西 南 交 通 大 学 学 报

第 54 卷 第 6 期
2019 年 12 月

JOURNAL OF SOUTHWEST JIAOTONG UNIVERSITY

Vol. 54 No. 6
Dec. 2019

ISSN: 0258-2724 DOI：10.35741/issn.0258-2724.54.6.27

Research Article

Computer and Information Technology

HEART CONDITION TELEDIAGNOSIS VIA BIO-SIGNALS SURVEILLANCE WORKBENCH BASED ON SIMPLE MAIL TRANSFER PROTOCOL TECHNIQUE

基于简单邮件传输协议技术的生物信号监测工作台进行心电图诊断

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Abstract

This article leads to the implementation and development of a Laboratory Virtual Instrument Engineering Workbench-based vital signs surveillance system for cardiovascular patients based on the Simple Mail Transfer Protocol technology. There are three main parts comprising the designed device, the first portion is a lap (circuit) built utilizing a hardware amplifier (AD620) called an electrocardiogram amplifier lap. Then comes the signal-conditioning lap with a practical amplifier (LM741). The second portion, is the signal conversion part from an analog signal to the digital signal using a data acquisition card. Moreover, cardiac data is processed and digital filtering techniques are performed to eliminate artifacts (noise) from the electrocardiogram signal acquired through the Laboratory Virtual Instrument Engineering Workbench system. Additionally, after preprocessing the cardiac signal the developed algorithm is utilized to calculate the heart-rate and analyze the heart condition (analyze the arrhythmia condition). In order to make the current labor more effective and attractive, Simple Mail Transfer Protocol technology has been added for remote diagnosis and monitoring purpose the state of the electrocardiogram signals easily over the internet, where the Simple Mail Transfer Protocol technology benefits is low-cost and effective in telediagnosis, which was previously a major problem overcome by this technique.

Keywords: Electrocardiogram, Data Acquisition, Simple Mail Transfer Protocol, High Pass Filter, Low Pass Filter

摘要 本文介绍了基于简单邮件传输协议技术的基于实验室虚拟仪器工程工作台的心血管患者生命体征监视系统的实施和开发。所设计的设备包括三个主要部分，第一部分是使用称为心电图放大器膝部的硬件放大器（广告 620）构建的膝部（电路）。然后是带有实际放大器（LM741）的信号调理圈。第二部分是使用数据采集卡从模拟信号到数字信号的信号转换部分。此外，处理心脏

数据并执行数字过滤技术以消除通过“实验室虚拟仪器工程工作台”系统采集的心电图信号中的伪影（噪声）。此外，在对心脏信号进行预处理之后，可以使用开发的算法来计算心率并分析心脏状况（分析心律不齐状况）。为了使当前的工作更加有效和有吸引力，已添加了简单邮件传输协议技术，用于远程诊断和监视，目的是通过互联网轻松地获取心电图信号的状态，其中简单邮件传输协议技术的优势在于低成本和有效的远程诊断，以前是此技术克服的主要问题。

关键词: 心电图，数据采集，简单邮件传输协议，高通滤波器，低通滤波器

I. Introduction

Electrocardiogram (ECG) is utilized for heart-rate measurement, the existence of any heart damage, the drug's impacts, or devices utilized for pacemakers (e.g. a pacemaker). The frequency range of the ECG signal normally between 0.05–100 Hz and its dynamic range is 1–10 mV. The ECG signal as presented in Figure 1 is characterized by 5 peaks and valleys assorted by letters P, Q, R, S, and T. The functioning of the ECG analysis system mainly depends on the delicate and efficient detection of the QRS complex, as well as the accurate and reliable detection of the T and P waves. The P-wave represents the upper chambers activation of the heart, activation the atria, while the QRS complex and T-wave represent the ventricles excitation or the lower chamber excitation of the heart.

The important action in automatic ECG signal analysis is the detection of the QRS complex. When the QRS detected, it means identified more examination details of ECG signal containing performed the heart-rate and the ST segment [1], [2]. Most modern ECG 12 lead surveillance systems are based on the ET, Wilson Central Station, and Goldberger leads are added [3]. The progressing ECG device is performed on the ET principle and utilized lead-II configuration. There have been many attempts for medical systems development comparable to the labor based on the above facts. This effort is mostly led by academia but deeply extending into the industries field. So, many research efforts were have been centering on either the bio signals surveillance aspect of feature extraction of ECG signal utilizing standard databases both falling short of expectation. After existing solutions were analyzed, this paper sets out to bridge the two main research efforts and test more products to investigate the direct effect on consumers in the medical field.

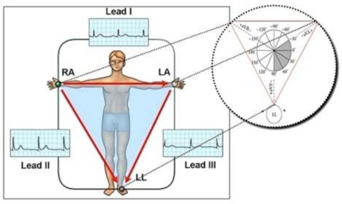

Figure 1. Wrist/ankle placements for 3-electrodes 3-lead system

This research presented a platform to survey portable ECG signals based on the 3-lead system and designed with the NI DAQ card (6008). The ECG data was gathered from the data acquisition (DAQ) card to the personal computer (PC) and then transmitted these signals to specialists via an "SMTP" technique in order to analyze the patient's condition.

II. Method and Materials

Based on Figure 2, a scheme is introduced for ECG Signal Monitoring based on LabVIEW. The overall system was designed in two parts: HW and SW.

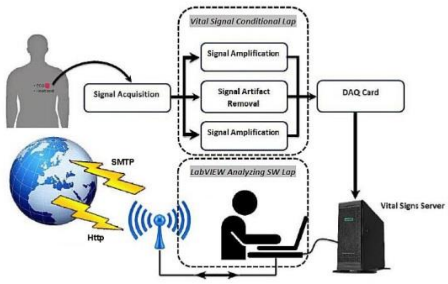

Figure 2. Scheme of ECG signal monitoring based on LabVIEW

The HW part includes the hardware amplifier (AD620), some passive components, an operational amplifier (LM741), a DAQ card, and a laptop that contains a LabVIEW app. The SW is utilized to display the ECG wave on the screen, implement the calculations, and convert the data from analog-to-digital (AD) form. The following subsections contain a detailed description of each part of the block diagram [4].

A. The Surface of Electrodes

The process of converting the physical parameter to electrical output is the main function of electrodes. The process of converting biological information to a quantifiable electrical signal is the function of the transducer. The transducer interface that serves as the electrode-electrolyte interface. The ideal electrode for this function is Ag/AgCl. The function of Ag/AgCl reduces impedance. A gel is used between the chest-skin surface and the electrode.

B. Signal-Conditioning Lap

The raw ECG signal is processed to receive the signal clearly and to control the signal bandwidth after receiving it from the subject. To accomplish this task, it utilizes the hardware amplifier for tiny signal amplification, whereas passive and active components are utilized for filter designing and amplifying. Figure 3 shows a diagram of how to construct a lap of signal conditioning. This lap was designed and tested to produce a clear ECG signal. It should be noted that the word "Lap" means circuit, it's intended to be a circuit of signal conditioning.

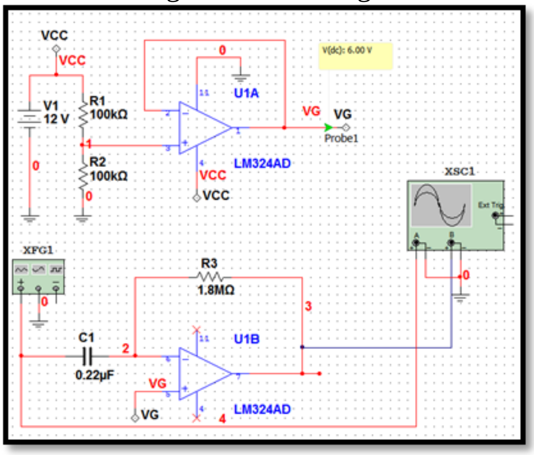

Figure 3. Lap of ECG signal acquisition

1) Hardware Amplifier

The following formula is utilized to calculate the voltage gain of the hardware amplifier:

$$G = 1 + \frac{49.4k\Omega}{R_g} \qquad (1)$$

$$G = 1 + \frac{49.4k\Omega}{1k\Omega} = 1 + 49.4 = 50.4$$

2) Operational Amplifier

The following formula is utilized to rate the voltage obtained by the operational amplifier:

$$G = 1 + \frac{R_3}{R_2}, \qquad (2)$$

$$G = 1 + \frac{200k\Omega}{1k\Omega} = 1 + 200 = 201$$

3) High Pass Filter (HPF) Behavior

As in formula (3), the passive AC coupling receives its feed from the hardware amplifier output with a cutoff frequency of 0.02 Hz such that HPF of 0.02 Hz (i.e HPFs).

$$f_{high-pass} = \frac{1}{2\pi R1C1} = \frac{1}{2 * 3.14 * 5.6 * 10^3 * 1000 * 10^{-6}}, \qquad (3)$$

$$f_{High-Pass} = \frac{5}{(\frac{22}{7}) * 56},$$

$$f_{high-pass} = 0.02 \text{ Hz}$$

4) Low Pass Filter (LPF) Behavior

As in formula (4), in order to remove high-frequency artifacts or movement artifacts, an amplified signal of second-stage is fed into an LPF with a cutoff frequency:

$$f_{high-pass} = \frac{1}{2\pi R4C2} = \frac{1}{2 * 3.14 * 10 * 10^3 * 1 * 10^{-6}}, \qquad (4)$$

$$f_{high-pass} = \frac{1000}{6.28} = 159.2 \text{ Hz}$$

C. Data Acquisition-6008 Card (DAQ Card-6008)

The signal conditioning lap output must be moved to the NI-DAQ card in order to convert the ECG signal to a digital form with an ADC (analog-to-digital convertor). The NI USB-6008 diagram is a low cost, I/O device. It is utilized to digitize the amplified ECG signal with filtering and enhancement. The NI USB-6008 card contains eight various analog input channels and a 12-bit AD converter running at a sampling frequency of up to 300 Hz. The frequency can be increased up to 200 KHz.

The function of a DAQ is the process of measuring electrical or physical phenomenon such as pressure, current, temperature, voltage, and sound with a computer [8], [9].

The DAQ system's principal components are sensors for DAQ measurements such as HW and PC with a programmable SW. DAQ systems provide a more robust, flexible and cost-effective measurement solution due to how it makes use of the processing, productivity, display and connectivity capabilities of computers.

D. LabVIEW or "Laboratory Virtual Instrument Engineering Workbench"

LabVIEW is a computer language dedicated to devices that program graphically in real time.

This programming language was created and developed for the purpose of creating code programs rather than programming text. It uses symbols, terminology, and formats that are recognized by engineers, technicians, and scientists. LabVIEW was programmed to be a GUI to help hardware pieces communicate with each other. Furthermore, LabVIEW presents built-in libraries that permit the user to work online and utilize various programming formats and systems. These graphically program hardware labor in real-time.

E. Simple Mail Transfer Protocol (SMTP)

Based on the application layer, it is considered to be a part of the TCP/IP protocol. There is a process called "store and forward" through which email is transmitted on networks through "SMTP" [7]. It works closely with a Mail Transfer Agent (MTA) to deliver communication to the proper computer, and then to the e-mail inbox.

III. The Design of Strategy

Figure 4 shows the approach to the design of the device. The various stages like finding the proper electrodes for an ECG signal from the body of the subject and the analog signal conditioning lap contains a filtering and amplifying phase, DAQ card, and DSP and display system.

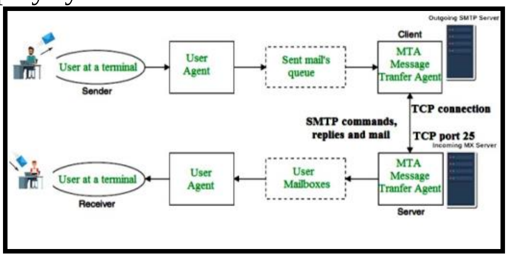

Figure 4. The overall designing device approach

IV. The LabVIEW Interface Designing

The progressing ECG system is utilized to record single input channels and cardiac data acquisition continuously. The single input channels permit users to record and save the record from one patient or more in a circular buffer, and simultaneously plot that data. Real-time data analysis, processing, and presentation is one of the common reasons for reading data while the acquisition process is in progress.

A. Input-Signal Retrieving

The function of a DAQ is to convert the signal acquired by the breadboard from the analog model to the digital model. Here, DSP utilized to generate high signal-to-noise ratio (high SNR) as needed, so that the heart diagnostic system is accurate.

B. DSP

The preprocessing of the ECG signal in real-time is utilized here, where a digital filter is utilized in order to eliminate a power line interferences and other available effects of artifacts.

C. Peak Detector and Threshold Detector

The indicators of peak and threshold are determined after processing. The indicators give some information to the specialists on the patient's average heart-rate. Figure 5 shows the complete ECG system idea developed in LabVIEW. The first part explains how the acquired data uses the data acquisition card (6008); in the next stage, it processes the retrieved data with Band Pass Filter, as well as a notch filter to eliminate the artifacts from the ECG signal [5], [6]. Additionally, the algorithm is implemented and developed for peak signal detection.

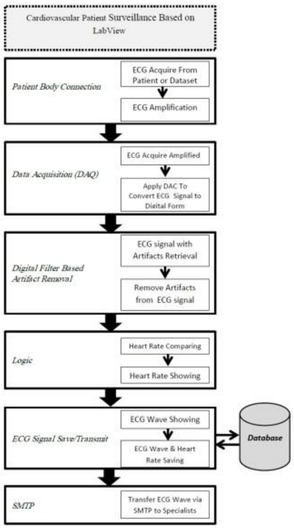

Figure 5. System methodology

In order to compute the heart-rate and recognize the arrhythmia condition, the following formula (5) is utilized:

$$\text{Heart Rate} = \frac{60}{t_2 - t_1}, \quad (5)$$

With $t1$ the first R wave is occurring and $t2$ the second R wave is occurring.

D. Display System Tool

The heart signals of the raw data processed on the laptop screen are shown in Figure 6. The displaying screen that displays raw ECG signals is completely compatible with LabVIEW ver. "4.5", "SMTP" ("Simple Mail Transfer

Protocol"). The advanced "SMTP" tool is utilized to send an acquired ECG signal image file via e-mail Express VI. The block panel developed utilizing LabVIEW permits data to be sent via emails from LabVIEW to a healthcare center or specialists rapidly.

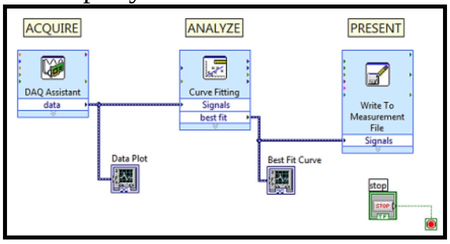

Figure 6. Heart-rate acquired, analyzing, and presentation

V. Experimental Findings

The proposed system is designed to work with a heart-rate monitor. As results are obtained in the proposed coding running VI at home, it sends a text or email to the relevant physician for the purpose of obtaining a diagnosis of a defect detected in the patient's heart. The proposed system lets the specialists check up on the heart waveforms of the patient continuously in real-time. The system works immediately when all hardware equipment is fully-connected. It is highly trustworthy and handy as well as cost-effective.

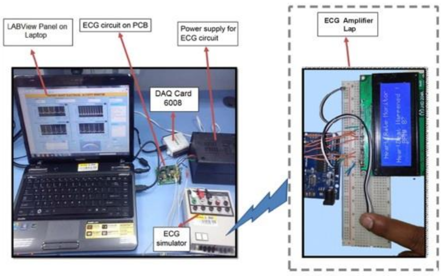

Figure 7. The infrastructure of the proposed system

VI. Discussion

The labor that has been completed is in two main parts: hardware and software. The transmitter/receiver is utilized to transfer the ECG data - this increased the cost of the device. On the other hand, the device has been integrated with hardware along with a data transfer software to use universal "SMTP" technology.

VII. Conclusion and Future Work

This article presented a biomedical-measurement system that is low-cost and has the ability to save ECG signals in a digital form for transmission purposes in rare or remote areas. The app devices have been described as using current commercial devices with the software by LabVIEW SW for continuous monitoring of an ECG signal. The suggested measurement system has the ability to send the data via "SMTP" with no lag time for the specialists or healthcare center.

It is possible to modify the proposed system by increasing the number of channels for raw ECG signals.

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