

Real-time ECG telemonitoring system design with mobile phone platform

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Abstract

In this paper, we propose an ECG (electrocardiogram) telemonitoring system based on a mobile phone platform. It transmits abnormal heartbeats, which are identified in the patient-worn unit (Holter), in real time by using MMS (multi-media messaging service) on GPRS (general packet radio service) and transfers all ECG data acquired and stored in the Holter by the Internet. By this way, the Holter can be used outdoors, and the communication cost can be reduced without losing important information of patients. The GPS (global positioning system) information provided by the Holter can be used to locate the patient for emergency help. To identify abnormal beats, we develop a real-time ECG classification algorithm that can be executed by the dual-core processor in the Holter. Experimental results show that the proposed system achieves an ECG classification accuracy of 98.98%.

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1. Introduction

Telemedicine, which refers to the utilization of telecommunication technology for medical diagnosis, treatment, patient care, and remote monitoring, is currently a significant area of research and development. It is seen as an important way of reducing medical costs by allowing for healthcare to be administered outside a hospital setting. Telemedicine can also be used within a clinical institution. One rapid growing area of telemedicine is the

long-term monitoring of patients with cardiovascular diseases at home. This is made possible with the emergence of portable ECG (electrocardiogram) telemonitoring systems, which are commonly used to record the arrhythmia when it happens or to record ECGs for allowing the experts to see various trends. ECG telemonitoring systems can be divided into two modes of operations: real-time mode, in which patient data are available at the server end immediately after acquisition, and store-and-forward mode, which involves accessing the data at a later time. In both modes, the ECG data are transmitted via computer networks [1–3], public telephone networks [4], or cable TV networks [5] to the server. In these system models, an expert is

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expected at places where he/she can use a PC to access the server for analyzing the ECG data, and the patient is bounded at a fixed place like home or healthcare center where a PC is equipped for transmitting the ECG. The use of wired network connected PCs limits the degree of freedom of both doctors and patients to move around.

To improve the mobility of the doctor, the GSM (global system for mobile communication) mobile telephony network was used for connecting the server. The mobile phone has been recognized as a possible tool for telemedicine since it became commercially available. By using remote portable devices such as notebooks and personal digital assistants that wirelessly connected to a computer network via GSM cellular phone, previous studies successfully demonstrated the merging of cellular communication and the Internet in telemedicine [6,7]. The role of the mobile phone in these designs was as a wireless modem for downloading data from a server to a portable computer. A current trend in telecommunication is the convergence of wireless communication and computer network technologies for providing mobile Internet access. Recently, Hung and Zhang [8] implemented a WAP (wireless application protocol) based telemonitoring system. It utilized WAP devices as mobile access terminals and allowed doctors to browse the monitored data on WAP devices in store-and-forward mode.

The improvement on the mobility of the patient is much less, comparing to the doctor. In many previous ECG telemonitoring systems, the patient-worn unit, known as the portable digital Holter, consisted of an ECG data acquisition circuit, an A/D converter, and a storage unit with a capacity being sufficiently large for 24 h of recording. To provide a very limited mobility of the patient, the Holter was equipped with an indoor, wireless transmitter for feeding the monitored data to a network connected PC [4,8]. A GSM modem was equipped with a PC for real-time transmission of ECG data from a moving ambulance vehicle in [9]. The focus of this design was on transmitting ECG data for consultation while transporting patients in emergency cases. This is probably because use of a GSM network is costly, and the data transmission rate is low. Recently, Rasid and Woodward [10] suggested a mobile telemonitoring system operating in store-and-forward mode by using a Bluetooth-enabled processor unit, which transmitted the monitored data to a Bluetooth mobile phone and subse-

quently via the GSM/GPRS (general packet radio services) network to the server. On the other hand, Engin et al. [11] used a mobile phone to transmit the measured ECG signal in real-time mode. In these designs [10,11], the mobility of the patient is improved. However, the analysis of ECG is not performed in the place where the ECG is acquired, i.e., the ECG is analyzed at the server end. In fact, there is a loss of efficiency in the use of the GSM/GPRS network because normal ECGs are also transferred, which implies a high cost.

In this paper, we propose an ECG telemonitoring system operating in both modes. In store-and-forward mode, the Holter records the ECG signal of the patient continuously up to 48 h. The monitored data is transmitted to the server through the Internet when a wired network is available. The Holter also contains a software program performing real-time ECG classification. When an abnormal heart-beat that the doctor concerns is detected, the Holter transmits it with the GPS (global positioning system) information to the server via MMS (multimedia messaging service) in real-time. The doctor at the server side could communicate with the patient also by using MMS if necessary. In the server, a GIS (geographic information system) is resided for locating the patient in an emergency case by using the GPS information packaged in the MMS message. By this way, the Holter can be used outdoors, and the cost for using the GPRS network is lowered because only abnormal ECGs are transmitted.

The remainder of this paper is organized as follows. The system is described in Section 2. The proposed system consists of a Holter and a server. The hardware and software designs of the Holter are described in Section 3. The system has been implemented and tested. Experimental results are reported in Section 4. Finally, Section 5 contains some discussions and conclusions.

2. System description

Fig. 1 illustrates the proposed telemonitoring system. This system consists of a portable Holter, and a server. The Holter is responsible for ECG data acquisition, storage, and real-time analysis. In the Holter, a software program is used to classify the input ECGs into several beat types. In case that the program classifies a current ECG beat into a beat type that the doctor concerns, the Holter transmits the ECG data with the GPS information to the server by using MMS in real time.

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