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Dynamic Computer Analyser for 24-Hour ECG Holter Recordings

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Abstract. A combination of hardware and software modules are presented for dynamic analysis of 24-hour ECG Holter recordings. The proposed system can acquire Holter tapes with user selectable sampling rate (up to 1600 Hz), can store and retrieve files that follow standardised formats (SCP-ECG, MIT-BIH etc.) and can analyse data through an open collection of external software modules. The system is also a part of an integrated computer cardiological environment that collects and organises patient information from different sites of a typical cardiological department.

1. Introduction

An ambulatory electrocardiogram is a portable recording of the heart rhythm taken during normal human activities. It monitors the heart's electrical activity as detected on the surface of the skin using electrodes placed on patient's body surface. The electrical impulses are then transmitted to an amplifier, which records them on a small magnetic tape recorder for later review by the physician.

Ambulatory electrocardiograph has been available since the early 1950s, when Dr. Holter introduced his portable electrocardiogram to the medical community. A Holter monitor is a small cassette tape recorder that is carried by a patient and can record 24 hours of two or three channels of ECG data (plus a reference 32 Hz sinus waveform) taken under several daily situations, like walking, sleeping, eating etc. Afterwards, these tapes are read by special computer systems that sample signals with predefined frequency (usually 250 Hz per channel) and a cardiologist specialist can preview or print selected areas of interest. Also, a final report is produced with averaging figures about cardiac rhythm, patient arrhythmia episodes etc.

Holter monitoring is normally used to detect and analyze data coming from Coronary Heart Disease (CHD) patients. Important features include PVCs (premature ventricular contractions) and ischemia episode detection.

Technology development has recently produced digital Holter recorders that apply digital recording methods and instead of using magnetic tapes and a separate computer analyser, they run in the same device an integration of amplifiers, filters, analog to digital signal converters and on-board memory. Data can then be transferred to a computerised system for subsequent review and analysis. Although these systems offer speed and simple device handling, they have a critical disadvantage: they operate as "black boxes", meaning that they work with preset parameters under certain conditions and perform particular analysis with minimum user input.

This can satisfy most of clinical routine work, but is inadequate for special or research analysis (like spectrotemporal analysis) where parameters like sampling frequency, signal processing procedures and exported file formats should be open and chosen by the user. Also, there is a lot of clinical information in analog Holter tapes, which represent data acquired over decades of clinical work, that in many cases await processing and validation.

2. Method

In this study we have implemented an integration of hardware and software modules which can analyze Holter recordings following an open system architecture. The proposed system consists of the following units (Figure 1):

(a) A computer controlled cassette player that includes amplifier and filtering units. The device can have stable or variable speed varying between 10 to 120 times the original recorded speed (1 mm/sec). In order to stabilize cassette player speed, special electronic circuits have been constructed that synchronize the cassette motor speed with the 32 Hz reference signal that is recorded as channel four in every Holter tape.

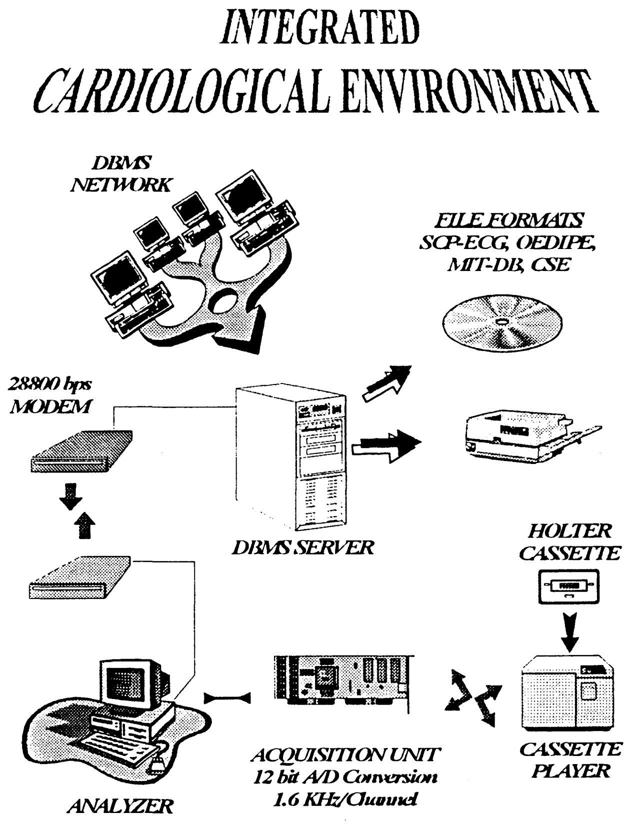

Figure 1: Overall system breakdown.

(b) An Analyzing Workstation (Analyzer) that includes A/D boards, software to support high speed acquisition and transfer direct to memory (DMA) or to magnetic media, and other software tools for ECG analysis (Heart-Rate Variability, ST segment and wavelet analysis etc.). The Analyzer can access central DBMS server by a high speed modem device.

High sampling speeds are required to keep the total acquisition time of the Holter recordings in reasonable levels (10-30 minutes). Our choice was a PCI-200098 multiple carrier board with maximum frequency of 100,000 Hz.

The control and acquisition software that was constructed, was implemented using Intelligent Instrumentation "Visual Designer" application generator, which runs under MS-Windows environment, eliminates time consuming programming and debugging by using graphical representation programming blocks (Figure 2). The analysis and data encapsulation software (Figure 3) was developed under Borland C++ for MS-Windows, has the ability to seek Holter tapes considering real patient time and has options to preview signals which can be saved or exported following standard file formats (SCP, OEDIPE or CSE). MS-Windows environment has been chosen because it offers an easy to use man-machine interface supporting network and multitasking functions.

The software can also call external procedures through Dynamic Link Libraries (DLL) like ischemia detection, wavelet or late potential functions that apply to pre-selected areas of the ECGs.

Another important feature is the indexing of saved ECG data following user comments that can be used during retrieval of patient record. For that purpose, a special DBMS procedure operates during previewing of the signals by linking special keywords to selected ECG areas. This way, statistical or other tests can be performed that use lemmas related to ECG signals.

(c) Finally, a Database Server that collects patient medical history from different hospital sites and performs queries and administration functions (security and backup procedures). Selected ECG data are stored in server resources and can be accessed by any privileged user of the network. Patient record has been implemented by following an object-oriented analysis approach, which offers expandibility and integrity of medical information structure.

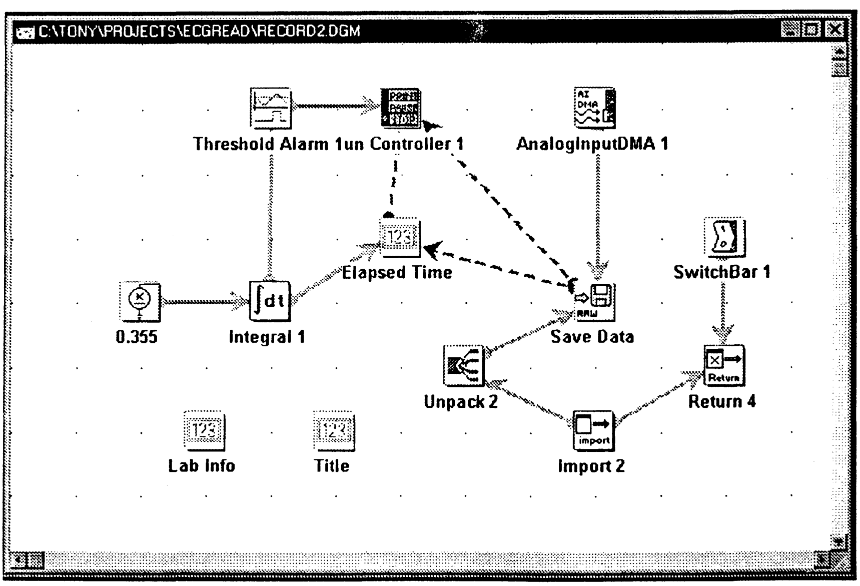

Figure 2: Block programming graphical environment.

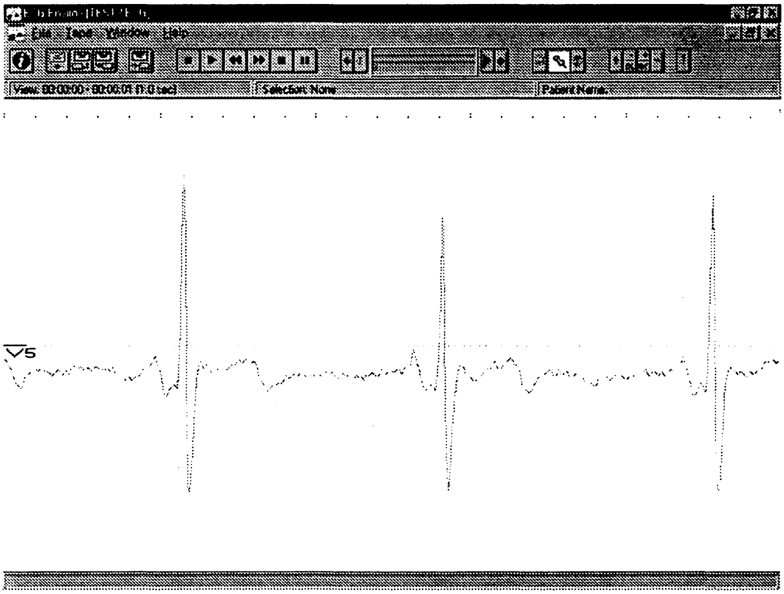

Figure 3: Sample screen from ECG analysis software.

3. Results And Discussion

The system has been examined and tested during normal operation in the First Department of Cardiology, of the AHEPA University Hospital. Several modifications have been performed during evaluation period in order to cover the needs of this particular department, which can be characterised as a typical Holter analysis site.

Holter magnetic tapes have been preferred in order to acquire signals with user selected dynamic A/D frequencies. Of course, software control, sampling and analysis modules can also be used with digital Holter configurations by applying specific hardware interface that can communicate with digital hardware.

Since acquired sampled data occupies huge amount of disk space (average of 130 MBytes per tape) special compression techniques are used for examinations to be accessed for further analysis. What is mainly used is that software ECG analysing modules communicate with remote patient database and fuse only resulting parameters and commented selected areas of interest.

The network feature of the system can also be expanded to cover wide area cardiological networks where data and signals should be accessed and fused through cable or modem connections (e.g. data can be transferred from ambulance or other "external" site).

Another area that has not been standardised yet, is medical database security. Current procedure is based on a discretional type database security policy using an access rights table which determines what access rights each user group (physicians, staff, administrators etc.) has to each kind of information (personal data, examination, diagnosis etc.).

4. Acknowledgement

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