HYBRID EFFICIENT COMPRESSION METHOD FOR ELECTROCARDIOGRAM SIGNAL TRANSMISSION BASED ON DISCRETE WAVELET TRANSFORM AND PRINCIPAL COMPONENT ANALYSIS

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SULTAN IDRIS EDUCATION UNIVERSITY

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ABSTRACT

In this study, the researcher proposed a new approach for the compression of ECG signals by reducing the ECG data size for storage purposes which could speedily transmit data from the client to the server, preserve important diagnostic information from distortion within compressed signals, and maintain the quality of the reconstructed signal. This research was based on an experimental design involving two phases. In the first phase, DWT, which is a powerful compression tool, was used to compress ECG signals. In the compression process, PCA transferred the properties of compressed signals to MECG to maintain important cardiac features of a diagnostic area. In addition, this tool was used to reduce data dimensions to achieve optimal compression. In the second phase, the encryption of ECG signals during data transmission was performed to safeguard the privacy of patients. The findings showed that the performances of DWT and PCA algorithms were relatively superior that those of existing algorithms. Specifically, PCA was highly effective in the compression of multichannel ECG data. Likewise, DWT was also effective in the ECG signal compression involving QRS Regions and Non-QRS Regions. Moreover, it was found that ECG signals, including biomedical signals, could be represented in low bits per pixel with good quality. Revealingly, the findings showed that the proposed method managed to attain an average CR of 11.00 %, with PRD is less than 0.66 % and QS is equal to 29.71 %. Overall, these findings suggest that DWT and PCA algorithms can be effectively used for ECG signal monitoring and diagnostic applications.

KAEDAH PEMAMPATAN HIBRID UNTUK PENGHANTARAN ISYARAT ELEKTROKARDIOGRAM BERASASKAN JELMAAN GELOMBANG KECIL DISKRIT DAN ANALISIS KOMPONEN UTAMA

ABSTRAK

Dalam kajian ini, penyelidik mencadangkan satu kaedah baharu untuk pemampatan isyarat ECG dengan mengurangkan saiz data untuk penstoran yang dapat menghantar data dengan laju dari klien ke pelayan, mengekalkan maklumat diagnostik yang penting dari gangguan isyarat yang termampat, dan mengekalkan kualiti isyarat yang dibina semula. Kajian ini menggunakan reka bentuk kajian eksperimental yang dijalankan dalam dua fasa. Dalam fasa pertama, DWT, yang merupakan alat pemampatan yang berkesan, digunakan untuk memampat isyarat ECG. Dalam proses pemampatan ini, PCA memindahkan sifat-sifat isyarat yang telah dimampatkan ke MECG untuk menyenggara ciri-ciri kardium yang penting dalam sesuatu kawasan diagnosis. Tambahan pula, alat ini digunakan untuk mengurangkan dimensi-dimensi data untuk mencapai pemampatan yang optimum. Dalam fasa kedua, penyulitan isyarat ECG semasa penghantaran data dijalankan untuk menjaga privasi para pesakit. Dapatan menunjukkan prestasi kaedah - kaedah DWT and PCA adalah lebih tinggi dari kaedah - kaedah yang sedia ada. Khususnya, PCA adalah amat berkesan dalam pemampatan data ECG multi saluran. DWT juga amat berkesan dalam pemampatan isyarat ECG melibatkan kawasan QRS dan kawasan bukan QRS. Tambahan pula, isyarat ECG, termasuk isyarat bioperubatan, dapat diwakili dalam bit-bit piksel dengan kualiti yang tinggi. Lebih menarik lagi, dapatan menunjukkan kaedah yang dicadangkan ini dapat mencapai purata CR setinggi 11.00% dengan PRD kurang dari 0.66% dan QS bersamaan dengan 29.71%. Keseluruhannya, dapatan menunjukkan kaedah - kaedah DWT dan PCA boleh digunakan dengan berkesan bagi aplikasi-aplikasi pemantauan isyarat ECG dan diagnosis.

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LIST OF ABBREVIATIONS

AES	Advanced Encryption Standard
AF	Atrial Fibrillation
AFD	Adaptive Fourier Decomposition
AV	Atrioventricular Node
AVF	Augmented Vector Foot
AVR	Augmented Vector Right
AZTEC	Amplitude-Zone-Time Epoch Coding
BAN	Body Area Network
bpm	Beat Per Minute
BPS	Bits Per Sample
BWA	Baseline Wander Artifact
CC	Computational Complexity
CCC	Computational Complexity Component
CDR	Compressed Data Rate
COMDEC	Compression and Decompression
CORTES	Coordinate Reduction Time Coding System
CPBC	Cycle Pool Based Compression
CR	Compression Ratio
CT	Cosine Transform
CVD	Cardiovascular Disease
DCA	Delta Code Algorithm
DCT	Discrete Cosine Transform
DCT-II	Discrete Cosine Transform-II
DHF	Discrete Hermite Functions
DPCM	Differential Pulse Code Modulation
DST	Discrete sine Transform

DST	Discrete sine Transform
DTM	Discrete Tchebichef Moments
DWT	Discrete Wavelet Transform.
ECG	Electrocardiogram
EKG	Electrocardiogram
EPE	Energy Packing Efficiency
EPR	Electronic Patient Record
EZW	Embedded Zerotree Wavelet
FB	Filter Bank
FD	Frequency Domain
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
FNC	Fix Number of Coefficients
FT	Fourier Transform
FT	Fourier Transform
GP	Gaussian Pyramid
GSM	Global System for Mobile Communication
HOSVD	Higher-Order Singular Value Decomposition
HPF	High Pass Filter
HR	Heart Rate
HRV	Heart Rate Variability
HRV	Heart Rate Variability
HT	Haar Transform
HWT	Haar Wavelet Transform
IA	Interesting Area
ICTS	Information and Communication Technologies
IDWT	Inver Discrete Transform
IEEEXplore	Institute of Electrical and Electronics Engineers
IPCS	Inverse Principle Component Analysis
JMRA	Joint-multi-resolution Analysis

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KLT	Karhunen-Loeve Transform
LA	Lead Left Arm Lead
LA	Left Arm
LCNQRS	Lossy Compression in non-QRS Regions
LCQRS	Lossy Compression in QRS Regions
LL	Lead Left Leg Lead
LL	Left Leg
LMS	Least Mean Square
LRNQRS	Lossy Data Reconstruction in Non-QRS Region
LRQRS	Lossy Data Reconstruction in QRS Region
LSD-OMP	Least Support Denoising-Orthogonal Matching Pursuit
LTP	Long-term Prediction
MCA	Muscle Contraction Artifacts
ME	Maximum Error
MECG	Multi lead Electrocardiogram
MHz	Mega Hertz
MIT-BIH	Massachusetts Institute of Technology Database
MM	Mathematical Morphology
MMS	mobile messaging system
MPCA	Multi-scale PCA
MRI	Magnetic Resonance Imaging
NIA	Noni-Interest Area
NLSPIHT	No List SPIHT
PBF	Band Filters
PC	Principal Components
PCA	Principal Component Analysis
PCM	Pulse Code Modulation
PDA	Personal Digital Assistant
PECA	Poor Electrode Contact Artifacts
PIA	Powerline Interfaces Artifacts

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PMA	Patient Movements Artifact
PRD	Percentage Root mean square Difference
PSNR	Peak Signal to Noise Ratio
PWCZ	Percentage Wavelet Coefficients to be Zeroed
QS	Quality Score
RA	Lead Right Arm Lead
RA	Right Arm
RE	Retained Energy
RE	Reconstruction Error
RLC	Run Length Coding
RLS	Interactive Least Square
RME	Root Mean Error
RMSE	Root Mean Square Error
ROI	Region of Interest
SA	Sinus Arrhythmias
SA	node Sino-atrial Node
SAPA	Scan-Along Polygonal Approximation
SE	Segment Element
SMS	Short Message Service
SNR	Signal To Noise Ratio
SPF	Stop Pass Filter
SPIHT	Set Partitioning in Hierarchical Tree
SS	Symbol Substitution
SVD	Singular Value Decomposition
TCP	Transmission Control Protocol
TD	Time Domain
TP	Turning Point technique
TxT	Text File
UD	Uncorrelated Domain
UDP	Unreliable Datagram Protocol

WA	Wavelet Analysis
Wash	Web of Science Database
WDR	Wavelet Difference Reduction
WSN	Wireless Sensor Networks
WT	Wavelet Transform
WWSN	Wireless wearable sensor

APPENDICES LIST

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter introduces the research topic, the statement of the problem, and research objectives. This chapter also presented the research scope, where technical and experimental domains are described.

A brief background of the research components is presented in Section 1.2. The research motivation also described in Section 1.3. The problem statement on which the direction of the research is based is identified and introduced in Section 1.4. The research questions are presented in Section 1.5. The objectives of the research are described in Section 1.6. The Research Gap presented in Section 1.7. The scope of the study is explained in Section 1.8. The significance of the study is described in Section 1.9, furthermore, in Section 1.10, the contribution was clearly presented. The main structure of the thesis is briefly outlined in Section 1.11. Finally, a summary of the chapter is presented in Section 1.12.

1.2 Research Background

The digital age is experiencing a tremendous explosion in data. The medicine signals are the novel contribution here. The effective preservation and diffusion of Electrocardiogram (ECG) signal is the main interest for research in respect of the processing of biomedical signals. The compressed data are among the best ways of increasing the growth of data. The biomedical fields that require the utmost compression techniques are a medical indicator.

Biomedical (life) signals, as well as medical images, are the most common and prevalent types of medical signals. The biological processes are the main resources for signs of medicinal vitality. As when needed, these signals are saved for a better diagnosis process. Therefore, according to the most significant vital signals are the ECG signal (Alam & Gupta, 2014).

An ECG is the major biological signal, where gives the cardiovascular function of the heart explicitly. Ranjeet, Kumar, & Pandey (2013) opines that it is a mean to cardiac arrhythmias diagnosis or heart illness. Cardiac arrhythmia is an illness or variation in the morphological features of the ECG. In such cases, information from the ECG is taken by the cardiologist and makes the analysis through pattern recognition. For the assessment of the condition of the patient's heart, the ECG requires recording for a long period of time. opines that this technique collects sufficient material that grows the capacity of ECG data (Ye, Coimbra, & Kumar, 2010).

For instance, 24 hours/7 days of the ECG signal recording with the specimen rate of recurrence equal to 360 Hz, and the sample resolution equal to 1-bits to produce a data of 40.8 MB each channel. The ever-growing data needs large storage capacity and larger bandwidth for transmission. Effective signal compression technology is needed if ambulatory recording systems and telemedicine applications are used (Craven, McGinley, Kilmartin, Glavin, & Jones, 2017) state that the lossless compression technique is very necessary because the ECG signal is a vital medical signal, but the compression ratio in this technique must be low (Wang & Meng, 2008).

The volume of ECG data increases with the channels intensification, the specimen rate of recurrence, specimen accuracy and recording time. Consequently, there is a need for a suitable technique to compress the signals. observes that the main objective of the ECG signal compression technique is to preserve the utmost valuable signal compression and clinical information with an adequate scope (Craven, McGinley, Kilmartin, Glavin, & Jones, 2016).

The ECG signal is utilized for heart disease diagnosing along with some other different tests. The information of the ECG signal is extracted and analyzed for study and proper diagnosis by physicians before any useful and meaningful explanations. Thus ECG has become an indispensable and effective signal processing tool for clinically important information, to reduce manual self-analysis and to develop advanced aid to the physician in making sound decisions(Craven, McGinley, Kilmartin, Glavin, & Jones, 2017).

Today, the ECG signal processing is founded in order to analyze these signals and it has demonstrated its significance to perform a full diagnosis of a wide range of heart diseases (Ye, Coimbra, & Kumar, 2010).

ECG machine is a very powerful and common screening tool for heart diseases. It is relatively inexpensive, non-invasive and easy to use. It does have some limitations. Understanding those limitations is important to put things in proper perspectives. The ECG monitor displays the electric activities generated by the heart and gives a snapshot of the heart rate and rhythm during the test; however, it does not reflect many underlying problems. Cardiac abnormalities may occur only intermittently and ECG needs to be performed at the right moment to capture the episodes(Tsai & Tsai, 2019).

At other times, a patient may have entirely normal ECG. To compensate for this, many ECG are performed when the patient is exercising, which increases heart rate and put the heart under stress. The exercise stress ECG test, in many situations, can reveal many hidden conditions which otherwise would not be detected. When the ECG machine displays an unusual pattern, there can be multiple unrelated reasons, including a normal variant(Huang et al., 2018) . A doctor needs to do more detailed investigation, including other tests (e.g. echocardiogram), to sort things out. False negative is probably the biggest concern with ECG. For some heart patients, the EKG may be entirely normal and yet their conditions should be reflected in the ECG. The reasoning behind this is not well understood. A good ECG reading does not preclude having the underlying heart disease and other symptoms, such as chest pain, must be taken into account and further evaluation may be required (Arican & Polat, 2018) . Not all heart problems will show up on an ECG. A prime example is vulnerable plaque (a form of atheroma). Vulnerable plaque is a fast growing deposit or degenerative accumulation of lipid-containing plaques on the innermost layer of the wall of an artery. Because artery walls typically enlarge in response to enlarging plaques, they do not affect blood flow and cannot be detected even in a cardiac stress ECG test. Yet vulnerable plaque is a major cause of heart attacks . A stress ECG test requires high-grade stenosis to show positive reading. High-grade stenosis is a good indicator of advanced heart disease; however it is not the major cause of heart attack. False positives and false negatives are common among clinical tests. A doctor has to weight all the evidence prior to making a diagnosis (Ramachandran & Bashyam, 2017).

In order to obtain a reliable and fast server, back4app provides these benefits, as it provides the ability to communicate between the two sides easily. The accessing to this server via this link: https://www.back4app.com/.

Note that all operations of ECG signals (Compression, Decompression, Encryption, and Decryption) are occur in both client side (patient) and server side(specialist), and finally the transmission occur via server back4app.

The advantages of this server:

- It is a limited-resource server and only suitable for applications that have a few users or for educational objectives only.
- In large applications, there are paid plans on the same site, through as well as great services after reserving domain, where the value of half a megabyte is estimated at about 500 USD.
- Provides the ability to get 10,000 monthly requests for free.
- It allows users to upload their applications to it easily and reliably.

This site contains 5 Plans; Free Plan -1G storage, Starter Plan, Basic Plan, Business Plan, and Professional Plan.

1.3 Motivation

Data processing efficiency can be greatly improved during transmission and reception by compressing data to a larger quantity. Therefore, compressed data may record less space in the database as well as help in the efficient data scan. This is evident through Telemedicine technology where it requires effective treatment of vast amounts of data collected from different health sensors linked to diverse patients in different isolated locations. Therefore, the management of large amounts of data generated in parallel with the progress of rapid biomedical technology is a challenge.

There are many signals that should be monitored continuously or periodically in a medical environment. Some of these common signals are the application of oxygen in the blood, the temperature and the arterial force or the waveform of the electrocardiogram.

The development of telecommunications tools in the field of healthcare has expanded access to healthcare providers, more effective tasks and overall high superiority of healthcare facilities. Nevertheless, the study reveals that there are numerous challenges such as medical faults and incomplete coverage of healthcare facilities in the underdeveloped and rural areas still occur universally (Ye et al., 2010).

Due to the absence of accurate and incomplete information on the website as well as the time required or the transmission is inadequate or inaccurate information is given by the patient to the medical physician, this lead to erroneous diagnosis and poses a risk to the patient's life (Martis, Acharya, Mandana, Ray, & Chakraborty, 2012).

To evade probable mistakes or inaccuracies in the process of compacting data before distributing it via the wireless sensor networks, it is suggested a hybrid technique should be adopted.

The researcher recommends an efficient ECG signal compression method for this thesis. In this research, the system consists of two main parts namely COMDEC signal for the client and the server respectively. The remote patient monitoring map can be illustrated in Figure 1.1.

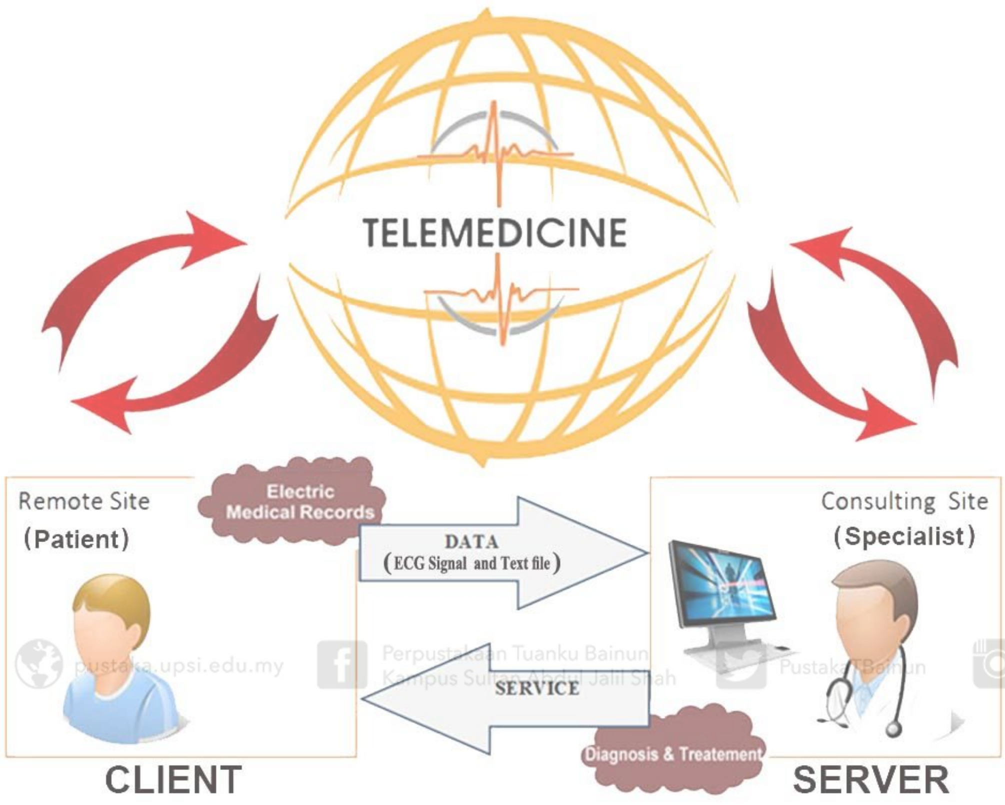

Figure 1.1. Remote Patient Map

1.4 Problem Statement

The previous ECG compression techniques have shown a steady improvement in the compression ratio, where these techniques generally lack quality considerations for reconstructing signals. However, technology applications are limited.

The ECG signal provides essential information to the cardiologist. These signals measured from the heart. Usually, a 24-hour recording is desirable for detecting heart abnormalities or disorders.

The tasks involved include the exploration of current ECG compression techniques and develop a compression algorithm that achieves a high compression ratio provided that important diagnostic information is retained within the reconstructed signal, which is useful in medical diagnosis. The quality of the reconstructed signal is most useful for medical diagnosis by preserving important clinical information during the compression process (Sayood, 2005)(Ramachandran & Bashyam, 2017).

With one lead to the heart, storage requirements can range from 26 Mbytes and 12-bit resolution sampled at 200 Hz, and with two leads, storage requirements can range from138 Mbytes and 16-bit resolution sampled at 400 Hz for a system. While the uncompressed digital signal requires a huge amount of memory. Where it requires a storage space of 28.8 Mbytes for a one-hour duration and a transmission rate of 64 kbps. Here, the compression is to represent this uncompressed signals with a minimum number of bits and optimum signal quality (Pooyan, Taheri, Moazami-Goudarzi, & Saboori, 2004)(Tsai & Tsai, 2019).

It can be seen that there is a direct correlation between the size of files on one hand and the cost of storage media, communications and cost of security on the other. Therefore, the more size of storage media, the higher the cost of communications and the higher the cost of security, and therefore, it is recommended to reduce the size of files in order to provide the above variable costs signal (Pooyan et al., 2004) (Mukhopadhyay et al., 2018).

Reduced data capacity helps to overcome all the problems that may occur in the bandwidth between the source and the destination. Such as a weak bandwidth or fall of one of the communication towers or any other communication problems. Compression is needed at a low bit-rate for both storage and telemedicine applications, with preserving the clinical diagnosis information. There is a continuous need for low bit rate and high-quality signal coders to optimally utilize the communication channel capacity (Alam & Gupta, 2014)(Ramachandran & Bashyam, 2017).

The effective significance of ECG data compression has become clear in several aspects of computerized electrocardiography including storage capacity increasing of ECG as databases for subsequent comparison or evaluation; feasibility of ECG transmitting in real-time over a public wireless network; Implement real-time rhythm algorithms cost-effective; fast ECG off-line transmission across public network lines to remote interpretation center and enhancement of all functions of ambulatory ECG surveillance and recorders. Also by compressing the ECG signal, it may help us further do the work to obtain the stable features that will be helpful for the ECG through a proper medical diagnosis (Alam & Gupta, 2014) (Kumar & others, 2017).

The targeting of ECG signals for transmission with different resolution from the patient to the physicians rapidly (transmit/ received speed), under various conditions (threat/stress/walking / high accuracy heart signals) is the main objective of this research. Therefore, the use of lossy ECG compression techniques to reduce the ECG signals size as far as possible and ECG transmission rapidly to the server while maintaining the characteristics of the compressed signal from the distortion as well as preserving the important medical information and preserve the manifestation of the QRS complex at the borderline between two frames is a problem of our research(Ramachandran & Bashyam, 2017).

1.5 Research Questions

There is a necessity to answer the next research questions:

Research Question 1: What is the best ECG signal compression quality for the purposes of telemedicine?

Research Question 2: What is the best signal compression algorithm to increase the efficiency in COMDEC process?

Research Question 3: What is the best method that increases the efficiency in COMDEC process?

Research Question 4: How the effectiveness of the ECG signal mobile device application for heart rate monitoring remotely (24/7) via telemedicine?

1.6 Research Objectives

Since ECG is a vital medical signal, clinical information is of paramount importance in diagnosis. Thus, the main objective of the ECG compression algorithm is to reduce the transmission time and storage facility or space without loss of clinically related information in the signal.

The goals of the research are:

1. To investigate the ECG signal compression quality for purposes of Telemedicine.
2. To propose an algorithm to integrate Discrete Wavelet Transform (DWT) and Principal Component Analysis (PCA) to increase the efficiency in COMDEC process.
3. To propose a method to increase the efficiency in COMDEC process.
4. To evaluate the ECG signal mobile device application for heart rate monitoring remotely (24/7) via Telemedicine.

1.7 Research Gaps

The review of the available literature reveals that different algorithms have been evaluated on a different database. Different algorithms were evaluated on various databases by a literature review available. Many kinds of compression criteria and errors have been utilized to display the differences between the original signal and the reconstructed signal.

Compression schemes are categorized into three classes, parameter extraction-based method, direct-based method, and transform-based method. The parameter extraction-based technique is irreversible where a process a specific parameter of the signal is extracted. Direct-based techniques process and code the signals in a time-domain (TD). Transform-based techniques process and code signals in the transformed domain. Existing data compression techniques are based on direct-based techniques or transform-based techniques (Jalaleddine, Hutchens, Strattan, & Coberly, 1990).

Generally, the direct-based techniques are better and superior to transform-based techniques with regard to error value and simplicity. Nevertheless, transform-based techniques perform a higher compression ratio and insensitive to noise included in the original ECG signal (Pooyan et al., 2004).

All methods and algorithms utilized for ECG signal compression have been studied for storage size reduction in order to achieve a higher transmission speed.

Based on Figure 2.4 described in Chapter 2, the proposed compression method was defined as below: ECG Signal Compression, Analytical Study, and finally select the Method-based, and Discrete Wavelet Transform-Based to as a starting point to determine the proposed compression method in this research.

Based on published literature, none of the above authors have even merged a method-based and discrete wavelet transform-based. A hybrid compression method for ECG compression using PCA belong to methods-based and DWT belong to the discrete wavelet transform-based has been designed.

Research work in this thesis will be focused on transformation based ECG signal compression methods because these methods provide better CR as compared to the Direct method.

The literature review reveals that more stress is laid on the development of simple compression schemes, in terms of computation, that produces high-quality reconstruction. A number of methods have been improved for ECG data compression, but still, no method can be claimed to reach a state of perfection to deal with all types of ECG signals.

There is scope to make a lot of improvement in the existing transformation based ECG compression techniques and to develop new, more efficient and effective and utilizing different transformation techniques that provide higher CR without significant loss of information. Therefore, there is a need to extend the research study in the transformation based ECG compression techniques.

1.8 Research Scope

The research area has mainly focused on ECG data compression for transmission purposes between patients to the physician via a wireless sensor network. However, more restrictions are applying to limit the scope as follows:

1. The study of this research is specified for the lossy data compression techniques to compress the ECG signal for telemedicine purposes.
2. The hybrid developed method is designed to be easy, enhanced and efficient.
3. The algorithm was to be implemented and simulated using Microsoft Visual C# Android application (Xamarin) programming language.

1.9 Significance of the Study

The patient's number increasing on the server-side leads to slow bandwidth between the client and the server, which in turn causes the failure to send patients cardiac data a continuously where will cause repeated interruptions due to this continuous increase.

Sending data from the patient continuously even in normal cases in order to know the patient’s condition is normal or abnormal (i.e. The patient is the target). It can also be considered a new and cheap way to reduce home caregivers.

This study is a great tool to relieve burdens on major hospitals, especially reputable Malaysian hospitals around the world. Where as a result of the large patients numbers of visits annually to these hospitals, it was necessary to provide an effective tool that contributes to the presence of the Internet by providing the best services to patients without being locally in those hospitals, thus giving more time to doctors to diagnose other numbers of patients without being restricted by time or queues.

1.10 Contribution

The contribution of the research is a follows:

1. build an efficient and reliable application for COMDEC an ECG signal, so that the loss in reconstructing the ECG signal is as low as possible, and the received ECG signal by a physician is acceptable and understandable and high precision.
2. Develop an algorithm for integrating DWT and PCA, so that it gives a high efficiency in COMDEC process. Sending an ECG signal (24/7) from the patient to the physician with minimal losses.

1.11 Research Organization

This thesis is introduced and organized in five chapters as follows: Chapter 1, is the introduction of the thesis and it explains the biomedical signal and the need to compress these signals. Since ECG is an essential biomedical signal, the focus is placed on the ECG signal, Cardiac Anatomy, and ECG characteristics. Further, the said chapter also explains the statement of the problem and the motivation. The problems that are associated with the current methods are equally itemized. The objectives of this study, as well as the research contributions, also discussed in this chapter.

Chapter 2 describes the background of the Biomedical Signals reflected in this study and they're diagnostic use. It also explained the related works of the present-day literature in the ECG signal compression field. Similarly, it explains the earlier studies into mobile biomedical signal surveillance devices and the explanation as well as the methodologies of signal compression on these devices. The compression techniques utilized in this study and the other techniques utilized in related studies were highlighted and analyzed.

Chapter 3 describes the research methodology of ECG compression. The chapter describes the comprehensive process of the compressed techniques utilized in the course of this study. The chapter further examines and presents common performance metrics. Lastly, the chapter presents the basic ECG Benchmark (MIT-BIH Arrhythmia dataset) which is used for testing with its justification for the selection.

Chapter 4 of this research, the discussions, the deliberations and outcomes of the proposed method testing on the criteria of the level of ECG signal compression is presented in this chapter. This chapter focused on the results from ECG signal compression based on DWT and PCA Algorithm. The chapter centers on testing the performance of compression at low signal distortion stages; maintains signal accuracy for visual display purpose, and verifies the integrity of maintaining the diagnosis using an algorithm to detect seizures.

Additionally, Chapter 4 deliberates on the probability of compression stages, increasing by permitting higher stages of signal distortion. The algorithm of automated seizure detection is engaged to define the maximum acceptable stage of loss, and accordingly, the maximum attainable compression stage. Lastly, it presents an analysis of the possible benefits of executing compression in a WSNs system. The chapter further analyzes and presents the computational cost of the compression in the hardware devices as well as maintaining the potential compressibility of data before transmission.

Finally, Chapter 5 summarizes the research work by presenting a summary and proposes future research. This chapter was centered on the conclusion and the influences of PCA and DWT on the ECG compression. ECG Data is compressed by minimizing the available bit stage to the quantization block. The signals that are consequential from the compression gains and stages of fidelity loss if compared with the original signals are highlighted. A comparative study of all methods is presented as well as the future scope of the work is outlined.

1.12 Chapter Summary

This chapter provides background about ECG signal compression and decompression (COMDEC) and remote monitoring over a telemedicine environment. In the statement of the problem, the priority of ECG compression, the quality of reconstructed signals, and remote patients' continuous monitoring were identified as a major problem in this research. The main objective of the study concentrates on improving the patients' healthcare in remote areas and developing countries by patient monitoring by the physician (24/7), and the specific objectives are also discussed. The final section of this chapter introduced the overall purpose of the other chapters of this thesis.