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Visualization of Cardiac Health Using Electrocardiograms

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The chapter discusses an efficient and novel method to assist the physician to visualize voluminous cardiac data acquired over several hours. The system uses different colors to identify different types of cardiogram signals. In the display strategy each ECG beat is represented by a grid. The visualization strategy is hierarchical; that is, it provides for viewing of data from different level of abstraction, and the physician can have a top down approach to narrow down the time interval and signal details. This display strategy is extended to sector graph, with a menu driven hierarchical display strategy, which progressively unfolds greater details for chosen intervals. Provision is made for changing the parameters of classification, and thus the physician has the option for fine tuning the classification.

4.1 Introduction

Electrocardiogram (ECG) is a representative signal containing important information about the condition of the heart. The shape and size of the P-QRS-T wave, the interval between the various peaks and the changing heart rate etc., contain indications that are very useful in diagnosis of heart ailments. The ECG being a non-stationary signal, the disease indicators may occur at random in the time scale. Therefore, the patient may have to be kept under observation for long intervals for accurate diagnosis.

The ECG signal is usually recorded in magnetic tapes (holter recording), a digitized version of which can be stored in computers. However, the above details are not clearly perceptible for casual observation of the bare signal on the screen. Therefore, it is convenient to analyze and classify the signal using computer, and display the results for clinical observation.

Visual media is a most effective tool for communication, especially when the data is voluminous with subtle variations. Normally the data size in biomedicine is enormously large. For example, the symptoms of disease may show

up only during certain period of the day, and that too may occur at random in the time scale. Therefore the physician may have to monitor and study the data over several hours for diagnostic purposes [1]. The tedium of reading voluminous data can be considerably reduced by using the computer for identifying and displaying the abnormalities occurring over a specified time interval [2]. In the present work, a hierarchical visualization technique is developed to aid the physician to identify the problem spots in the data recorded over long intervals. The vast data for the entire period under study is compressed and displayed on the computer screen using a color code to indicate different (ECG and) heart rates. The user can readily identify any deviation from normalcy by scanning the pattern. The user-friendly visualization tool allows the user to progressively expand the selected portion of the pattern for a closer study. Provision is made for the user to define or alter the thresholds of classification.

The signal can be viewed at different levels of hierarchy, which will progressively unfold greater details of the ECG signal and heart rate. At the highest level of abstraction, the data for 24 hours can be viewed in a single frame, and at the other extreme end, the individual ECG patterns can be displayed on the computer screen. Provision is made for the user to define or alter the thresholds of classification. Such techniques of 'software visualization' have been used in the past, to display programs, program artifacts and program behavior [2].

Proper recognition of beats is impeded by power-line interference; electromyogram noise and baseline drift which are often present in the ECG signal. In long-term monitoring, electrode impedance can increase considerably resulting in very low signal-to-noise ratio, which can make detection practically impossible in a single lead. Therefore, usually two or three leads are used for monitoring [4].

Several studies to classify various cardiac arrhythmias have been reported [5–7]. A number of techniques have been used for identification of arrhythmias including correction waveform analysis [8], time-frequency analysis [9], complexity measures [10], and a total least squares-based Prony modeling algorithm [5]. Different features are extracted from the ECG for classification of ventricular arrhythmias including QRS and ST segment based values, heart rate, spectral features, AR coefficients, complexity measures and nonlinear measures [5–7].

In the past, Udupa *et al* have proposed a set of algorithms for interactive visualization, manipulation, and measurement of large 3-D objects (e.g., heart) on general-purpose workstations [11]. They have addressed the use of these algorithms for visualizing medical data. Morikawa *et al* have investigated the feasibility of four-dimensional electrocardiography (4-D ECG), a new display in which the vector loop was rotated and scanned along a timed axis to overcome the shortcomings of vector cardiography (VCG) [12]. The P wave delineation score, signifying good agreement with the intraobserver