Production and Interpretation of Electrocardiograms

Introduction

Heart rate monitoring is used for identifying unusual patterns in the rhythm of a heartbeat, which can be a symptom of cardiovascular disease. An electrocardiogram (ECG) is a test that records both the muscular and electrical activity of the heart. The general shape of a heartbeat in an ECG plot is 1) an initial pulse (P), 2) a slight dip followed by a sharp peak and a rapid decline (QRS), and 3) secondary pulses (TU). The time between consecutive QRS pulses in the ECG is used to determine the heart rate of the subject [1], [2]. This paper summarizes different methods of collecting ECG data, interpreting those signals, and determining the heart rate from them.

Electrocardiogram devices and signal acquisition

Electrocardiogram testing at a hospital

One option for obtaining an ECG is to be tested at a hospital or medical clinic. These examinations are typically performing by having 3, 5, 12, or 15 electrodes attached to the subject's skin. Each ECG examination takes around 10 seconds to read and print the results [3]. For someone with insurance, the cost to receive an ECG at a hospital varies from $30 to $500 in copays. Without insurance, the cost to receive an ECG test ranges between $200 and $3000. Receiving an interpretation of the ECG reading by a medical doctor costs an additional $50 to $100 [4], [5].

Electrocardiogram monitoring devices

Electrocardiograms can also be obtained from monitoring devices; these should be used if an individual's heart rate is irregular and might not show up on a single test at a hospital [6]. Examples of ECG monitoring devices are portable ECG monitors, cardiac event recorders, and implant devices. Both portable ECG monitors and cardiac event recorders require electrodes to be attached to the subject's body to record heart activity; the most significant difference between the two is that cardiac event recorders do not continuous collect ECG data. Implant devices are placed underneath the skin near the heart and continuously monitor one's heart rate [3]. Both portable and hand-held ECG monitors take approximately 30 seconds to collect ECG data [7]. The ECG80A from CONTEC (~$300) portable ECG monitor uses 12-electrode contacts to monitor heart activity. Both the MD100E ($259) and the PC-80 (< $200) portable monitors use 3-electrode contacts, while the AfibAlert ($349 - $449), InstantCheck ($500 - $800), and ReadMyHeart (< $200) monitors all require 2-electrode contacts to monitor heart activity. Some portable ECG monitors do not require electrode contacts to measure heart rate: the Dimetek Micro Ambulatory ECG Recorder (~$300) and HeartCheck Pen ($259 + $12.50 per interpretation) use hand contacts for

obtaining ECG data. The AliveCor/Kardia ($99) and ECG Check ($129) not only use hand contacts for recording heart rate but also display ECG graphs on a smartphone [8].

Interpretation of electrocardiogram signals

Electrocardiogram signals are amplified for ease in reading the data, and the time between QRS peaks is used to determine the heart rate. Digital filtering is used to remove noise caused by the human body, remove the mean value from the signal, normalize the signal, and remove baseline wander [9]. Lynn's filters, a Daubechies DB4 Wavelet, and a biquad band stop filter comprised of fourth-order Butterworth filters with a highpass frequency of 15 Hz and a lowpass frequency of 20 Hz are all effective in reducing noise [2], [9], [10]. One way for determining the QRS peaks of the ECG signal is by applying first-order derivative and moving average filters to the signal and keeping only the values that are greater than 40% of the maximum signal value [10]. Two other methods for locating QRS peaks are to use a signal threshold and to use the autocorrelation of the filtered signal followed by a peak detector [9]. These signal filtering techniques can be implemented on hardware using the TMS320C6711 DSP Starter Kit connected to a desktop computer which runs Code Composer Studio software to process the ECG signals [10].

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