Imaging of electrocardiogram (ECG) signals

Jelena Tesic, University of Belgrade

Advisor: Dr. Dalton S. Arantes, UNICAMP

IAESTE Traineeship, 1997/98

Unicamp, Campinas, Brazil

Imaging of the ECG signals

1. Abstract

An electrocardiogram (ECG) is an electrical recording of the heart and is used in the investigation of heart disease. This project mainly involves development and application of an algorithm for effective storage of the data during the Holter monitoring. Holter ECG monitoring is a continuous recording of the hearts electrical activity, while patient does usual daily activities. The test is useful for diagnosing irregular heart beats that may not show during a resting EKG. The idea is to synchronize the recorded signal and save it in an acceptable format for MPEG2 video compression. Visualization of the series of the frames would show a static picture if electrocardiogram is normal. In this case, MPEG2 video compression is highly effective algorithm to compress data and the storage of the compressed signals in this way is more efficient.

2. Introduction

The aim of my project is to create different modules in C of an algorithm for storage of electrocardiogram data. Those segments could be modified depending on the ECG signal and research results. The first part is processing of ECG signals for storage and visualization purposes and the second part is compression of the signal using MPEG2 video compression algorithm.

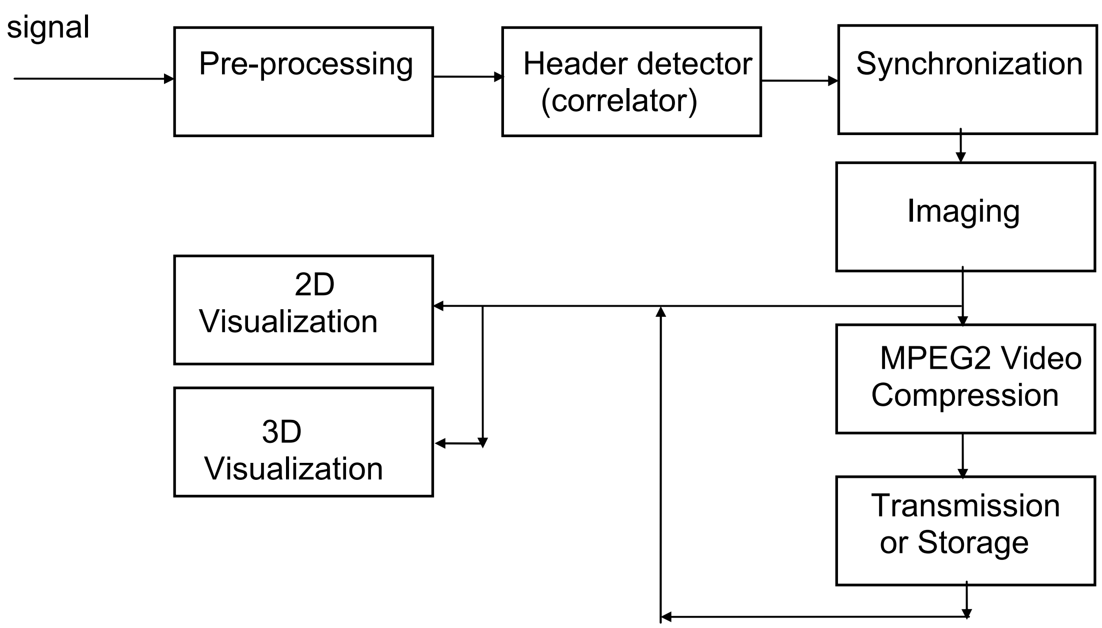

Fig 2.1 ***Block diagram***

3. ECG Signals Characteristics

Sinus rhythm, in the normal state of the heart, has certain characteristics. The small, usually rounded, P-wave is at the beginning of the series. QRS complex follows the P-wave, much larger in size this represents the impulse traveling across the ventricular conduction system. These are usually straight lines forming sharp waveforms. After this comes the T-wave, the period when the ventricles reset for the next impulse. These events are coming in a sequence for every heart beat. By noting the shape, consistency and the time between these waveforms, it is possible to diagnose certain heart diseases. The diagnosis of the normal cardiogram is made by excluding any recognized abnormality.

Fig 3.1 *Normal Sinus Rhythm*

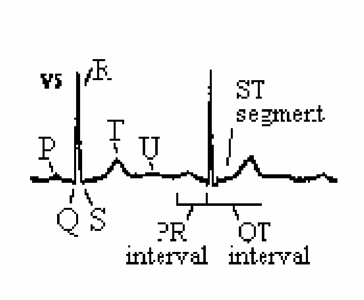

Fig. 3.2 *Characteristic wave*

Normal Sinus Rhythm	
P-R interval	0.12 to 0.20 sec.
QRS duration	0.04 to 0.12 sec.
Q-T interval	Less than 0.42 sec.
Rate	60 to 100 bpm

In the case of the Normal Sinus Rhythm, certain pattern of the waveforms and the values of some parameters are defined. The signal rate is in the range of 60 bpm (bits per minute) to 100 bpm. So, it is possible to define the shortest period between two impulses and the maximum width of the interval (window), where the next impulse begins, if the heart is working normally. Typical QRS form could be used as a header for the detection of the next impulse in ECG strip.

ECG database signal files exist in several formats. Any of these formats can be used for multiplexed signal files, in which samples from two or more signals are stored alternately. /* describe MLII (modified lead II) i V1 (V5)*/

4. Signal processing techniques

Preprocessing of the recorded ECG signal is needed in order to determine its characteristics that will be used for synchronization of the signal.
/* Communication Systems , Detection of the signal in the noise */

4.1. Cepstral Analysis

/* The idea; determination of the peak in signal spectra for finding N and w,
do we need that if we know the range of bit rate . . . */

4.2. Signal Detection

/*Matched filters, correlator, threshold, header determination, adaptive methods */

5. Synchronization of the signal

MPEG2 Video compression algorithm requires as an input a series of frames, where a horizontal size and a vertical size of a frame have to be a multiple of 16 (the dimension of macroblock). Visualization of the series of the frames would show a static picture if electrocardiogram is normal and the signal is synchronized. That means that the difference between corresponding pixels should be minimized. It is possible to define a size of the signal "period". The "period" of the signal starts when the header is detected and ends when the next header is detected. Knowing the range of rates of the normal heart, a number of samples that one "period" have, is always in a interval $\left[f_s[Hz] * \frac{60s}{N_{\max}[bpm]}, f_s[Hz] * \frac{60s}{N_{\min}[bpm]} \right]$, where the f_s is the samplinf frequency, $N_{\min}$ is the minimal normal bit rate per minute (60), and $N_{\max}$ is the maximal normal bit rate per minute (100).

We are using the idea of PCM synchronization in !!!Where the header is N-bit pattern and the size of the frame is defined by the maximal bit rate per minute, as shown above. /*describe the algorithm*/

6. MPEG2 Video Compression & Visualisation

/* Change this . . . */
MPEG2 video was born which set out to fulfill the requirements of the planned digital broadcast networks. MPEG2 can give much higher resolution video (TV studio quality) at lower data rates, and covers film, TV and computer formats. It is also backwards compatible with MPEG1. The language that makes up the MPEG2 video standard is extremely wide-ranging, which makes it very flexible. It is made up of different levels and specifications which can be combined to suit all applications. This means MPEG2 has a wide area of application especially as high technology becomes more and more available to more people from sources such as the internet. MPEG-2 Video is a generic method for compressed representation of video sequences using a common coding syntax defined in the document ISO/ IEC 13818 Part 2 (CD: Nov. 1993, DIS: March 1994) by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), in collaboration with the International Telecommunications Union (ITU) as Recommendation H.262.

The MPEG-2 Video Standard specifies the coded bit stream for high-quality digital video. As a compatible extension, MPEG-2 Video builds on the completed MPEG-1 Video Standard (ISO/IEC IS 11172-2), by supporting interlaced video formats and a number of other advanced features, including features to support HDTV.

As a generic International Standard, MPEG-2 Video is being defined in terms of extensible profiles,each of which will support the features needed by an important class of applications. At the Sydney MPEG meeting, the MPEG-2 Main Profile was defined to support digital video transmission in the range of about 2 to 15 Mbits/sec over cable, satellite, and other broadcast channels, as well as for Digital Storage Media (DSM) and other communications applications. Building on this success at the New York meeting, MPEG experts from participating countries in Asia, Australia, Europe, and North America further defined parameters of the Main Profile and Simple Profile suitable for supporting HDTV formats.

MPEG experts also extended the features of the Main Profile by defining a hierarchical/scalable profile. This profile aims to support applications such as compatible terrestrial TV/HDTV, packet-network video systems, backward compatibility with existing standards (MPEG-1 and H.261), and other applications for which multi-level coding is required. For example, such a system could give the consumer the option of using either a small portable receiver to decode standard definition TV, or a larger fixed receiver to decode HDTV from the same broadcast signal.

The technical definition of MPEG-2 Video has been completed. This was a critical milestone, and MPEG-2 Video was scheduled for a Committee Draft in November 1993. Sweet spot sampling dimensions and bit rates for MPEG-2:

Dimensions	Coded rate	Comments
352x480x24 Hz (progressive)	2 Mbit/sec	Half horizontal 601. Looks almost NTSC broadcast quality, and is a good (better) substitute for VHS. Intended for film src.
544x480x30 Hz (interlaced)	4 Mbit/sec	PAL broadcast quality (nearly full capture of 5.4 MHz luminance carrier). Also 4:3 image dimensions windowed within 720 sample/line 16:9 aspect ratio via pan&scan.
704x480x30 Hz (interlaced)	6 Mbit/sec	Full CCIR 601 sampling dimensions.

/* How to apply this to ECG signal and the purpose . . .*/

7. Application and Results

In order to apply this algorithm in practice, we used signal files from MIT-BIH Arrhythmia Database CD-ROM.

Most of them are format 212 files, which means that each sample is represented by a 12-bit two's complement amplitude. The first sample is obtained from the 12 least significant bits of the first byte pair (stored least significant byte first). The second sample is formed from the 4 remaining bits of the first byte pair (which are the 4 high bits of the 12-bit sample) and the next byte (which contains the remaining 8 bits of the second sample). The process is repeated for each successive pair of samples.

The usual sampling frequency (in samples per second per signal) is 360 Hz.
/* use Matlab, see the 3D signal: header, signal, rate ??? */
/* results, 3D sequency, compression, . . . */

8. Further Possibilities

/* adaptive procedures for finding the correct values of header, period and window size (in samples) */

9. Acknowledgments

I would like to thank Dr. Dalton S. Arantes for his help and guidance, as well as for the opportunity to be involved in this interesting and exciting project. Also, I am very grateful to Dr. Arantes's group and to the graduate students from DECOM for their help and support during my traineeship at Unicamp.

10. Listing