On-Board Signal Quality Assessment Guided Compression of Photoplethysmogram for Personal Health Monitoring

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***Abstract*— Photoplethysmography (PPG) is a popular diagnostic tool for the assessment of various cardiovascular functions. Under continuous ambulatory measurements, PPG data get corrupted due to motion artifact (MA). Thus, on-board pulse signal quality assessment (SQA) before transmission can save the battery life of the wearable device for portable health monitoring applications. This article describes an SQA guided compression (SQAGC) of PPG data using a modified gain-shaped vector quantization (GSVQ) technique. The SQA was performed using kurtosis and autocorrelation to generate a binary classification rule to detect good quality pulses. Only these were considered for further compression. A notable contribution is reconstruction error minimization using the extracted features from the residual signal using a deep autoencoder (DAE), achieving a low percentage root-mean-squared difference (PRD). The SQAGC technique was evaluated using public databases like MIMIC-II, BIDMC, and PRRB as well as with real volunteers' PPG collected in the laboratory environment. The SQA achieved an accuracy of 96.5% to identify good quality PPG segments out of expert annotated 9200 beats. The compression factor (and PRD) with 400 min duration data from Physionet MIMIC-II, BIDMC, PRRB, and volunteers' data were 15.8 (and 0.31), 15.7 (and 0.21), 17.8 (and 0.33), and 18.2 (and 0.59), respectively, using 12-bit resolution and 125 Hz sampling. A real-time on-device implementation using quad-core ARM Cortex-A53, 1.2 GHz, supported by 1 GB RAM, achieved a latency of 546 ms with 327 kB of memory engagement for a 3 s PPG window. The compression ratio (CR) achieved comparable results, while PRD outperforms the published results using MIMIC-II data set.**

***Index Terms*— Compression, percentage root-mean-squared difference (PRD), photoplethysmogram, quality assessment, vector quantization.**

I. Introduction

PHOTOPLETHYSMOGRAPHY (PPG) is a noninvasive optical technique that has established its potential for measurement of various cardiovascular parameters like blood oxygen saturation, heart rate variability, vascular compliance, respiration rate, blood pressure, and cardiac output [1].

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With the miniaturization of biomedical sensors, developments in information and communication technology and low-power embedded computing, there has been much improvement in the quality-of-life of ambulatory patients [2]. Under ambulatory monitoring, voluntary movement of the peripheral body parts of the subject introduces motion artifact (MA) in the acquired PPG. Intense MA can entirely corrupt a PPG signal, and without its minimization, can lead to misdiagnosis in PPG-based measurements [3]. However, for short-duration and sudden hand movements that introduce burst noise [4], traditional signal processing methods may not produce effective results. When prolonged data are available for analysis, an alternate method is to identify and selectively discard MA-corrupted segments so that only the good quality pulses can contribute toward medical diagnosis. For real-time unsupervised ambulatory monitoring, on-board assessment of signal quality can save battery life by reducing unnecessary data transmission of the MA-corrupted data segments [5]. Signal quality assessment (SQA) from MA-corrupted PPG is an emerging area of research in the last few years. Published works on SQA techniques broadly include time-domain (morphology-based) analysis [6], [7], and signal quality index (SQI)-based artificial intelligent models [8]–[10]. Among these, the majority of the methods rely on PPG beat-segmentation and then asses the pulse-wise quality either through time domain, or frequency domain or a mixture of them for feature selection, followed by a binary classifier. However, under intense MA corruption, PPG beat detection and segmentation is a really challenging task, and only limited literature is available with fair success [4]. Second, under few cardiac malfunctions like atrial fibrillation which changes the pulse morphology, techniques solely based on correlation may have limited success on SQA. From this aspect, non-segmenting approaches seem to provide a better solution [11], [12]. In [11], eight SQI indices were proposed to optimally define the signal quality of a MA-corrupted PPG, and skewness was found the best discriminating feature among all. The work in [12] considered both healthy and stroke patients for SQI estimation using both time- and frequency-domain statistics.

Till date, a limited number of research literatures are available for on-board PPG SQA [13]–[15]. These include computing time-domain features to test a Bayesian hypothesis [13], autocorrelation function, absolute pulse amplitude,