Robust heart rate estimation from cardiovascular signals unobtrusively acquired in a wheelchair

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Abstract:
Many wheelchair users have augmented cardiac risks, namely diabetics, and stroke victims in recovery. This paper describes the developments taken to assess a wheelchair user's heart rate from inconspicuous cardiac measurements. Unremarkably acquired cardiac signals are greatly affected by artifacts, generated by wheelchair motion, and the subject's daily actions. Furthermore, the impedance plethysmogram (IPG) and the ballistocardiogram (BCG), two signals with significant information on the cardiovascular system, suffer significant morphological modifications from patient to patient, and when his posture changes. To robustly estimate the heart rate in these difficult circumstances, it was applied a real-time sine fitting methodology, an approach never used in biological signals. This method applies a sliding power-window to abstract the cardiac signal morphology, and then uses 7 parameter sine fitting to obtain the fundamental frequency of the signal, the heart rate. Sensing hardware was embedded in a manual wheelchair to acquire the subject's IPG and backrest and seat BCG. This implementation allows continuous monitoring of cardiac activity without more mobility limitations. Validation tests of the hardware and software show that the developments made are able to cope with the signals' variations, and provide accurate estimates of heart rate for diverse subject's under various conditions.

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Contents

Although the electrocardiogram (ECG) is the most studied electrophysiological signal, other signals may reveal more informative. The impedance plethysmogram (IPG), and the ballistocardiogram (BCG), are signals informing on the subject's heart and respiratory rates sharing a key characteristic, the possibility of being imperceptibly acquired. This feature is of much worth as it preserves the so-called "patient's autonomic space" [1]. Comfortably assessing a subject's cardiopulmonary condition without constituting a threat to his independence nor his quality of life is significant, especially for subject's who require continuous monitoring. This setting is becoming increasingly important, as modern societies are marked by aging and an increase in the incidence of cardiovascular diseases [2]. To contain economic costs and improve efficiency of cardiovascular care services [3]–[4], home telecare monitoring devices and methods of low obtrusiveness are being growingly explored [5]–[6].