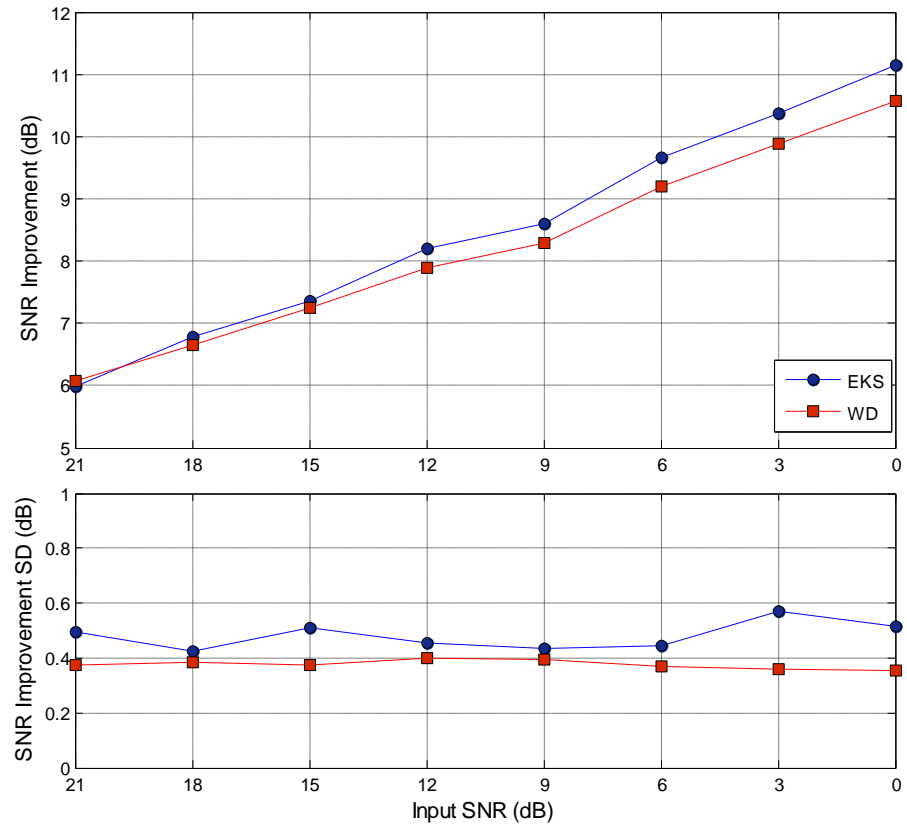


Figure 11: The mean (top) and standard deviation (bottom) of the output SNR improvement versus input SNRs for our model-based Bayesian PCG denoising and Wavelet denoising.