Ain Shams University
Faculty of Engineering
Electronics and Communications Department

Biomedical Signals Compression

A Thesis
Submitted in partial fulfillment of the requirements of a Master of Science degree in Electrical Engineering

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Faculty of Engineering – Ain Shams University

Electronics and Communications Engineering Department

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Statement

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Electrical Engineering (Electronics and Electrical Communications Engineering Department).

The work included in this thesis was carried out by the author at the Electronics and Electrical Communications Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis was submitted for a degree or a qualification at any other university or institution.

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ABSTRACT

Biomedical signals, in general, are the electrical signals that represent different actions in the body. Specifically, the electrocardiogram signal (ECG) describes the human heart activities. The compression of this signal is highly beneficial for either wireless transmission or storage. In this work, a new technique for ECG compression is developed and introduced. The technique is based on the observation that the ECG signal in the normal conditions is very stable with highly correlated successive pulses. Thus, the technique performs differential encoding between each new pulse and a stored reference pulse. This idea is inspired by the techniques of video compression where the inter-frame changes are very limited. Therefore, a high signal compression ratio can be obtained. Simulations on selected records from the MIT-BIH database are performed to assess the introduced technique performance and compare it to the modern techniques. The algorithm also addresses common problems and inefficiencies that commonly affect the ECG signal and shows that it can overcome them without a major loss. The performance is characterized by the compression ratio (CR) which measures how much the algorithm is capable of compressing the signal and the percentage of root mean square differences (PRD) that measures the dissimilarity between the reconstructed and the original signals. The proposed algorithm achieves a CR of 105 with PRD below 1.25% for stable ECG signals. Moreover, a comparison with the existing ECG compression methods demonstrated the superiority of the new proposed technique.

Keywords — ECG Signal Compression, MIT-BIH Arrhythmias, Biomedical Signals Processing, WBANs, Wearable Devices.

SUMMARY

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The Electrocardiogram signal is highly significant for the diagnosis of the cardiac state. ECG tests provide a very quick, inexpensive, painless and safe way to examine the human heart. From the ECG recording, a cardiologist can assess the heart rhythm, diagnose a heart attack, check the blood flow and figure out any abnormalities in the heart. Normally, cardiologists acquire a 24-hours recording for the ECG signal taken by multiple electrodes (conventionally, 3 or more). Typically, ECG signals are sampled 360 times per second. Each sample is then represented by 11 bits to convert it to the digital domain. This results in a bit rate of around 4 Kbps per electrode. For storage purposes, the 24-hours 3-leads recording requires at least 128 Mbytes of memory. Thus, the need for compressing this signal is increasing for either storage or wireless transmission.

Since the sixties of the twentieth century, a lot of work has been done to develop a compression technique that is capable of decreasing the size of the signal without negatively affecting the quality of the signal. This thesis introduces a new technique for compressing the ECG signal. It is based on exploiting the similarity between the successive heart beats. The proposed technique is inspired by the video compression techniques as it considers the successive heart beats as the successive

video frames. This analogy enabled the technique to borrow some concepts from the standard video compression techniques and apply them to the one-dimensional ECG signal.

The introduced algorithm is carefully designed to find a good compromise for the trade-off between the signal quality and the compression capability. The efficiency of the algorithm is quantified by the compression ratio (CR) which measures how much the algorithm is capable of compressing the signal and the percentage of root mean square differences (PRD) that measures the dissimilarity between the reconstructed and the original signals. The results are then compared to the existing developed techniques. The proposed algorithm was shown to be superior to the existing algorithms in the literature.

Accordingly, the thesis is organized in six chapters as follows:

Chapter 1: gives a short introduction of the motivation, objective, major contributions and, the thesis organization.

Chapter 2: is a review of the technical and mathematical backgrounds of the concepts and methods used throughout the proposed technique. The definition, main characteristics, and the inefficiencies of the ECG signal are introduced. Also, the mathematical operations deployed in the implementation of the proposed technique are discussed in this chapter in addition to some basic compression concepts. Finally, the basics of video compression techniques by which the proposed algorithm is inspired are included.

Chapter 3: provides a detailed literature review over the existing electrocardiogram signal compression techniques and their development over the years. This chapter categorizes the existing techniques into different categories and sub-categories. Exam-

ples for every category are given to demonstrate the concepts of operation. Finally, a survey on the state-of-the-art work is presented.

Chapter 4: introduces the idea of the proposed technique with the detailed implementation of the system block diagram. The implementation challenges of each step of the algorithm are stated and the ways by which they were overcome. Additionally, some intentional problems are introduced to the test signal. Finally, the simulation results are introduced and compared to the modern methods.

Chapter 5: introduces a generalization for the technique developed in Chapter 4 in order to broaden its range of strength and leverage its efficiency. Although the basic algorithm proves its efficiency in the stable signals, its performance degrades in some cases. Thus, the technique is thoroughly enhanced such that it is capable of compressing various test signals with different conditions. Finally, the technique is tested against selected ECG recordings and the simulation results show its superiority over the already-existing technique.

Chapter 6: gives the conclusions of the thesis and introduces several recommendations and suggestions for the future work.

CONTENTS