World Academy of Science, Engineering and Technology
International Journal of Electrical and Computer Engineering
Vol:9, No:01, 2015

Robust Heart Rate Estimation from Multiple Cardiovascular and Non-Cardiovascular Physiological Signals Using Signal Quality Indices and Kalman Filter

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Abstract : Physiological signals such as electrocardiogram (ECG) and arterial blood pressure (ABP) in the intensive care unit (ICU) are often seriously corrupted by noise, artifacts, and missing data, which lead to errors in the estimation of heart rate (HR) and incidences of false alarm from ICU monitors. Clinical support in ICU requires most reliable heart rate estimation. Cardiac activity, because of its relatively high electrical energy, may introduce artifacts in Electroencephalogram (EEG), Electrooculogram (EOG), and Electromyogram (EMG) recordings. This paper presents a robust heart rate estimation method by detection of R-peaks of ECG artifacts in EEG, EMG & EOG signals, using energy-based function and a novel Signal Quality Index (SQI) assessment technique. SQIs of physiological signals (EEG, EMG, & EOG) were obtained by correlation of nonlinear energy operator (teager energy) of these signals with either ECG or ABP signal. HR is estimated from ECG, ABP, EEG, EMG, and EOG signals from separate Kalman filter based upon individual SQIs. Data fusion of each HR estimate was then performed by weighing each estimate by the Kalman filters' SQI modified innovations. The fused signal HR estimate is more accurate and robust than any of the individual HR estimate. This method was evaluated on MIMIC II data base of PhysioNet from bedside monitors of ICU patients. The method provides an accurate HR estimate even in the presence of noise and artifacts.

Keywords : ECG, ABP, EEG, EMG, EOG, ECG artifacts, Teager-Kaiser energy, heart rate, signal quality index, Kalman filter, data fusion
Conference Title : ICSIP 2015 : International Conference on Signal and Image Processing
Conference Location : Singapore, Singapore
Conference Dates : January 08-09, 2015