

# Detection, Delineation and Unsupervised Classification of the Phonocardiogram Sounds in Presence of Severe Valvular Anomalies

Hossein Naseri\*, Mohammad Reza Homaeinezhad, Ali Ghaffari, Ali Golmirzaei, Abbas Atyabi, Amir Hosseini Sabzevari, Mohammad Aghaee, Sanaz Ghanipour, Abuzar Sekhavati, Emad Naseri, Zahra Emkanjoo, Mehrdad Haghjoo, Reza Rahmani and Mohammad Mahdi Daevaeiha

This paper presents a new method for detection, delineation and unsupervised classification of PCG sounds. First, the PCG signal was preprocessed and then for detection and delineation of the PCG genuine sounds incidence locations, a window was slid on the pre-processed PCG signal. In each slid of the analysis window, the value of mid-sample of window was replaced by the Gaussian first-order moment of the signal excerpted by the window. By these calculations, not only the signal is denoised, but also a peak representing location of the sound incidence appears that can be delineated by various methods such as application of a minimum slope forward-backward local search starting from the sound location. Afterwards, in order to extract efficient features aimed for unsupervised classification of the segmented heart sounds, some frequency-based techniques such as cosine Fourier integral (CFI), fast Fourier transform, short time Fourier transform (Wigner-Ville spectrum) and packet wavelet transform were assessed. For clustering of delineated PCG signal sounds, curve-length values of the segmented sounds CFI were calculated in the frequency between 5-400Hz. Then, histogram of the calculated features was estimated using Parzen approximation method. The estimated histogram was smoothed via an adaptive smoothing algorithm aimed for making an oscillatory and noisy trend differentiable. Afterwards, local maximums of modified histogram were determined and assigned as the center of clusters. Also, for each detected local maximum, the corresponding encompassing local minimums were determined and assigned as cluster boundary. The proposed algorithm was applied to fifty 4-min PCG signals gathered from patients with different types of valve diseases from their 2R (aortic), 2L (pulmonic), 4R (apex) and 4L (tricuspid) positions by an electronic stethoscope (3M Littmann 3200, 4 KHz sampling frequency). The operating characteristics of the proposed method is the average accuracy  $Acc=98.91\%$  and  $93.50\%$  for sound detection and unsupervised classification, respectively.