Prototype System Design of ECG Signal Acquisition with Lossless Data Compression Algorithm Applied for Smart Devices

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***Abstract*--This paper presents an efficiently wireless ECG acquisition system with lossless data compressing algorithm. The proposed algorithm were evaluated by using all patterns from MIT-BIH arrhythmia database, and the analytic result shows that the proposed lossless algorithm achieves the CR value of 2.64 in average. Therefore, the proposed algorithm has very outstanding performance.**

I. INTRODUCTION

In modern wireless e-health systems, it becomes a very essential work to monitor the physiology of patients, for example, long time monitoring or 24-hrs nonstop recordings for electrocardiogram (ECG) and some other bio-signals. After acquiring these physiological signals, medical diagnostic can be further proposed for the purposes of telemedicine. An efficient data compression technique dramatically saves the memory space for storing these medical recordings, shortens the communication time, and lowers the power consumption of monitoring devices.

In General, the compression methods could be classified into lossy and lossless algorithms. The lossy method for compressing ECG signals has been widely used because of high compression ratio performance. Previous approaches were divided into three categories: 1) removes the redundancy from the signals, and then achieves higher data compression ratio; 2) Uses the transform algorithm [2]-[5] that converts a time domain signal into frequency domain (or other domains); 3) parameter extraction compression method using peak picking method, and the linear prediction method [6], [7].

For the lossless compressing methods, Chen *et al*. [8] adopted linear prediction and Huffman coding (HC) to compress the ECG data, and Dakua *et al*. [9] used Burrows-Wheeler transform (BWT), move-to-front (MTF), and run length encoding (RLE) [10] schemes to obtain an excellent result of CR value. Chua *et al*. [11] also have a good CR value by employing differential pulse code modulation (DPCM) and Golomb-Rice (GR) encoding. To reduce the complexity in algorithm realization, Chen *et al*. [12] presented a lossless encoding method by using DPCM and a two-stage HC process. With different application requirements such as high-compression rate and perfect reconstructed algorithms, we only focus on developing lossless compressing algorithms in this paper.

II. PROPOSED ACQUISITION SYSTEM AND COMPRESSION ALGORITHMS

The proposed system utilizes some commercial ICs to be key components, such as instrumentation amplifier, pre-amplifier, operational amplifier, analog-to-digital (ADC) converter and digital signal processing circuits (Altera FPGA). Additionally, a Nios2 processor is built for data control and task management. To shorten the data compressing time and to avoid the Nios2 overload, a concept of hardware and software co-design is employed in implementing the proposed compression algorithm. Also, to avoid the data loss caused by channel interference during the period of data transmission, the proposed acquisition system embedded orthogonal frequency division multiplexing (OFDM) scheme. A high-performance recursive DFT (RDFT) chip [13] is therefore integrated with Nios2 to execute the operation of Fourier transform for the proposed lossy compressing algorithm and OFDM. Then, we program an Android's APP for a smart phone which is communicated with the proposed acquisition circuit by Bluetooth. Figures 1 and 2, respectively, show the proposed architecture design and system materialization.

The flowchart of the proposed method as shown in Fig. 3 is employed to obtain perfect reconstructed ECG signal. The steps are sequentially processed as follows: 1) Peak detection (PD); 2) QRS-wave difference; 3) Backward difference (BD); 4) HC. The result shows that the average CR of the proposed method is 2.64:1. It can be easily found that there are some shared procedures between the proposed two novel compressing methods, and this implies that these two algorithms are compatibly run / implemented in the same system.

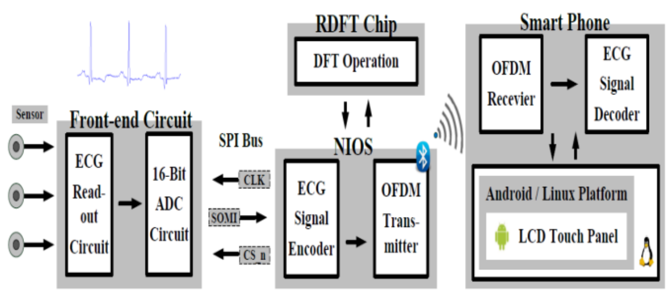

Fig. 1. Architecture design of the proposed ECG signal-acquisition and data-compression system.

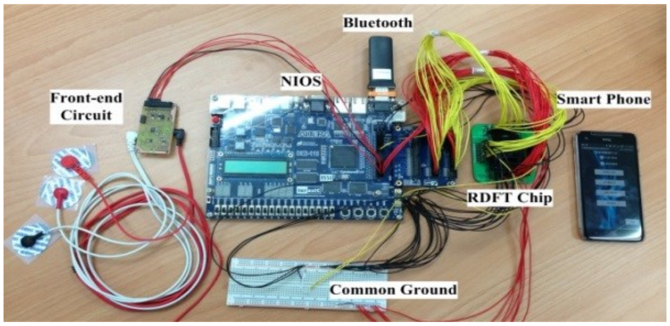

Fig. 2. Materialization of the proposed ECG signal-acquisition and data-compression system.

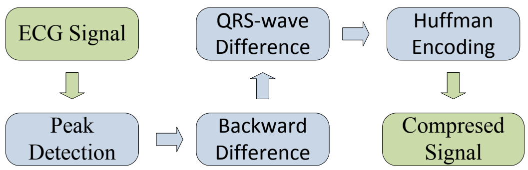

Fig. 3. Flowchart of the proposed lossless ECG compression.

III. IMPORTANT COMPARISON RESLUTS

Table I results that the proposed lossless compression algorithm has a very high CR value compared with Chen *et al*. [11]. Therefore, the proposed algorithms have very outstanding performance.

TABLE I PERFORMANCE COMPARISONS OF VARIOUS LOSSLESS COMPRESSING ALGORITHMS

Method	Kernel Algorithm	Pattern	CR
[8]	HC	All	1.9
[9]	BWT+MTF+RLE	102-104,117	2.65
[11]	DPCM+Golomb-Rice	All	2.38
[12]	DPCM+2-stage HC.	All	2.43
This work	PD+QRS+BD+HC	All	2.64

IV. CONCLUSION

The proposed design presents a wireless physiological signal sensing system applied for telehealth system and telemedicine. Additionally, lossless data compressing algorithm is proposed and integrated with this prototype system. The proposed acquisition circuit embedded the OFDM and RDFT chip design is helpful to avoid the data loss because of channel interference during the period of data transmission.

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