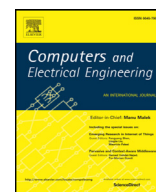




Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compelecengA remote electrocardiogram monitoring system with good swiftness and high reliability[☆]Hanlin Chen^{a,*}, Hongwei Liu^b^a Department of Electronic and Information Engineering, Beijing Electronic Science and Technology Institute, Beijing 100070, China^b Intelligent Transportation System Center, Ministry of Transportation, Beijing 100088, China

ARTICLE INFO

Article history:

Received 27 July 2015

Revised 2 February 2016

Accepted 2 February 2016

Available online xxx

Keywords:

Two-level Load-balance Monitoring Strategy

Parallel PCA-ICA Algorithm

Dynamically Variable Time Interval

A2F500

MD5

ABSTRACT

To solve the problems of long time delay and low reliability in existing systems, a Two-level Load-balance Monitoring Strategy (TLBMS) is proposed in this paper. In monitoring terminal level, based on customizable System-on-Chip A2F500, monitoring terminals implement parallel Principal Component Analysis and Independent Component Analysis (PCA-ICA) algorithm to fulfil quickly preprocessing and feature extraction of electrocardiogram (ECG) signals, and give a pre-classification and alarming mechanism. Depending on the results of pre-classification, monitoring terminals transmit only eigenvectors to monitoring center at a Dynamically Variable Time Interval (DVTI). This will reduce the quantity of data transmission dramatically, which means it will lead to high robustness of communication and short time delay. In monitoring center level, monitoring server processes eigenvectors directly, and realizes quick classification, diagnosis and rescuing. To ensure the correctness of communication and protect data from being falsified, Message Digest Algorithm MD5 is realized to verify the integrity of data.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Cardiovascular disease has become a major disease that seriously threatens people's health and life. The attacks of cardiovascular disease are not only paroxysmal and occasional, but also the time for treatment is critical, thus patients need a real-time and round-the-clock monitoring service. Electrocardiogram (ECG) can accurately reflect the situation of cardiovascular disease, and has become main diagnostic basis of cardiovascular disease. Therefore, we are in sore need of a remote monitoring system that can conveniently and reliably obtain ECG signals of patients, timely analyze ECG signals, and give quick diagnosis and rescuing measures.

With rapid development of wireless technology, mobile phones are gaining acceptance to become an effective tool for cardiovascular monitoring. Based on mobile communication, a number of remote ECG monitoring systems have been developed in latest decades [1–3]. These systems can give a long-term and ambulatory ECG monitoring. The overall structure of these systems is pretty similar, as shown in Fig. 1. The monitoring system consists of a quantity of portable monitoring terminals, monitoring center and mobile network. Monitoring terminals acquire raw ECG signals of patients, and periodically transmit them to monitoring center via mobile communication. Along with the assistance of doctors and ECG database,

[☆] Reviews processed and recommended for publication to the Editor-in-Chief by Guest Editor Dr. N. Velmurugan.

* Corresponding author. Tel.: +86 1083635091; fax: +86 1083635093.

E-mail address: hanlin_chen@sina.com, chen_hanlin@besti.edu.cn (H. Chen).

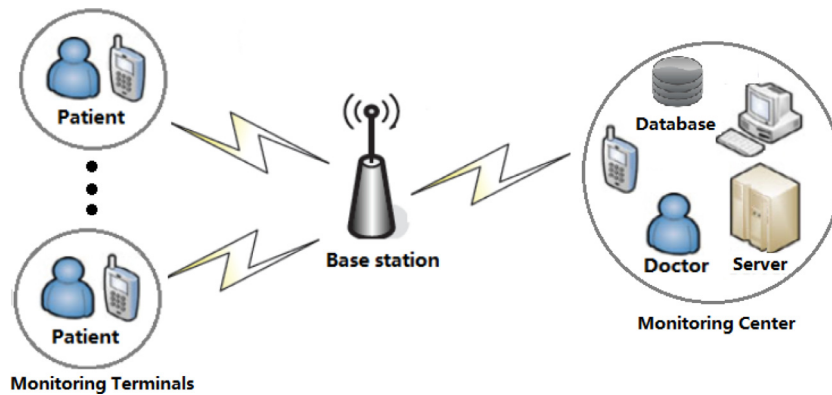


Fig. 1. Overall structure of remote ECG monitoring system based on mobile network.

monitoring server accomplishes preprocessing, feature extraction and classification of ECG signals, realizes automation diagnosis, and gives rescues when emergencies happen.

However, a kind of continuous wireless ECG monitoring solution needs frequent communication and big ECG data packages, because of the requirement of data analysis. Large amounts of data transmission over a long time could eventually cause transmission bottlenecks, which increase time delay, and reduce the reliability and the robustness of communication. Furthermore, massive data analyses bring a huge burden to monitoring server, which will lead to low speed and accuracy. The problem is prominent greatly with the increase of monitoring capacity. Therefore, for decreasing the amount of data transmission, data compression technique is proposed in the [4,5]. In these applications, ECG data are compressed with a reasonable complexity of the implementation, while maintaining clinically acceptable signal quality. Data compression reduces the size of ECG signals, however, compressed ECG data must be decompressed before performing analysis and diagnosis. The additional step brings a significant processing delay for identification task. This will become an obvious burden if millions of compressed ECG segments need be decompressed by monitoring center. A novel method directly analyzing compressed ECG data is proposed in the [6,7]. The method performs faster than current methods, but its results have a low accuracy, especially because of signal distortion during ECG data compression.

The main focus of the paper is on the swiftness and the reliability of remote ECG monitoring system on the basis of maintaining a high accuracy. According to the drawbacks of existing ECG monitoring systems, a Two-level Load-balance Monitoring Strategy (TLLBMS) is proposed. In monitoring terminal level, through the method of realizing parallel Principal Component Analysis and Independent Component Analysis (PCA-ICA) algorithm with Field Programmable Gate Array (FPGA), monitoring terminals can not only complete acquisition, preprocessing, and feature extraction of raw ECG signals quickly, but also give an effective pre-classification and alarming mechanism to achieve a quick rescue. After the completion of these tasks, monitoring terminals transmit only a small size of eigenvectors to monitoring center at a Dynamically Variable Time Interval (DVTI). Depending on the degree of ECG abnormality, time interval of transmitting is variable dynamically. The less ECG abnormality is, the longer time interval is. Hence, the amount of communication data reduces greatly and the problem of transmission bottlenecks is solved. It leads to short time delay, high reliability and robustness of communication, and large monitoring capacity. In monitoring center level, monitoring server can process eigenvectors directly, get diagnostic results and take corresponding measures quickly. When sudden heart attacks are detected and immediate medical rescues are needed, monitoring center will dispatch emergency personnel quickly based on Global Position System (GPS) information of patients, and doctors can guide patients to do self-rescue via mobile communication. To ensure the correctness of data transmission and protect data from being falsified, Message Digest Algorithm MD5 is realized to verify the integrity of data. When the verification fails, monitoring center returns the error flag that means retransmission. Furthermore, based on diagnostic results, monitoring center can adjust time interval of data transmission compulsorily or require the transmission of raw ECG data. These measures can avoid false process and pre-classification of monitoring terminals, and get diagnostic results with high accuracy. Thereby, proposed remote ECG monitoring system has very good swiftness, high reliability and accuracy.

The rest of paper is organized as follows. Section 2 describes hardware design of system. Section 3 presents software design of monitoring terminal, involving FPGA implementation of Parallel PCA-ICA Algorithm and MD5 hash algorithm, and software design of ARM CortexTM_M3. Section 4 presents software design of monitoring center. Section 5 shows results. Section 6 discusses results and finally Section 7 concludes the paper.

2. Hardware design

Hardware design includes design of monitoring terminal and design of communication module in monitoring center. Except having no acquisition circuits of ECG signals and adding a serial communication interface to monitoring server, other

Download English Version:

<https://daneshyari.com/en/article/6883751>

Download Persian Version:

<https://daneshyari.com/article/6883751>

[Daneshyari.com](https://daneshyari.com)