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

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In the name of Allah, the Most Gracious and the Most Merciful

Alhamdulillah, first and foremost, praise is Allah, the Cherisher and Sustainer of the World and to the Prophet Muhammad (Peace and Blessings of Allah Be Upon Him) who was sent by Allah to be a great teacher to the mankind.

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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.

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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

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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

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

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F Sample of Pseudocode of DWT Algorithm

G Sample of Pseudocode of PCA Algorithm

H Sample of Pseudo Code of Server Preparing for Sending and Receiving

I Mobile App (Sending and Receiving ECG Signals between Patient and Specialist)

J Cardiologist Evaluation Report for Mobile App

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CHAPTER 1

INTRODUCTION

1.1 Introduction

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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

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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.

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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

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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

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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,

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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.

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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.

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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.

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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

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signal for the client and the server respectively. The remote patient monitoring map can be illustrated in Figure 1.1.

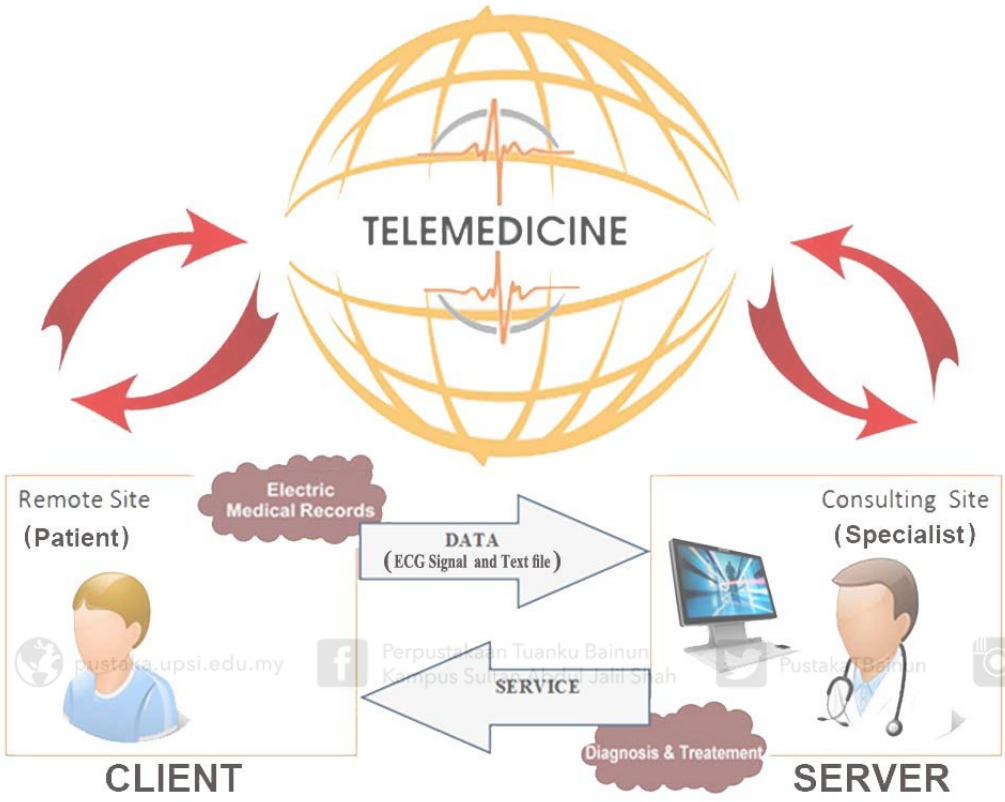


Figure 1.1. Remote Patient Map

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.

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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).

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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

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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).

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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

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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:

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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?

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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

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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).

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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.

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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.

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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.

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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.

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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:

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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.

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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.

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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.

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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.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

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This chapter presents a detailed description of a literature review background for this research. In Section 2.2, a systematic review protocol for the area of ECG signal compression is presented, followed by an overview of ECG compression in Section 2.3. In Section 2.4, open Issues and challenges are discussed. Furthermore, a theoretical background of the recommended solution is discussed in Section 2.5. Besides, a literature survey of the strengths and weaknesses of related articles is elaborated in section 2.6. Section 2.7, presented a summary of the related articles. Moreover, the conclusion is presented in Section 2.8.

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2.1.1 Overview of ECG

One of the most vital and intuitive tests for the present condition of the patient is ECG record graphically (ECG) which depicts the electrical function of the heart in a human body. The heart activity of a human being produces electrical waves which are measured as an ECG signals. The ECG signal is the measure of the bioelectrical signal produced at the surface of the human body due to the beating of the heart. According to (Blanco-Velasco, Cruz-Roldan, Godino-Liorente, and Barner, 2007), this signal depicts extremely important information to the physicians, as it provides a patient‘s cardiac condition at the moment.

As most of the hospitals are going for the electronic patient record (EPR) of the patients, data compression has become a big issue in the world of biomedical electronics, as the need for more and more record maintenance of the patients is required without saturation of the available storage. Besides this, recording the patient‘s cardiac data in the digital format with appropriate accuracy so that even minor changes occurring in the ECG record can be traced is of great concern in the area of biomedical signal processing. For instance, 24-hour ambulatory ECG with a three-channel characteristically has a storage capacity of over 50 MB. Therefore, it is required to compress the data effectively in order to reduce the storage cost and convenient conveyance of the record over telephone lines and other channels that poses a limited channel’s capacity. This necessitates an effective data compression technique (Pooyan et al., 2004).

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The core aim of any compression method is to realize maximum data volume reduction while conserving the substantial signal morphology characteristics upon 33reconstruction (Pooyan et al., 2004). Figure 2.1 shows a typical ECG waveform.

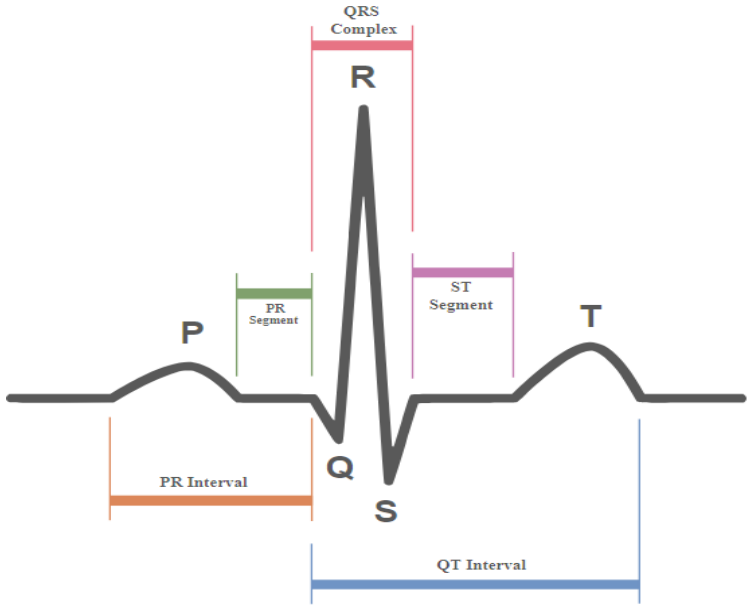


Figure 2.1 The Standard ECG Wave (INTERVALS)

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2.1.2 Telemedicine

Telemedicine is the assimilation of telecommunication equipment with the progressions of information technology. It is intended at improving healthcare supply to a large population. This technology helps the transmission of pathological and imaging reports of patients through the telemedicine networks, in order to offer consultation by experts situated in geographically diverse places. Hernandez, Mora, Villegas, Passariello, and Carrault (2001) (Tsai & Tsai, 2019), observe that the assimilation of biomedical instrumentation technology and mobile communication represents a significant role in

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telemedicine considering physicians who are far away from the system could also get the health status of their critical patients. The improvements made in the area of biomedical engineering have led to the growth of other perfect biomedical equipment to measure important physiological limitations and the expansion of interdisciplinary fields to battle the effects of body disease and malfunctions. Healthcare delivery in remote areas is enhanced by improving continuing care. Advantages of telemedicine technology include:

1. Saves cost and time that should be incurred in travel
2. Quick and easy access to expert
3. Cost-effective post-treatment consultation
4. Effective use of medical resources.

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In order to achieve the optimum transmission of the ECG signal from the patient to the physician, an authenticated server was used. The goal of the authenticated server is building client/server applications that communicate using sockets. This technique performs the transmission/receiving simulation through building client /server and then ECG signal transmission process beginning between them. This server is a door between the application process and end-end-transport protocol, and Figure 2.2, shows the connection between client and server through the authenticated server. There are two types of transmission control protocols (Ramachandran & Bashyam, 2017):

1. UDP: unreliable datagram (no connection between client/server). In UDP, the data may be lost or received out-of-order.

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2. TCP: reliable, byte-stream oriented (client must contact server), the server must have created a socket (door) that welcomes the client's contact (Law & Leung, 2003) (Tsai & Tsai, 2019).

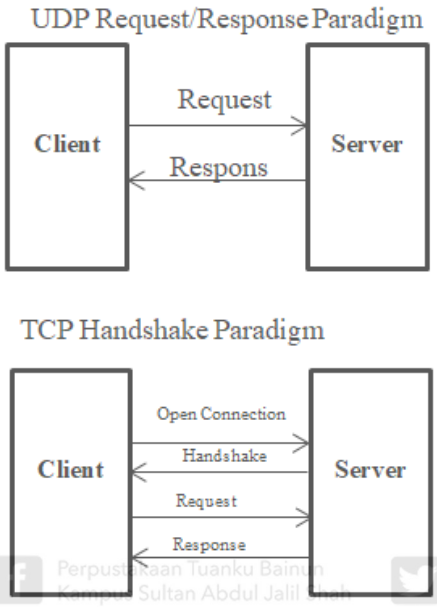


Figure 2.2 Process Communication Through TCP and UDP Protocols

Usually, a server operates on a particular computer and has a socket bounded with a specific port number. The server here is waiting, monitor to the socket for a client in order to bind a connection request.

At the client-side, the client identifies the hostname of the machine on which the server is operating and the port number on which the server is monitoring. To implement a request of connection, the client tries to meet with the server on the server's machine and port. Furthermore, the client requires identification to the server, so it binds to a local port number that it will utilize

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through the connection. This is usually assigned by the system (Xue & Zhu, 2009).

2.1.3 Mobile healthcare (mHealthcare)

A term of mHealthcare utilized for the medical practices of public healthcare supported by mobile instruments such as mobile phones, tablets, PDAs, etc., is called mobile healthcare or mHealthcare. mHealthcare field usually includes the mobile and multimedia telecommunications technologies utilization in the healthcare provision. The term of mobile health was founded by Robert Istepanian as the use of mobile communication emerging technologies and the creation of the network for healthcare (P. Cipresso, S. Serino, D. Villani, C. Repetto, L. Sellitti, G. Albani, A. Mauro, A. Gaggioli, and G. Riva, 2012).

The mHealthcare development arises of the following restrictions:

1. Increasing population growth continuously, a burden of high disease, medical care is low, large numbers of patients arrived in remote rural areas, and limited financial resources to support health information systems.
2. Mobile phone technologies grow rapidly, and advanced healthcare infrastructure availability. There is an opportunity to afford medical healthcare for rural populations by mobile phones at a lower cost. The objectives of health care are the following.
3. increasing access to economic and effective healthcare services

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4. Improve the ability to diagnose and detect diseases.
5. To provide more information about public healthcare with immediate action.
6. Increase an opportunity for continuing medical education access for healthcare workers.

The improvement in wireless infrastructure and mobile technology can afford medical care more quickly to remote rural populations. The field of mobile health promotes better medical care by communicating with health professionals at greater distances (Mechael, P. N, 2006).

Advanced mobile technology also offers the capability of direct voice information transferring. As a result, advances in technology are improving the ability to access information and bidirectional communication. However, the real-time application of mobile medicine poses many difficulties in data collection remotely and disease surveillance (Cipresso et al., 2012).

Remote surveillance and diagnosis of cardiac patients are not challenging in mobile medical care. The ECG data transmission and storage from patients to the cardiologist physicians by mobile phone is a big challenge for cardiac disease diagnosis (Mechael, 2006).

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2.1.4 Bio-signals

The Bio-signal term refers to every sign that are being created in the human body or some various living organic entity and every the most particularly it's used for speaking to each one of those signs from living life forms that are observed to gain a clear valuable data. The term is usually referred to as flags of an electrical nature at the same time, and any non-electric-signs are also checked.

A bio-signal is the type of signal in humans that can be monitored and measured continuously. The bio-signal term is commonly utilized for referring to biomedical signs, but it also refers to electrical and non-electrical signs both. The common understanding is to refer only to varying time signals, although spatial parameter differences (Cipressoi et al., 2012).

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1. Electroencephalogram (EEG)
2. Electrocardiogram (ECG)
3. Electromyogram (Young).
4. Electrooculography (EOG)

The essentially utilized approved bio-signals by specialists in the medical evaluation and also used by the medical and healthcare apps are summarized in Table 2.1.

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Table 2.1

Summary of Different Biosignals

Biomedical Parameter	Voltage(V)	Number of used sensors	Information rate (b/s)
Electrocardiogram	0.50 - 4.0 mV	05-09	15000
Heart Beat Sound	Very Less	02-04	120000
Heart rate	0.50 - 4.0 mV	02	600
Electroencephalogram	2-200 μV	20	4200
Electromyogram	0.1-5 m	02+	600000
Respiration rate	Less	01	800
Temperature of body	0-100 mV	01+	80

2.1.5 ECG Wave Pattern

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The one-cycle ECG signal contains P wave, QRS, T wave and U wave which are rarely visible. The baseline voltage is the line taken from a T wave to the next P wave, also known as iso-electric line, as shown below in Figure 2.3:

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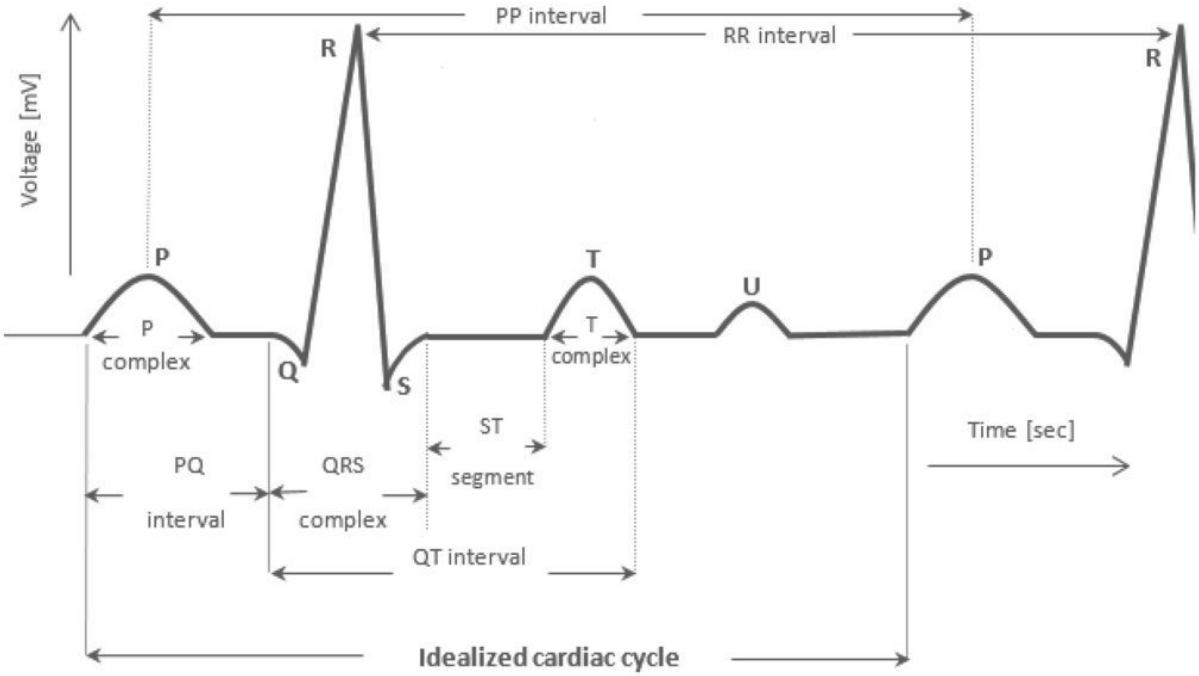


Figure 2.3 General ECG Signal

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1. Wave P: first wave view and indicates depolarization of the atria. Meanwhile, the electrical pulse starts from the SA node to the AV node that propagates through the two headphones. The amplitude of this signal is approximately 1 mV.
2. QRS complex: indicates the depolarization of the ventricles. The QRS complex has three peaks: Q and S are negative peaks and R is the positive peak. This is the largest voltage deviation of about 10 to 20 mV and a duration of 80 to 120 ms.
3. PR segment: This is the time between the start of the P wave and the beginning of the QRS complex. During this time, the electrical impulse propagates from the atria to the ventricles through the AV node.
4. Wave T: this is a positive deviation shortly after the QRS complex and indicates the repolarization of the ventricles.
5. ST-Segment: this is the time between the S wave and the beginning of Twave and is

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between depolarization and repolarization of the ventricles. The ST segment is always aligned in the isoelectric line.

6. Wave U: this is a small deviation after the T wave that represents the repolarization of the Purkinje fibers.

2.1.6 Electrocardiography (ECG) Data Compression

Among the primary aims of ECG, Data compression is to realize without any loss of the diagnostic features of the signal the maximum compression of the data. Data compression techniques can be categorized into two main groups namely lossy and lossless techniques. Lossy techniques do not get a precise reconstruction but higher compression can be acquired (Alesanco & García a, 2008). Conversely, techniques from the lossless group can get a precise reconstruction of the original signal but low data rates cannot be realized through these techniques. The ECG compression methods usually used are lossy in nature. The methods are classified into three groups (Jalaleddine et al., 1990) (Kumar & others, 2017):

1. One of the methods is the Direct-Based Method though which the real signal samples are examined and evaluated (TD) (Pooyan et al., 2004). Direct compression such as Amplitude-Zone-Time Epoch Coding (AZTEC) method, modified AZTEC, the Coordinate Reduction Time Coding System (CORTES), Turning Point (TP) technique, Scan-Along Polygonal Approximation (SAPA), fan, Delta Code Algorithm, Peak-picking, Cycle-to-Cycle, Differential Pulse Code Modulation (DPCM) and the Long-term

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Prediction (LTP) (Philips, 1993). Most of the above-mentioned techniques are highly efficient in data compression but due to the inability of exact reconstruction like actual signal and discontinuities occurring, the results are unacceptable to the cardiologists. Nevertheless, a major decline of such breaks is realized by means of a smoothing parabolic filter at the suitable boundary of amplitude distortion to the ECG (S. C. Saxena, Kumar, & Giri, 2007).

2. Transform-Based Methods, in which the first signal is transformed in a suitable domain and then spectral and energy distribution examination of the signal is carried out (Pooyan et al., 2004). Other transformations employed in transformational compression techniques are Haar Transform (HT), Fourier Transform (FT), Walsh Transform, Discrete Cosine Transform (DCT), Karhunen-Loeve Transform (KLT) (Pooyan et al., 2004) (Pandey et al., 2016), Wavelet Transform (WT) and the optimally Warped transform sub-band coding (S. C. Saxena et al., 2007). Linear transformations such as FT, Cosine Transform (CT), and Walsh Transform are useful to the signal whereas the compression through redundant sample decrease is used in the transform domain instead of in the TD. Usually, the transformation method yields a sequence of coefficients, which decrease the quantity of data that is needed to sufficiently symbolize the original signal. The highest Compression Ratio (CR) for multi-lead ECG data among all the transformative methods has been reported for the KLT method. Additionally, the KLT causes De-correlated to Transform Coefficients and reduces the entire entropy compared to the other transforms. The calculation time

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required to compute the KLT basis vectors is very intense and that gives room for the use of sub-optimal transforms with fast algorithms such as CT, FT, and HT (S. C. Saxena et al., 2007).

3. Parameter Extraction-Based Method is an irretrievable procedure with which a specific parameter or features of the signal can be extracted. The removed or extracted parameters (for instance, measurement of the probability distribution) are later used for grouping centered on previous knowledge of the signal features (Jalaleddine et al., 1990) (Kabir et al., 2017). A preprocessor is used to get features of the ECG signal and the same is used in the future to restructure the signal. Peak Peaking, Linear Prediction Methods, Syntactic, Neural Nets and Cycle Pool Based Compression (CPBC) are the techniques under this group. In almost all the compression techniques, a technique is useful for the purposes of selecting the slope segments, line segments, segment lengths, setting of error thresholds, the amplitude of segment extreme points and coding schemes. Furthermore, a technique is used to interpret information warehoused in some coded system to restructure the signal (S. C. Saxena et al., 2007). Figure 2.4. shows the generalized block diagram of the ECG signal COMDEC system.

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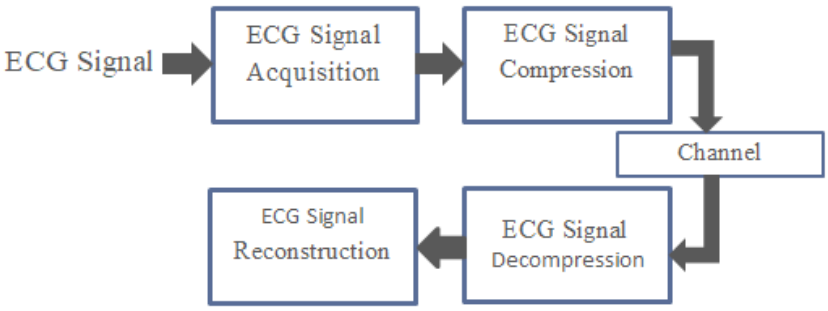


Figure 2.4 Generalized Block Diagram of ECG COMDEC System.

2.2 Systematic Review Protocol

In this section, presented the systematic review protocol utilized in this research. In the following subsections, the systematic review technique described information sources, study selection, search, and eligibility criteria.

2.2.1 Method

The utmost significant keyword in the scope of this thesis is compression and this excludes any other compression of other types than a cardiac signal compression (chest compression). For a systematic review of all the methods developed for ECG signal compression, we searched different databases, such as Science Direct, Web of Science and IEEE Xplore, with the keywords filter:

(telecare OR tele care OR telecare OR tele health OR telehealth OR telemedicine OR telehealth OR remote monitoring) AND (ECG OR EKG OR

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electrocardiogram) AND compression. A total of 396 publications were collected between 2012 until 2017. Table 2.2 shows the databases and the number of publications searched. There are three criteria were used to select these references: COMDEC ECG signal, 24/7 service providing (self-triage), and review/survey articles. The research also limits the scope to the English literature nevertheless, consider ECG compression-related areas. Among these publications, 95 ECG signal compression papers were used as references according to the criteria including 15 of review and survey paper. Finally, 20 papers from Science Direct, 9 papers from Web of Science and 51 paper IEEE Xplore. Table 2.2 databases and number of related publications (selected/total references).

Table 2.2

A database and Mumber of Related Publications (Selected/total References).

Database	Number of Publications
IEEE Xplore	51/80
Web of Science	9/80
Science Direct	20/80

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2.2.2 Information Source

There are important and essential databases that are relied upon in the research to select the approved scientific articles. Authorized digital databases have been selected to target our scientific articles. These databases permit access to articles in various scientific and medical fields. These huge databases have been chosen for their comprehensiveness and have wide vision in different fields of science specifically in the field of our research (telemedicine). As well as a full clear vision of what authors have reached in this area. These databases are:

1. IEEE Database: the huge database concern with all related topics of electronic engineering, computer science, electrical engineering, applied physics, information technology among others.
2. Science Direct Database: is one of the most important gates of the world of knowledge and at the same time one of the most valuable sources of information, which provides access to various scientific fields of technical and medical.
3. Web of Science Database: it is a world-leading database that provides reliable content in multiple disciplines (science, astronomy, computer science, medical science, etc.), which is the most important in the world in terms of the coefficient of impact. This database based on indexing a Multi-disciplinary study in the fields of social sciences, arts, and humanities as well as the sciences.

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2.2.3 Study Selection

In this phase, the study selection is carried out through searching in the literature sources. Screening and filtering are the next phases to be completed. There are three essential screening steps:

1. First screening step, here, the collected articles between 2012 - 2017. In this phase, all the duplicated articles are excluded.
2. Second screening step, filter articles by reading the titles and abstract of each article and exclude each article is out of the domain.
3. Third screening step, full-text reading, and exclude the review paper that is out of criteria and out of domain as shown in Figure 2.5.

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2.2.4 Search Process

The search began in October 2016, through three major databases, IEEE Xplore, Science direct and web of science (WOS) databases. The search process includes queries. Each database has a particular formula for writing the query. The query is a mixed keyword and includes telecare, telecare, telecare, telehealth, telehealth, telehealth, in diverse variations and joined by the operator OR, and ECG, EKG, ECG in diverse variations, joined by the operator AND. The outcomes obtained included all articles that inclusive ECG signal compression methods without transmission or methods of compression of ECG signal for transmission in order telemedicine or telecare. The inquiry text is demonstrated in Figure 2.5.

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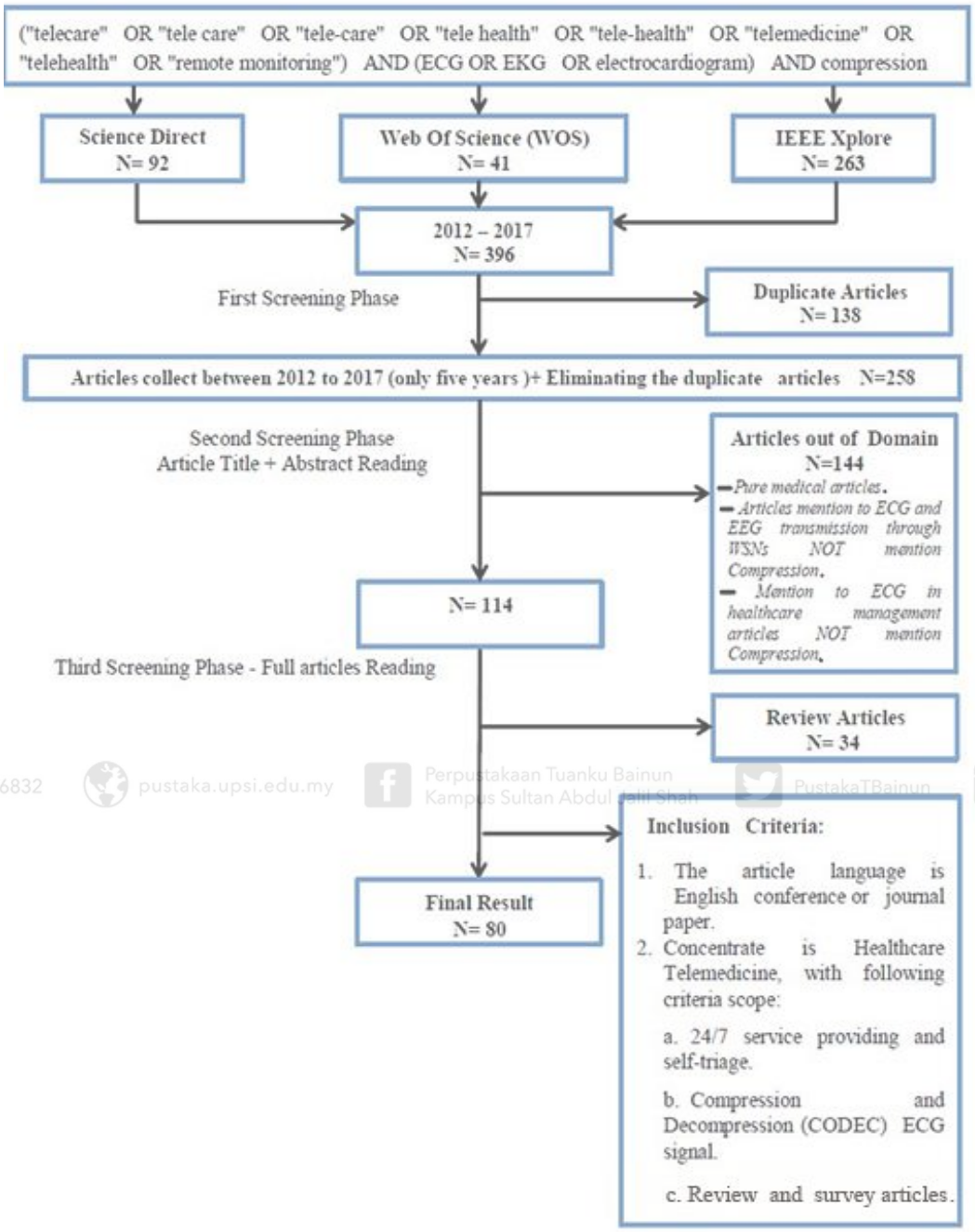


Figure 2.5 A Study Selection Flowchart Consists of Search, Query, and Inclusion Criteria

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During the search process, chapters of books and other kinds of reports were excluded, the search process was limited to journals and conferences articles only to the most relevant scientific articles, where we considered that these two venues are most potential to include all relevant scientific works trend of ECG signal compression to achieve the telemedicine.

2.2.5 Taxonomy Analysis

The results of the initial search in 396 articles: 41 from Web of Science, 92 from Science Direct, and 263 from IEEEXplore, over the span from 2012 to 2017.

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One hundred and thirty-eight (138) articles were duplicates among the three library databases. After screening the titles and abstracts, 144 more articles were excluded, resulting in 114 papers. Thirty-four (34) articles were excluded from full-text reading, leaving 80 articles in the final included set. Those papers were read thoroughly for the main purpose of finding out a general map of the conducted research.

2.2.6 The Eligibility Criteria

In Figure 2.3 each scientific article related to current work criteria was listed. At this phase, the subsequent elimination of the duplicate articles and collect only articles between the years 2012-2017, the articles were removed in the third iterations of

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filtering and screening that have unrelated with current domain and criteria. There are many reasons for article exclude:

1. The article is not in English.
2. In general, the goal here is ECG signal compression with concentrates on compression criteria, ECG signal transmission from the patient to the physician rapidly, and what transmission affects such as, weakness and limited communication, failure in the transmission network. Additionally, while preserving the clinical information in the transmitted ECG signal.

2.3 An overview of ECG Compression

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The compression of the ECG signal is indispensable in applications such as multi-channel ECG data storage and transmission, ambulatory monitoring systems, and telemedicine. The amount of ECG data to store/transmit grows with the rise in the sample resolution, sampling rate, recording time and a number of channels. In broad-spectrum, the ECG compression techniques should realize the following contradictory purposes (Sayood, 2005).

1. Decrease the quantity of digitized ECG data as much as imaginable with little execution overheads related to it.
2. Reserve the diagnostic information content in the remodeled signal. Although, a widespread variety of ECG compression techniques have been suggested in the literature, nevertheless, remains an active area of study, as superior techniques

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for realizing the contradictory requirements of better compression ratio and superior signal quality are in need.

A quite number of authors have shown this by executing various lossless, lossy and controlled ECG compression techniques and reporting developments in signal quality and compression efficiency. ECG compression techniques can be classified as the following:

1. Lossy compression or irreversible compression in which each reconstructed ECG sample differs from the corresponding original ECG sample by a value called loss, which cannot be recovered. Near-lossless compression can be considered as a lossy compression in which the loss is very small.
2. Lossless compression or reversible compression in which the original ECG samples can be retrieved exactly from the compressed signal and no loss of information is involved.
3. Controlled compression in which the quality and compression efficiency can be controlled based on the specific application requirements (Istepanian, Hadjileontiadis, & Panas, 2001) (Tsai & Tsai, 2019).

A major concern of ECG signal compression algorithms is the allowed error range, which can be tolerated for the reconstructed signal while preserving the diagnostic information. There is a need for a method that can be tailored to the requirement of the specific application, depending on whether the quality or the compression efficiency is more important. Hence a controlled ECG compression scheme is

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designed and evaluated in which the quality and compression efficiency can be controlled based on the requirement, by varying the threshold ranges for the residues and the manner in which the flag bits are directed to the receiving end (Nygaard, Haugland, & Stavanger, 1998) .

The suggested compression systems are verified on carefully chosen records from the normal dataset such as MIT-BIH Arrhythmia dataset.

ECG records pertaining to various clinical rhythms are chosen for evaluating the proposed schemes and also for comparing them with other known methods (Giurc, & Mereu, 2002) (Huang et al., 2018).

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For the purposes of performance assessment and contrast, different distortion measures such as Percent of Root-Mean-Square Difference (PRD), Root-Mean-Square Error (RMS), Signal-to-Noise Ratio (SNR), and Compression Efficiency measures such as Compressed Data Rate (CDR) in bit/s, Bits Per Sample (BPS), Compression Ratio (CR), and Bit Rate (bits per second) are used. This research consists of the following main sections, Review and Survey, Development and Design Study, Evaluation and Comparative Study and Analytical Study according to the literature taxonomy demonstrated in the following Figure 2.6.

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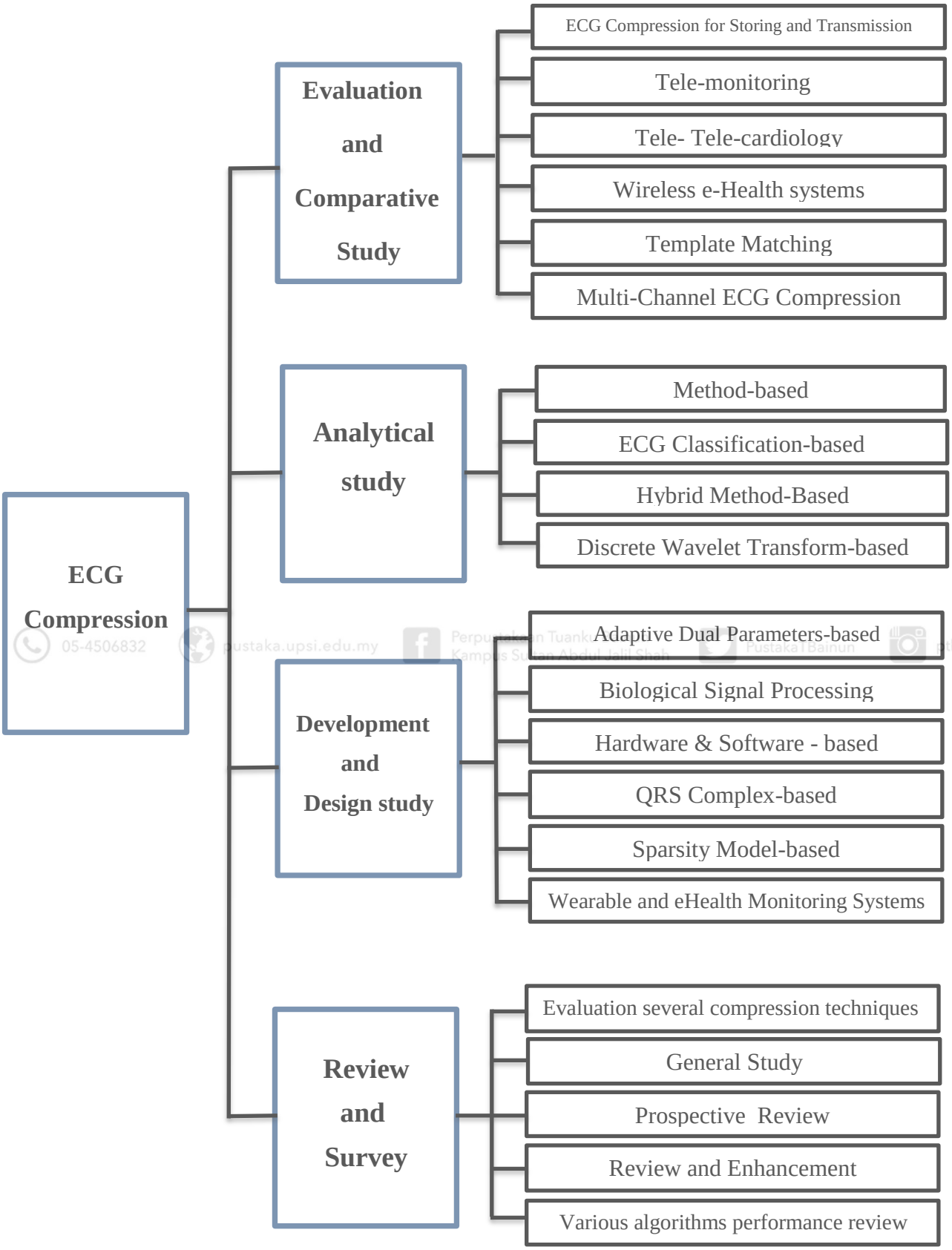


Figure 2.6 A Taxonomy of Research Literature on ECG Compression

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2.3.1 An Overview of Review and Survey Articles

Normally, the initial and utmost study works on ECG compression apps are examined articles that expected to obtain novel methods, and enabling these methods to the medical community, and originate some descriptive statistics, so as to know and appreciate the effects and possibilities of ECG compression through correct medical assessment alongside.

The stress-free and major class to notice is the reviews grounded on a general study (B. Singh, Kaur, & Singh, 2015) (V. Kumar, Saini, & Sunkaria, 2010) (Luz, Schwartz, Cámara-Chávez, & Menotti, 2016) (Neeru, 2017) (4/14 articles). A less significant collection of articles offer review and enhancement (Padhy & Dandapat, 2014) (R. Kumar, Kumar, & Singh, 2016a) and different ECG compression techniques review (Kale & Gawali, 2016) (B. M. Reddy, Subbareddy, Reddy, & Elamaran, 2014) (4/14).

Examples of this category include the reviews different ECG compression techniques review(Kale & Gawali, 2016) (B. M. Reddy et al., 2014), general study (B. Singh et al., 2015) (V. Kumar et al., 2010) (Luz et al., 2016) (Neeru, 2017), prospective review (Pallavi & Chandrashekar, 2016) (Craven, McGinley, Kilmartin, Glavin, & Jones, 2015) (Fira & Goras, 2015), review and enhancement study (Manikandan & Dandapat, 2014) (R. Kumar et al., 2016a) and various algorithms performance review (Pandhe & Patil, 2015) (P. K. Jain & Tiwari, 2014) (GORAS & FIRA, 2014).

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Regardless of their generality, some of these surveys confirm on particular parts, such as, (Kale & Gawali, 2016), presented a review of the diverse ECG compression methods and ECG compression applications available in literature, which can be assisted in ascertaining the suitable method for the application of particular requirements, and Reddy et al. (2014) presented a tutorial review on data compression with detection of the fetal heartbeat from noisy ECG. Singh et al. (2015) focused on their articles by making a comparison of the main methods (direct, transform, parameter extraction and 2D approaches) of ECG data compression which are proposed to reach a lossless compressed data with fairly high CR and low PRD. While, V. Kumar et al. (2016), offered an effort for a general idea of ECG data compression, with a bibliographic survey of significant background, practical requirements, the current state and techniques on portable devices for 24/7-on-line cardiac monitoring.

Luz et al. (2016) presented a survey of current studies found in literature concerning the ECG-based arrhythmia grouping methods and deliberated the key techniques employed for the construction of these automatic methods and two major methods used for assessment: inter-patient intra-patient. Neeru, (2017) focused on the assessment of numerous compression systems for ECG data compression and also provided the comparison of the several ECG compression methods such as AZTEC, CORTES, Turning Point, DCT, Delta Coding among others in terms of diverse performance metrics like CR, PRD, and QS. Pallavi & Chandrashekar (2016), discussed how four compression algorithms were implemented, out of which two are direct compression techniques whereas others are transformed techniques. While Craven et al. (2015) presented a broad and a detailed review of compressed

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sensing or compressive sampling CS in the bioelectric signal compression app. Conversely, Fira and Goras, (2015) presented a proportional study concerning the quality assessment for ECG signal compression and recommend a new measure for performance measurement as a substitute to the present PRDN.

Manikandan & Dandapat (2014) introduced a potential review of Wavelet Bases ECG compression techniques and their performances centered on discoveries acquired from numerous experiments carried out employing both spotless and noisy ECG signal. Whereas R. Kumar et al. (2016) submitted a review of the progress made in data compression research and development with a focused study on ECG signal compression based on 2D-Transform since its inception. On the other hand, Pandhe & Patil (2015), explained in their article a review of present ECG compression techniques and developments to make them easier for convenient ECG recorder. Similarly, (P. K. Jain & Tiwari, 2014) presented an article intended to offer a comprehensive review of the current developments of such heart monitoring systems. In a related development, Gora and Fira (2014) discussed a number of latest findings on ECG signal compression and classification with specific importance on compressed sensing are reviewed. This argument shields parts concerning data acquisition, separation, pre-processing, reconstruction, feature extraction, classification and quality assessment founded on a new quality score defined in this communication.

Based on the foregoing, we include Table 2.3 summary articles classification based on Review & Survey study.

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Table 2.3

Classifying the Articles Based on the Type (Review & Survey)

No	Author	Categories	Motivation	Challenging	Recommendation
1	Ammara Masood.et al-2013	A Review of Techniques and Algorithms	First, it is a study that related to all the steps needed for developing an automatic diagnostic system for skin cancer detection and classification. Second, it presents knowledge to the searchers to extraction proper feature selection methods for making correct diagnosis of melanoma . Third, it proposed a framework that highlights the importance of developing benchmarks and standard approaches for model validation.	There are no computers that can replace an experienced clinician's intuition.	The refinement of current approaches and development of new techniques will help in improving the ability to diagnose skin cancer and achieving our goal significant reduction in melanoma mortality rate.
2	Azadeh and Adel Al-Jumaily-2011	Overview paper	Automation of skin cancer detection can reduce the false positive or false negative clinical diagnosis because it adds a quantitative observation to the clinical eye observation.	The automated skin cancer system can be well designed as a substitute of the clinician in melanoma diagnosis.	Classification is considered as a significant task in building and developing reliable automated systems for the diagnosis of skin lesions.
3	Ekaterina G.et al-2014	A review & survey paper	Spectral properties are related to the biochemical content, pigmentation, and the morphology of the tissue. The fluorescence spectroscopy of the human skin is very important in the real-time determination of existing pathological conditions.	In the clinical practice that the standard biopsy could cause dissemination of the cancer cells; it is not advisable to be applied in many cases, including some cutaneous neoplasia.	This spectral distortion, related to melanin pigmentation, must be taken into account when clinical investigations are conducted; Moreover, the patient's skin photo type forms an important part of the algorithm, when the AF detected is to be used in diagnostic applications.
4	Bayo and Ademola-2015	Survey of head and neck skin cancer patients living with HIV	This study shows that albinos make very poor use of free and available antiretroviral therapy services.	The patient stays away from the HIV clinic and suffers the graver consequences later, also the larger community often pays heavily for this in the long run.	The benefits antiretroviral medication may encourage them over time to attend conventional HIV clinics.

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No	Author	Categories	Motivation	Challenging	Recommendation
5	Blake Friedman-2015	A Review paper	Additional studies examining the most effective means of modifying tanning habits found that emphasis on the aesthetic advantages of sun protection might be more effective than education on melanoma risk alone.	Due to the misinformation surrounding indoor tanning and UV-related health benefits, patient education regarding sun protection, the risks of UV exposure, and alternative means of obtaining vitamin D are necessary.	Health care providers should consider educating parents on the risks of indoor tanning and to encourage parental contribution to discussions on tanning bed avoidance.
6	Khalid M-2015	Review and Analyze study	This is the first study of skin cancer in Dammam where the most common type of skin malignancy in this study was BCC and SCC in the head and neck region, which is similar to other studies from Saudi Arabia.	Based on a survey of literature the Melanoma considered a rare skin neoplasm in Saudi Arabia which is different from incidence and pattern of MM in the west.	The most common skin cancers are BCC and SCC depended on the DFSB and MF studies in Saudi Arabia.
7	Konstantin and Rafae-2012	This review presents an overview of research in the computerized analysis of dermatological images	- They classified publications related to the computerized analysis of dermatological images into several categories. - This review is the extended categorization of existing clinical and dermoscopic feature descriptors.	At present, such systems cannot yet be used to provide the best diagnostic results or replace the clinicians' skill or histopathology.	An important step to improve output quality in these systems and unite the efforts of different research groups working in this area is to create a publicly available benchmark dataset for the algorithms being developed of this field.
8	M.C.F. Simões-2015	Review paper	Most exciting are theranostic agents, which combine treatment with imaging into a unique formulation.	Limitations in the current therapies are signal for the requirement of novel therapies among several treatment approaches.	A nanotechnology provides an exceptional opportunity on the molecular scale through specific interaction with cancer cells and inhibition of their function with Several formulations used into the medical practice and have become the standard of care.
9	Saverio Caini-2015	A systematic review of the telomere and the risk of skin cancer.	They reviewed and meta-analyzed the existing evidence on the association between PLTL and the risk of cutaneous melanoma and NMSC.	The main limitation of this meta-analysis lies in its reduced sample size, especially for what concerns non-melanoma skin cancer.	As a rule, one should keep in mind that PLTL is variously associated with the risk of several common diseases, so the choice of hospital controls should be done with much caution in order to avoid obtaining incorrect results.

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No	Author	Categories	Motivation	Challenging	Recommendation
10	Tasnuva Haque-2015	Mini-Review paper	Topical therapy has an established role in the management of specific NMSCs and AK, particularly for improve skin appearance and quality of life for patients.	Overall, evidence for the efficacy of topical retinoid in the management of AK is lacking and thus they remain unapproved for therapy of this condition.	Alitretinoin is a first-generation retinoid which activates both RARs and RXRs, and modulation of genes responsible for cell proliferation and differentiation is used for the management of skin lesions in patients with AIDS-related KS.
11	Bruno M.C.-2015	A Review paper	M-Health services and applications propose healthcare delivery anytime and anywhere overcoming geographical, temporal, and even organizational barriers with low and affordable costs.	Cooperation between m-Health applications is a challenge that needs a more comprehensive study.	Cooperation methods aim to the better efficiency, performance of mobile devices, data privacy and security, and influence of m-Health applications on end-users/patients' daily routine.
12	Jibin Liu-2016	A systematic review and meta-analysis of coffee intake level and the MM risk	They evaluate the association between the coffee intake level and the MM risk, then found that participants with more caffeinated coffee intake may have reduced MM risk using meta-analysis methods.	The ranges for coffee intake differed between this study, which may lead to the heterogeneity of risk estimates between the groups. 2) The interactions between caffeinated coffee intake level and UV-light exposure level and their roles in the MM risk are largely unknown. 3) meta-analysis of published studies, may lead to a biased, false-positive association as the small studies with null results may not yet be published.	This study may provide important public health implications for the prevention of MM.

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No	Author	Categories	Motivation	Challenging	Recommendation
13	Shaheel and Neil R -2014	Reviews for management of skin cancers	The management options for NMSCs can be categorized into surgical and non-surgical options, by Clinical treatment is to remove the tumor to achieve a high cure rate, preserve as much local tissue as possible and produce an optimum cosmetic result.	The correct clinical diagnosis for NMSCs can be challenging, and a biopsy is usually required, with surgeons electing to perform an excision biopsy of the whole lesion to ascertain the diagnosis, rather than doing an incision biopsy.	The treatment choice depends on the type and location of the tumor, the age and health status of the patient, available local services and experience, and the patient's choice.
14	Sophia Colantonio-2014	Systematic review paper	The results of this meta-analysis support the growing body of evidence that the use of indoor tanning increases the odds of melanoma.	In particular, observational studies can produce misleading results regarding the association of tanning bed use and melanoma as the exposure to tanning beds could not be allocated randomly or use blinding.	Randomized clinical trials are the gold standard of evidence, but they are unethical for studying the carcinogenic potential of tanning beds.
15	A.P. Kassianos-2015	Review of the smartphone apps available for melanoma detection	The first review that evaluates the content of smartphone apps available for melanoma detection for previously unaffected individuals or those previously diagnosed with skin cancer, and generalist clinicians.	Although the apps reviewed which only available in English from the online stores; therefore we may have failed to identify any apps published in other languages.	The smartphone apps based on evidence could contribute towards minimizing the diagnostic delay experienced by people with melanoma, which may be significantly caused for mortality.

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2.3.2 Development and Design Study Articles

In this section, the work was divided into different categories, large and smallest categories. We separated the incorporated works into a big group of wearable and eHealth monitoring systems studies (24/45), and a few other smaller categories of biological signal processing (ZHANG, CHEN, WU, & LI, 2012) (Demongeot et al., 2014) (C.-H. Luo et al., 2016) (3/45) and sparsity model-based (J. Zhang, Gu, Yu, & Li, 2015) (Friedler & Mount, 2015) (Grossi, Lanzarotti, & Lin, 2015) (3/45). Among them, there are three categories, adaptive dual parameters-based (Arvinti & Costache, 2014) (B. Huang, Wang, & Chen, 2013) (Swarnkar, Kumar, & Khanna, 2014) (M. Abo-Zahhad, Al-Ajlouni, Ahmed, & Schilling, 2013) (Wissam et al., 2017) (Hameed, Salman, Mohamad, 2016) (6/45), hardware & software-based(Xu, Zeng, Zou, Han, & Zeng, 2014) (Chacko John Deepu & Lian, 2015) (Attarmoghaddam, Khayat, & Maymandi-Nejad, 2016) (Pineda-López, Martinez-Fernández, Rojo-Álvarez, & Blanco-Velasco, 2014) (4/45), and QRS complex-based (Dhar, Mukhopadhyay, Mitra, Baig, & Mitra, 2014) (R. Kumar, Kumar, & Singh, 2015) (Ranjeet, Kuamr, & Pandey, 2012) (5/45).

Arvinti & Costache (2014) discussed a performance of the Daubechies Mother Wavelets on ECG compression, and Swarnkar et al. (2014), outlined the Wavelet filters performance of ECG compression created on linear predictive coding utilizing various thresholding functions, while Abo-Zahhad et al. (2013) present an ECG compression algorithm built on the optimum choice of wavelet filters and threshold levels in various sub-bands that reach maximum data volume decline while ensuring the quality of reconstruction signal. Huang et al. (2013)

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presented ECG compression by means of context modeling arithmetic coding with dynamic learning vector–scalar quantization.

Wissam et al. (2017) presented an efficient process of the denoising and the compression of the ECG signal, and Hameed et al. (2016) in their article focused on suggesting an extremely effective compression technique depending on both Run Length Coding (RLC) and Fast Lifting Wavelet Transform (FLWT) for both 1 and 2 dimensional ECG data. On the other hand, ZHANG et al. (2012) presented an effective compression technique which is suggested by encoding the sequence index of atoms founded on Matching Pursuit (MP) algorithm with over-complete Gabor dictionary, which has the merit to modify the CR according to the practical request with low distortion. Jacques Demongeot (2014) suggested a new method for compressing biological signals called Dynalets. While Ranjeet et al. (2012) suggested a methodology to optimized a wavelet filter bank for compression of ECG signal.

Luo et al. (2016) implemented a system utilizing flexible Poly-Dimethylsiloxane (PDMS) dry electrodes in its place of wet electrodes to get ECG signals. Wang & Meng (2008), suggested a 2D ECG compression core created on the No List SPIHT (NLSPIHT) algorithm and VLSI architecture is simply accessible so it can be modified to other tile sizes.

Attarmoghaddam et al. (2016) presented the plan of a low-power and area effective hardware engine for multi-channel compression of ECG signals. (Flavio Minos Pineda-Lopez, 2014), improved architecture of a convenient system allowing

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the acquisition, storage, processing and transmission in real-time, both as a 12-lead standard ECG and as long-term Holter. But Deepu and Lian (2015) developed a novel ECG processing method for common data compression and QRS detection in WWSN (wireless wearable sensor) and, the aim of the algorithm is depressing the average complexity per task. While Dhar et al. (2014) proposed an effective method to remove high frequency and power line interference noise from digitized ECG signal and compression of that improved signal in a lossless manner.

R. Kumar et al. (2015) introduced an algorithm founded on Singular Value Decomposition (SVD) and Wavelet Difference Reduction (WDR) methods for ECG signal compression that deals with the vast data of ambulatory system, while Mukhopadhyay, Mitra, and Mitra, (2013), implement a software-based efficient and reliable ECG data compression and transmission scheme. Kanhe & Hamde, (2016) suggested an ECG compression system utilizing Discrete Hermite Functions (DHF). The ECG signal is spread over the DHF basis and the 2D wavelet-based compression is carried out. Zhang et al. (2015) suggested an energy effective CS-based approach for on-node ECG compression to decrease airtime over energy-hungry wireless links. Meanwhile, Friedler & Mount (2015) introduced an outline for conserving and processing kinetic data compression spotted by WSN.

Grossi et al. (2015) explained a new ECG signal compression framework centered on sparse demonstration utilizing a set of ECG segments as a natural basis.

Craven et al. (2015) proposed an ECG signal compression method by means of compressed sampling/sensing method created on the Block Sparse Bayesian

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Learning (BSBL) algorithm. While Lalos, Alonso and Verikoukis (2014), introduced two new CS founded on ECG reconstruction algorithms that reduce the models that are necessary to be conveyed for a correct reconstruction, by manipulating the block structure of the ECG in the TD and in an Uncorrelated Domain (UD).

Liu, Zhang, Fan, & Fu (201) projected a fast CS algorithm that is built on a crossbreed model of the Block Sparse and MMV models whereas Al-Busaidi, Khriji, Touati, Rasid, and Mnaouer (2015) introduced an operative real-time compression system to overwhelmed the restriction of payload scope of the transmission channel.

Gurve, Saini, & Saini (2016) proposed a method for better version of the prevailing ASCII character encoding ECG data compression, while Ma, Zhang, and Dong (2015), presented an innovative ECG compression technique for e-health applications by using Adaptive Fourier Decomposition (AFD) algorithm crossbred with Symbol Substitution (SS) method. Similarly, Siao, Hsu, Lin, and Lee (2014) suggested a different method for ECG data compression regarding healthcare monitoring system that assists in reducing the consumption of power in the course of wireless communication.

Hatim, Latif, El Bachari and Arioua (2016) introduced a developed ECG lossy compression scheme that can spread great compression ratios with less error which creates an appropriate atmosphere for a real-time ECG signal surveillance.

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R. Kumar and Kumar (2015) discovered a unique algorithm for ECG signal compression grounded on Joint-multi-resolution Analysis (JMRA) by means of Gaussian Pyramid (GP) and Wavelet Analysis (WA). On the other hand, Allami, Stranieri, Balasubramanian, and Jelinek (2016) described a computationally immature nevertheless, a resourceful algorithm that realizes great ECG reduction degrees but sustaining important diagnostic features such as QRS, PR, ST, RR, and QT intervals.

Allami et al., (2016) developed an efficient software written in the C-platform founded on a novel ECG data compression algorithm were adopted to different ECG data of all the 12 leads (i, ii, iii, avr, avl, avf, v1, v2, v3, v4, v5, v6) reserved from PTBdb (Diagnostic ECG Database). Ibaida, Al-Shammary and Khalil (2014) offered a different fractal-based ECG lossy compression method to addresses the problematic issue relating to the traffic coming from and going to cloud ECG compression.

Teijeiro, Félix, Presedo, and Zamarrón (2013) described a circulated open avenue that accommodates a sequence of frequent problems in the present telemedicine systems called SERVANDO. Also, Ding and Zilic (2016) presented a low-complexity compression scheme of ECG signal founded on the Haar Wavelet Transform (HWT) for mobile devices usage. While Z. Liu, Yu, Chen, Yang, and Guan (2016) introduces a compatible CR valuation method of ECG signal and suggest a mutual model of the link between Sparsity and CR in order to equilibrium the CR and reconstruction quality.

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Varga, Bokor and Takács (2014) presented an efficient and transparent flexibility infrastructure for multi-sensor built on mobile patient surveillance and teleconsultation. Wu, Tsai, and Chang (2012) described design and implementation of an ECG signal surveillance system that is compatible with existing mobile telecommunications networks. Bera and Gupta (2016) described a real-time, lossy ECG compression algorithm built on delta encoding using variable length symbols.

Fang, Huang, and Tseng (2013) introduced a unified system for convenient ECG surveillance with an on-board processor for time-frequency examination of Heart Rate Variability (HRV). C J Deepu, Zhang, Heng, and Lian (2016) introduced the design of low power -lead ECG-on-Chip with a unified real-time QRS detection and lossless data compression for wearable wireless ECG sensors. Anoop and Parani (2016) developed a hardware project for continuous health monitoring and alert system. C. Wang, Jin, Qin, and Zheng (2016) also described a wearable ECG surveillance device with a customized SoC. Ahn, Noh, and Jeong (2015) implemented a system for wearable ECG monitoring in real-time. While Mishra & Agrawal (2015) implemented a new design tested entirely for immediate sensing and 24×7 transmitting significant physiological signals over cellular networks.

Based on the foregoing, we include Table 2.4 summary articles classification based on development and design study.

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Table 2.4

Classifying the Articles Based on the Type (Development & Design)

No	Author	Categories	Motivation	Challenging	Recommendation
1	Abdul- Rahman.et al Ali-2014	Design a new segmentation method	They proposed a new segmentation method including Fuzzy C-Means (FCM) and morphological erosion.	A misclassification pixels in the image as small white spots and the irregularity of the shape lesion typically outcome provided by most segmentation approaches.	Morphological erosion is able to remove any noise and misclassification pixels, but it is also able to highlight the shape of the lesion in a more uniform object.
2	Aidin Taeb.et al-2013	Design a technology (mm-wave)	The devices are designed to provide maximum sensitivity for the reflected signal from various samples.	The reflections from the BCC lesions are completely different from the healthy part.	The WR-22 Reflect meter testing on different patients, suffering from BCC cancer proved the accuracy and usefulness of devices in real cases between healthy and unhealthy lesion.
3	Alzbeta Elizabeth et al-2012	Development of technology(EIT)	The EIT system provides a lower number of malignant lesions that remain undetected at an early stage, which would increase patient prognosis and the effectiveness of further treatments.	The new images showed great improvement in the target position error and resolution, which were respectively improved by 44% and 23% while image artifacts decreased by 70%.	Due to the fact that voltage measurements are less sensitive to conductivity variations distant from the electrodes, resulting in numerical instabilities and computing errors for the difference of images.
4	Ammara Masood.et al-2015	Developing an automatic diagnostic system for skin cancer detection	Presents knowledge that helps the researchers judge the importance of making a correct diagnosis of melanoma.	There are no computers that can replace an experienced clinician's intuition.	The well-design studies are needed to ascertain which design features and analysis procedures are likely to lead to a better model.

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No	Author	Categories	Motivation	Challenging	Recommendation
5	Apoorva Raikar-2013	Development and set-up diagnostic methods	They presented a new diagnostic method, the ELM 7 point checklist , defines a set of seven features, based on color and texture parameters, which describe the malignancy of a lesion.	Early detection of melanoma is one of the greatest challenges of dermatologic practice today.	The automated system proposed might help less experienced dermatologists in the future.
6	Bernhard r. Tittmann-2013	Development two-frequency approach for noninvasive of cancerous	They developed a novel two-frequency approach for noninvasive evaluation of cancerous tissue with optimum depth and resolution.	Due to existence trade-off between depth of penetration and resolution that becomes the observation of an internal structure of a thickly sectioned biological tissue with the SAM is complicated.	To overcome this trade-off, our approach was to use two frequency regimes, a low-frequency regime in the range of 25 to 50 MHz and a high-frequency regime of 400 to 600 MHz.
7	Diego Caratelli.et al2011	Development to enhance device reliability	The locally conformal FDTD has been adopted as a detailed and insightful understanding of the physical processes responsible for the performance class of devices, that is very important in order to enhance the structural reliability, and optimizing the design cycle.	It has been numerically found that the resonant frequency of the considered sensors is significantly affected by the electrical properties of the skin.	In particular, electrodes controllec frequency radio signa to tune the curvature probe and, hence, acnieve an accurate scanning over a large area.
8	Diego Caratelli.et al-2012	Development to enhance structural reliability	The locally conformal FDTD model can be extended by including the piezoelectric effect through the constitutive relationships describing the mechanical and electrical properties of the materials forming the considered class of MEMS-based probes.	Due to the detection of melanoma-related anomalies, therefore the full-wave electromagnetic characterization of reconfigurable antenna sensors is used.	To enhance the structural reliability, optimizing the design cycle through of adoption of the locally conformal FDTD procedure.

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No	Author	Categories	Motivation	Challenging	Recommendation
9	Fritzi Töpfer.et al-2014	Design a millimeter-wave medical probe for skin cancer diagnosis.	The sensor is able to detect natural skin variation as well as artificially induced skin reactions in standardized dermatological experiments, and thus shows the potential of millimeter-wave measurements for skin diagnosis.	Two measurement instruments agree very well with their characterization of the skin damage. Moreover, the monitoring of the trend of the skin healing/recovery process is much clearer for the microwave measurements than for the reference instrument.	Sodium lauryl sulfate (SLS) exposure is widely used as a standardized dermatological test for provoking skin irritation and is used here to test the potential of the probe for diagnosing chemically induced defects in the skin.
10	Fritzi Töpfer.et al-2015	Develop new material	Presented broadband millimeter-wave probe was designed and found by technical evaluation to be well adapted for the diagnosis of skin cancer.	In the reproducibility situation of the preparation of such samples is low and the properties of these samples change with temperature and with time.	A new type of silicon-based samples introduced which can be tailor-made to mimic the dielectric properties of tissue of different water content and which are long-term stable.
11	Ioana Dumitrache.et al-2014	Development is using one AI algorithms	The skin lesions were used to do a classification into healthy and suspect of a nevi database, Through preprocessing and processing parts used natural computing approaches, like cellular automata and reaction-diffusion cellular nonlinear networks, and classification was done using SVM.	Two situations were presented. In the first one, the healthy data were 100% correctly recognized, while the suspect data were 25% misclassified, leaving 75% correct results. From the total test data used, 90% were correctly recognized. In the second one, the healthy data were 33 % misclassified, while all suspect nevi were correctly recognized.	To improve the preprocessing and processing part: automatic removal of the black frame using RD-CNNs and cellular automata, hair wire removal efficiencies for signature extraction using natural computing, location of useful genes to eliminate artifacts.
12	Kyle Phillips.et al-2015	Create an application in smartphone for melanoma detection using (SVM)	The goal of our research was to create a mobile melanoma detection application that could be used for the identification of melanoma on the skin in its earliest stages.	As hypothesize that leaving out border irregularity and diameter would not have a disastrous impact on the classification accuracy as current decision-making models.	To automate the extraction of the variance, we will write a simple Matlab script which could extract the variance of each of the RGB layers and save the variance to a feature vector.

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No	Author	Categories	Motivation	Challenging	Recommendation
13	Lucia Ballerini.et al-2012	Development is using one AI algorithms	1) These results are based only on normal color images, unlike the dermoscopy method, which requires a specialized sensor. 2) The multi-class classification method covers the majority of skin lesion types. This differentiates from most other approaches that concentrate on only two or three class instances of the problem.	Most of the AKs are misclassified as BCC and they should remember that AK is a pre-malignant lesion.	The consequences of these mistakes are not as dramatic as if they were diagnosed as benign. Thus, an additional split in the hierarchy may improve results.
14	Marco F. Duarte.et al-2013	Development is using one AI algorithms	Support vector machines (SVMs) have been used to tackle diverse classification and regression problems and are one of the most effective tools for these tasks.	Classification rates for the various problems varied from 40% to 75%, depending on the test performed and feature used.	Found many different classifiers which correct 100% of false negatives and 80–100% of false positives from bulk eumelanin classification. These classifiers operated on the invasive melanoma vs. nevi and melanoma in situ vs. nevi problems.
15	Margarida Ruela.et al-2013	Develop a computer-aided diagnosis (CAD) system	The system was tested using both manually and automatically segmented images. The descriptors which achieved the best individual performance were simple shape (SS) features, regardless of the apply segmentation method.	In the lighter regions from the border of the lesion are sometimes neglected by the segmentation algorithm. However, these regions usually provide valuable information and are considered by dermatologists when performing manual segmentation.	Image segmentation was performed both manually, by an expert, and automatically, by using an adaptive thresholding algorithm.
16	H. R. Mhaske.and D. A. Phalke -2013	Development and using two AI algorithms	Support vector machine classifier, Back Propagation Neural network and K-Means clustering algorithm have been used	The accuracy depends on the type of wavelet. The accuracy obtained is different for different types of wavelets.	The wavelet is the concept which is based on multi-resolution theory. Therefore, Fourier transform gives only frequency information of an image while wavelet is used to get information about frequencies as well as temporal information about it.

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No	Author	Categories	Motivation	Challenging	Recommendation
17	Omar Abuzaghleh. et al-2013	Development smart-phone named (SKINaid)	SKIN aid proposes to help users prevent developing skin cancer by triggering a real-time alert that informs the users to 1) avoid exposure to harmful UV radiation and 2) avoid consuming, risky foods and/or encourage eating beneficial foods.	Unprotected exposure to UV radiation and consuming certain foods are considered to be the most important risk factors for skin cancer.	The novel smartphone users to aid in the skin cancer prevention and pain treatment which consists of two stages, prevention stage and treatment stage.
18	Omar Abuzaghleh. et al-2014a	Development smart-phone	The components of the system presented to aid in the malignant melanoma prevention and early detection through automated segmentation algorithm and a novel framework proposed to classify the dermoscopic images into normal, atypical and melanoma.	Most people diagnosed with non-melanoma skin cancer have higher chances to cure, but melanoma survival rates are low compared to other skin cancer types.	Early detection of melanoma considered one of the major factors to increase the chance of cure significantly.
19	Omar Abuzaghleh. et al-2014b	Development smart-phone named (SKINcure)	The components of the SKIN care system present to aid in the malignant melanoma prevention and early detection that a novel framework proposed to classify of the dermoscopic images into normal, atypical and melanoma.	The most important risk factor for Melanoma skin cancer is unprotected exposure to UV radiation.	The early diagnosis of malignant melanoma increases the chances for cure significantly, while the real-time image analysis system proposed to aid in the malignant melanoma prevention and early detection is highly in-demand.
20	P. Sabouri-2014	Design and evaluation of classifiers in order to discriminate melanoma from non-melanoma	They presented an interactive object recognition methodology for border segmentation of clinical skin lesion images using an efficient mobile device.		

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No	Author	Categories	Motivation	Challenging	Recommendation
21	Shahid Haider-2014	Development of computer-aided diagnostic methods	The hybrid feature model is introduced for characterizing skin lesions that combine low-level and high-level features and augments them with a set of physiological features extracted from dermatological photographs using a nearest-neighbor nonlinear model to improve classification performance.	The visual assessment strategy taken by dermatologists is hampered by clinician subjectivity and suffers from low sensitivity.	Computer-aided diagnostic methods based on dermatological photographs are being developed to aid in the melanoma diagnosis process, but most of these methods rely only on superficial, topographic features that can be limiting in characterizing melanoma.
22	Tarun Wadhawan-2011	Develop a portable library in smartphone	Presented the SkinScan library, which implements several image processing and image analysis algorithms for melanoma detection, and evaluated whether these algorithms can run on processors used on smartphone devices.	Despite their various systems, but in this study has been tested only on the iPhone 4 device.	It is possible to run sophisticated biomedical imaging applications on smartphones and other handheld devices, which have the advantage of portability and low cost.
23	Thanh-Toan-2014	Development of automatic melanoma diagnosis system	Proposed an efficient segmentation scheme by combining fast skin detection and fusion of two fast segmentation results, new features which efficiently capture the color variation and border irregularity of segmented lesion and an efficient criterion for selecting features.	Smartphone-captured images taken under loosely-controlled conditions for melanoma detection, as well as image processing performed on the smartphone is subject to computation and memory constraints.	By using automatic feature extraction methods, e.g. sparse coding, it may help to find more efficient features.
24	Yun Seo Koo-2012	Develop a new type of conformal flexible microstrip antenna	The antenna operates at 434 MHz and is designed to be easily mounted on curved body contours.	The hyperthermia treatment will cause a rise in the localized tissue temperature due to EM energy deposition in the tissue.	Therefore, the EM energy will provide relative temperature for superficial tissue disease, as well as the ability to localize the heat within tissues so as to maximize heat delivered to malignant tumors and minimize the dose to healthy tissue.

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No	Author	Categories	Motivation	Challenging	Recommendation
25	Gaddi Blumrosen-2011	Design of new mobile health (m-Health) named C-SMART	C-SMART platform is a new mHealth platform for a continuous real-time remote patient monitoring.	It is designed to use existing software and hardware resources and as such it is excepted that future implementation of this platform will manage to reduce costs, support different vendors mobile phones, and enable friendly common user interface.	A full implementation of the C-SMART platform suggests encouraging nationwide collaboration that will enable optimal sharing of medical databases, medical applications and authorized medical stuff or patients' family members.
26	Martine Nezerwa-2015	Developing mobile applications	The main feature of this application is that it will attempt to monitor the caregiver for signs of distress and depression for underserved populations.	In a world run by technology, the majority of these elders are feeling left out, overwhelmed by all these technologies and by how fast they are changing.	Conducting research and developing applications that aim to create the team bringing the technology for underserved populations and also beneficial to the students that lead to fast technology to participating in real-world projects.
27	Ryan Littman-Quinn-2011	Developing mHealth applications in Botswana	Although implemented on a relatively small scale, have demonstrated the ability of mobile phone technology to serve as clinical and educational tools by health care providers, and to facilitate patient adherence through mHealth in Botswana.	Although limited resources, Botswana's health care, and medical education programs benefit from political stability and reliable mobile phone infrastructure, providing the ideal framework for mHealth initiatives.	This process will require an expansion of the collaborative relationships between public and private stakeholders, clinicians, researchers, and educators involved with mHealth in Botswana.

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No	Author	Categories	Motivation	Challenging	Recommendation
28	Xiaoyun Chen-2011	Developing mobile medical application under the 3G network	Presented a system is valid and stable, also reflects the system can provide customers a quick and convenient medical treatment and health information consulting service under a 3G mobile communication network environment.	Due to some limitations in the previous mobile technology to make audio with video synchronous transmission in moving environment becomes possible, and it has more bandwidth, better communication quality, variable transmission rate, and better frequency utilization.	Using model is applied with 3G network environment, it enables clients to carry on health archives management, hospitals and doctor query, medication guide and health services, telephone-doctor and making an appointment for medical treatment through the intelligent terminal.
29	Engin Mendi-2014	Development of the Windows Phone and Android environments.	They presented mobile frameworks automating the process of lesion detection in dermoscopy images.	Due to the subjectivity of human interpretation in dermoscopy images for the detection of melanoma, there has been a growing interest in the development of automated systems to help clinical diagnosis.	Further, we should extend this work to examine dermatology images with dermatologist-drawn boundaries of lesions for a quantitative comparison.
30	Luís and Márcia-2013	Development a mobile-based prototype to analyze skin lesions	They presented a prototype of a mobile-based system for skin lesion analysis using supervised classification through development Android application on the smartphone.		They look to use of the smartphone camera, through the incorporation of a macro lens and the usage of polarized light illumination to capture images with dermoscopic quality.
31	Rui Hu-2013	Developing an automated dermoscopy system for analysis of skin lesions	They presented a bag-of-feature approach to build a classifier for automatic detection of BU using lesion texture and color.	Particularly, the overall performance will decrease, due to the codebook size and feature vector become too large.	Using smartphones, especially the latest generation ones, which combine portability, low cost, and high performance can safely run sophisticated biomedical imaging applications in quasi-real-time.

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No	Author	Categories	Motivation	Challenging	Recommendation
32	Annett Korner-2015	Developing the NMSC system	This study raises awareness for health care professionals to be vigilant about supportive care needs and the psychological health of patients with non-melanoma skin cancer.	Patients with a non-life threatening illness may also struggle with psychological distress and that these patients might have greater unmet supportive care needs.	By recognizing patient needs, cancer-related concerns and early signs of distress is the first step toward addressing them through the care team which can make an important difference in patients' lives well beyond treating the skin malignancy.
33	Carolyn Heckman-2015	Development and preliminary assessment to address skin cancer risk	Describe the systematic and comprehensive process of development of UV4.me, an online intervention to address risk behaviors that may lead to skin cancer among young adults.	The challenges of conducting this type of work are, in part, the time, money, and expertise required to conduct such a project.	1) gather input from multi-disciplinary experts and the intended population during the entire development process; 2) use mixed methods to provide the most complete and useful information; 3) include the planned population and procedures informative and pilot testing; 4) plan and manage the time, money, and expertise needed for the project carefully prior to and throughout the project; and finally, 5) Be willing and able to revise plans, procedures, the website, and potentially the budget and timeline as the project progresses.
34	In Young and Allan-2015	Developing of the studies for several mouse models of skin carcinogenesis.	The mouse skin is considered as a solid tissue model of normal stem cell organization, it provides us with information that will be critical for understanding the origins of cancer stem cells from normal stem cells or reprogrammed differentiated progenitors in response to tissue damage.	When reduced exposure to inflammation dramatically decreased overall yields of papillomas and Class A carcinomas, more Class B carcinomas with a high frequency of Ink4/Arf genetic alterations were observed.	(1) the Class B tumors may undergo alternative genetic events possibly involving Ink4A at an early stage of carcinogenesis, or (2) the Class B tumors may arise from an early stem cell that does not require such extensive reprogramming by inflammatory and tumor-promoting stimuli.

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No	Author	Categories	Motivation	Challenging	Recommendation
35	Marco Rainer-2015	Development and improvement of NCAEC application	The variant of de-epithelialization and subsequent NCAEC application presented in this study improved the aesthetic outcome significantly in all cases.	They offer enough tissue for sufficient defect reconstruction, they have limitations such as the mismatch of color and the high volume and low elasticity of the transplant.	By NCAEC application for secondary aesthetic improvement in complex facial defects, as it is a concise and proven method.
36	Nicole Glode-2015	Developing and analysis of the synthetic CB receptor agonists in the treatment of cancer	These studies suggest that the plant-derived CB receptor agonist THC inhibits the growth of transplanted melanoma cells through antagonistic effects on its characteristic pro-inflammatory micro-environment.	Some studies showed that the treatment with CB receptor agonists or antagonists influences the growth of tumor cells.	Using different in vivo models we provide evidence that the endogenous cannabinoid system does not influence the growth of chemically induced skin tumors.
37	Philippa H. Youl-2015	Design the Healthy Text	The Healthy Text intervention considered effective in inducing significant improvements in sun protection and any type of skin self-examination behaviors.	SMS-delivered intervention considered far-reaching, flexible, and individualized.	The addition of visual components that highlight sunburn, appropriate sun-protective clothing, or thorough skin self-examination practices may help to further improve these behaviors.
38	Sebastián E. Godoy-2015	Development a standard methodology for detecting skin cancer	They performed a cross-sectional study of 102 subjects using DTI to classify the malignancy of lesions. This is the first time that a fast and non-invasive screening approach based on DTI achieves these levels of performance.		
39	Shivangi Jain-2015	Development of the computer-aided diagnosis system for skin cancer	Their proposed system can be effectively used by patients and physicians to diagnose skin cancer more accurately.	This system is more useful for the rural areas where the experts in the medical field may not be available.	In the future, this system could serve the purpose of automatic diagnostics of the Skin Cancer.
40	Abderrahim Bourouis-2013	Development and Design a mobile health application	They presented an innovative development by a low-cost smartphone-based intelligent system using an integrated camera.	An important device for patients in remote areas, poor and developing countries can scan, analyze and make regular skin examinations in any place.	

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No	Author	Categories	Motivation	Challenging	Recommendation
41	Upkar Varshney-2014	Developing and evaluating mobile health	Presented a framework for mobile health with four categories of patients, healthcare professionals, IT and m-health applications	limited focus on four categories which could include additional categories of regulatory environment and security and adoption of mobile health	M-health could the intelligent monitoring of patients can lead to better health outcomes at a lower health care cost.
42	Andrea Paradisi - 2014	Develop skin neoplasms in patients with vitiligo	They presented the largest study examining the risk of patients with vitiligo to develop both melanoma and non-melanoma skin cancer.	The limitations are the difference in age distribution groups and possible differences in medical surveillance would bias the estimate in the direction of an increased risk in patients with vitiligo.	This study pointed out to the patients with vitiligo should be protected themselves from sun exposure and exercise closer surveillance.
43	Heather Roebuck-2015	Developing Roebuck SCAN tool	The Roebuck SCAN tool is easily adaptable to different populations with various stages of clinical competency.	The survey, available made only to NPs in 1 state, which affects the generalizability of the findings.	Further endeavors should be exploring the results in other states and countries to determine the knowledge level and learning needs of NPs and other health care professionals caring for patients in dermatology practices.
44	Jiaqi Liu-2016	Development a melanoma using HDAC inhibitors comparing with normal skin cells	They presented both HDAC5 and HDAC6 as tumor promoters in melanoma proliferation and metastasis through different signaling pathway and shaded some light on the potential mechanisms.		Both HDAC5 and HDAC6 considered good diagnostic and therapeutic targets for controlling melanoma.
45	Joanna and Ryszard-2013	Development an algorithm could be a part of a whole 7 point checklist melanoma diagnostic system	They proposed a new approach to the assessment of dots and globules irregularity of the pigmented skin lesion that will be used not only the young inexperienced dermatologist but first and foremost by family physicians.	Despite the fact, that the results are satisfactory, the proposed algorithm will be still developed.	

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No	Author	Categories	Motivation	Challenging	Recommendation
46	Sadi Rashtak-2015	Develop a skin cancer after lung transplantation	The increased risk of skin cancer among patients with lung transplantation is likely because their immunosuppressive regimens are stronger, which emphasizes the importance of the immune system in protecting against skin cancers in the non-immunosuppressed population.	Particularly, the risk of developing subsequent skin cancer after initial skin cancer is substantially among patients with lung transplantation.	It is important to educate patients regarding ultraviolet protection and importance of self-skin examination, and follow-up, frequent for skin cancer screening by a trained professional is essential for early detection of skin cancers among the high-risk population of patients with lung transplantation.
47	Shedia M. Hammoud-2016	Development of non-melanoma skin cancer in patients with vitiligo	They have conducted extensive research to obtain all the available evidence regarding the occurrence of melanoma and NMSC in patients with vitiligo.	1) Protect skin against the sun. 2) The role of the anti-melanocyte immune response in vitiligo; 3) Often melanoma could not form in vitiligo. 4) Low risk of BCC and SCC in patients with vitiligo.	
48	Udit J. Chaube-2016	Design and development of novel synthetic compounds for the treatment of skin cancer	They developed one component of 6h, showed favourable action against skin cancer and treated tumours, demonstrating the potential of the series.	Due to a sudden rise in the incidence of skin cancer throughout the world and the available chemotherapy is facing problems.	
49	Yating Wang-2016	Development photoacoustic (PA) and ultrasound (US) imaging system	They developed an integrated photoacoustic (PA) and ultrasound (US) imaging system is employed for the combined PA/US imaging strategy.	Due to confused between melanoma with a naevus in clinical screening frequently, therefore, misdiagnosis results lead to serious medical consequences.	

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2.3.3 Evaluation and Comparative Study Articles

In line with the reviewed works in the previous section, the subsequent sections present six (6) parts of the literature contents; namely, ECG compression for storing and transmission-based (El Bcharri, Latif, Jenkal, & Abenaou, 2016) (Jha & Kolekar, 2016) (Motinath, Jha, & Kolekar, 2016) (Sahal & John, 2014) (Ktata & Mahjoubi, 2012) (Saberkari & Shamsi, 2012), Multi-channel ECG compression-based (Isa, Jatmiko, & Arymurthy, 2014) (Sharma, Dandapat, & Mahanta, 2012) (Padhy & Dandapat, 2014), Tele-cardiology app-based (Lim, Kwan, & Lee, 2016) (Polania, Carrillo, Blanco-Velasco, & Barner, 2015), Tele-monitoring app-based (Tawfic & Kayhan, 2015) (Bera & Gupta, 2016a), Template Matching-based (T.-Y. Kim, Noh, & Jeong, 2015) (B.-H. Kim, Noh, & Jeong, 2013), and Wireless e-Health Systems-based (B.-H. Kim et al., 2013) (Lai et al., 2013) (K. Luo, Li, & Wu, 2014). Mapping the works on evaluation and comparative study into distinct categories highlights various aspects of research coverage and compression methods.

For example, (Hatim et al., 2016) proposed a resourceful and effective technique of the ECG signal compression by means of the DWT and Run Length Encoding (RLE). Jha and Kolekar (2016) presented a proficient ECG data compression and transmission algorithm founded on DWT and Run Length Encoding (RLE).

Motinath et al. (2016), presented a novel ECG data compression algorithm based on DWT utilizing best mother wavelet selection for an upright compression performance in terms of CR, PRD, SNR, QS, RMS, and PRDN.

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Ktata and Mahjoubi (2012) evaluated the compression routine and features of Zerotree Coding Compression Schemes of ECG applications by two methods and they are the Embedded Zerotree Wavelet (EZW) and SPIHT. Furthermore, Padhy and Dandapat (2014) proposed a novel compression method founded on Higher-Order Singular Value Decomposition (HOSVD) for Multi-lead ECG (MECG) data. While Lim et al. (2016) on their part presented another compression method for ECG data compression by means of Discrete Tchebichef Moments (DTM) as an alternative to general and popular methods such as DCT and Wavelet Transform (WT). Conversely, Saberkari and Shamsi (2012) performed a different algorithm in ECG signal compression that is consist of compression in the rate of recurrence domain by means of four transforms; DCT, Fast Fourier Transform (FFT), Discrete Sine Transform (DST) and DCT-II. In another study, Sharma et al. (2012) proposed a Multi-scale PCA (MPCA) for MECG data compression. Also, Isa et al. (2014) proposed the implementation of the SPIHT algorithm to a multi-lead ECG signal compression.

Polania et al. (2015) suggest exploiting the arrangement of the wavelet representation of the ECG signal to increase the routine of CS-based techniques for reconstruction and compression of ECG signal. While Tawfic and Kayhan (2015) presented two approaches to work with the presence and absence of noise, these methods are Least Support Orthogonal Matching Pursuit (LS-OMP) and Least Support Denoising-Orthogonal Matching Pursuit (LSD-OMP).

Bera and Gupta (2016a) described a modest lossy compression algorithm for single-lead ECG by means of a crossbreed encoding approach, which can be

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employed for patient monitoring applications. Furthermore, T. Y. Kim et al. (2015) presented and implemented a segmentation and model matching founded on the ECG compression algorithm for the wearable ECG measurement system.

In a related development, B.H. Kim et al. (201) developed and implemented a model founded on ECG compression Algorithm for mobile device applications whereas Kuo, Lin, and Wu (2017) proposed a CS-based ECG monitoring system with operative AF detection. While Lai et al. (2013) presented a new effective DCT-IV-based ECG compression algorithm with a higher Quality Score (QS) and a better CR. Lastly, K. Luo et al. (2014) projected a vibrant and active compression system to overcome the challenge of ultralow power and real-time wireless ECG application.

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Based on the foregoing, we include a Table 2.5 of summary articles classification based on evaluation and comparative study.

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Table 2.5

Classifying the Articles Based on the Type (Evaluation&Comparative Study)

No	Author	Categories	Motivation	Challenging	Recommendation
1.	Aurora Sáez-2014	A comparative study of different classification methods.	They proposed to identify the global pattern that a lesion presents by modeling in different ways using different classification methods.		It should be outlined that no previous attempts of global pattern model-based classification of full lesions can be found in the literature.
2.	Catarina Barata.et al-2014	A comparative study of two different strategies	Comparing local and global strategies for the detection of melanomas achieved very good results in this database.	Most works considered global and local features played an important role but they do not attempt to clarify if one of these features plays a more relevant role.	Although, color, features provided performance better than texture features, since differential structures play an important role in the medical diagnosis of the dermoscopy images, and therefore, we would expect that this behavior could be captured by texture descriptors.
3.	Cínthia Caetano-2015	Characterize and evaluate the effects on melanoma cell for bullfrog oil microemulsions.	They presented a study to synthesize, characterize and evaluate the in vitro effects on melanoma cell line (B16F10) of bullfrog oil microemulsions associated or not with Chitosan, surfactant, and bullfrog oil (CSBO) and surfactant and bullfrog oil (SBO), respectively.	The study proved that there are no reports in the literature on the evaluation of possible cytotoxic activities of bullfrog oil against tumor cells.	This study showed the potential of these systems can be used in biomedical approaches aiming towards cancer therapy in vivo.
4.	Deepika Singh.et al-2014	A comparative study of various edge detection of skin.	Analyze Canny edge detection is the best approach for edge detection as it improves the signal to noise ratio, thus when used with the Otsu method gives the most promising result.	The gradient method caused higher pixel values along object edges and low pixel value elsewhere, that leads to over-segmentation due to noise and other local irregularities of the gradient.	Melanoma epiluminency image the model which comprising of median filtering, Otsu segmentation, and Canny edge detection considered the best optimistic approach for melanoma diagnosis and detection.

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No	Author	Categories	Motivation	Challenging	Recommendation
5.	Fritzi Töpfer.et al-2013b	Evaluating and comparing different prototype probe diagnosis.	Presented a new micromachined high-resolution microwave measurement probe for skin cancer diagnosis, and on a novel method of creating test samples with tailor-made permittivity, for mimicking tissue layers of different microwave properties.	The effective macroscopic permittivities of these silicon layers can be tailor-made by varying the size of etching holes in a periodic pattern which is substantially smaller than the wavelength.	The resulting effective permittivity depending on the etch hole size is listed in Table, for mimicking tumor layers within healthy skin tissue layers of different thicknesses and at varying depth. These values resemble the permittivity of skin tissue with different water content.
6.	Ioannis Valavanis.et al-2013	Comparative study and selection malignant vs. benign.	The imaging features were found to be less associated with disease status (malignant vs. benign) than genes according to IG ratios and GORevenge analysis compared to the 32 genes.		
7.	Md. Khaled Abu Mahmoud-2011	Comparison and classification of two segmentation methods used to identify the normal skin cancer from the malignant skin.	They presented two segmentation methods used to identify the normal skin cancer from malignant skin and to extract useful information from these images that passed to the classifier for training and testing.	This study concludes that there are some possible factors of the low classification results.	A possible improvement and generalization are to deal with the effect of large variation and overcome it by using larger databases.
8.	Naser Alfred-2015	Evaluation of skin cancer detection system using the pigment network structure.	They proposed an automated skin cancer detection system on Dermoscopy images using the pigment network structure which is extracted via directional Gabor filters.		Should focus on pigment network analysis to extract new efficient features and Testing the system with a different larger dataset.
9.	Oleksandr and Vincent -2015	Evaluation using an artificial electric skin model.	The novel contactless, non-invasive skin cancer considered a diagnostic tool based on resonance microwave Reflectometry and experimentally evaluated using an artificial dielectric skin model.	The raw images display much lower resolution, contrast than other images and therefore the detection of the early-stage tumors of λ/10 characteristic surface size can represent a significant challenge.	By reliability and accuracy of tissue discrimination can be substantially enhanced by using numerical processing of the raw images based on correlation algorithms which could facilitate the way of the proposed technique to clinical practice.

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No	Author	Categories	Motivation	Challenging	Recommendation
10.	Omar Abuzaghleh. et a l-2015	Compared with smart phones using the phone's camera.	The smartphones use by users to attach dermoscopy to the phone's camera to capture images of skin lesions which analysis of the image and inform the user if it is a benign lesion, atypical or melanoma.	The incidence of skin cancers has reached a large number of individuals within a given population, especially among whites, and the trend is still rising.	Early detection is vital, especially concerning melanoma because surgical excision currently is the only life-saving method for skin cancer.
11.	Abdul Hakim-2011	Evaluation of m-Health applications and their impact on users	The model indicated that a well-informed technology design will increase the intention to use the m-Health applications, and perceived usefulness is more significant to the intention to use m-health applications than the perceived ease of use.	There many issues reported in e-HTAM of smartphones.	The pilot study was conducted to empirically assess the acceptance of the use of smart phone devices (m-Health) in the field of medical informatics. It was also designed to report on the level of m-Health acceptance and how it addressed the overall model consistency and reliability of e-HTAM.
12.	Arka Bhowmik-2015	Evaluation of Theoretical study performance of (FMTWI) technique	The method for thermal evaluation of skin cancer uses low peak power and relatively less time for evaluation.	The theoretical study predicts that the subsurface blood flow could be a limiting factor for the diagnosis of small volume lesion using FMTWI technique.	Computing the phase information and transforming the raw thermograms into phase grams have shown the merit of this imaging method allowing clear differentiation of different melanoma stages.
13.	Sonia A. Lamel-2012	Evaluation of a Mobile teledermatology	They evaluated a Mobile teledermatology using cellular phones that are an innovative and convenient modality of providing dermatologic consultations for skin cancer screening.	Two limitations collected through the number of images were not transmitted instantaneously because of technical difficulties, then we also not able to capture dermatoscopy images through mobile phones.	The widespread use of cellular telephones and the expansion of wireless networks, meaningful integration lead to innovative telemedicine.

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No	Author	Categories	Motivation	Challenging	Recommendation
14.	Annan Yang-2016	Evaluate and modify factors in the study mechanisms of skin tumorigenesis on the mouse	They found that a DS mouse model which has reduced the incidence for some kinds of solid tumors had a susceptibility to papilloma formation in a chemical carcinogenesis model.	Given the multiplicity of different causes for different cancers, it is not terribly surprising that protective effects of trisomy 21 (and mouse models of it) involve diverse mechanisms with greater or lesser effects in different types of cancer.	The use of trisomic mouse model to study the genetics of people with DS will further our understanding of the mechanisms that underlie both protection and susceptibility to different forms of this disease.
15.	J. del Boz-2015	Describe and Evaluate the risk profile of golfers and golf course workers	The aims of this study were to describe the risk profile of golfers and golf course workers and evaluate the impact of skin cancer prevention and early detection intervention.	Although of this study could not by themselves, bring about improvements in sun protection behavior, where most participants in our study said that they intended to change their sun exposure habits and to examine their skin more frequently.	A key factor in the success of the campaign the fact that it was carried out at the site of risky behavior. Another factor was the development of a multi-component intervention model that included innovative techniques and a motivational strategy.
16.	Ashley Wysong-2014	Assess odds of NMSC after adjusting for the skin type, sun exposure history and indication for NSAID use.	The strengths of this study include the prospective design, large number of cases and long follow-up period, as well as detailed information on key skin cancer risk factors by NSAID use, was validated.	No, exist a significant dose-response relationship with longer duration of NSAID use.	Further studies are needed to evaluate the ideal duration and dosage of NSAID use for NMSC chemoprevention as this has implications for limiting side effects from long-term use.
17.	Paul D. and Hannah E.-2015	Comparison among Melanoma reports with nonmelanoma skin cancer.	They presented a standardized report to clinicians and their patients to offset the perceived time and the inconvenience of the report of the pathologist.	Audits remain vital to understanding whether datasets which by necessity require constant updating are being adopted and effectively utilized.	

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2.3.4 Articles Related to Analytical Study

Transmission of ECG signal from one area to another is an imperative portion of telemedicine applications. Huge ECG signals take more time for transmission which makes telemedicine development and progression boring and unfeasible. When these signals are exposed to compression, there will be either damage to the data or size will not be reduced much. To address this problem, there is a need to permit some loss of data so as to enable the size to be reduced and besides, the diagnostically significant sections remain undamaged. This is referred to the process of region-based compression'. The majority of the studies in the analytical study group rely on their analysis on ECG signal apps (18/95), which is essential for the studies that examine the correctness of compression in compression depend on CR.

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The analytical study classified into four sections, Discrete Wavelet Transform-based (Ranjeet et al., 2013) (R. Kumar & Kumar, 2015a) (R. Kumar & Kumar, 2015a) (Abdelmounim, Haddadi, Belaguid, & others, 2014), ECG Classification-based (Pandhe & Patil, 2014) (S. Chen, Hua, Li, Li, & Gao, 2017), Hybrid Method-Based (Jha & Kolekar, 2015) (R. Kumar, Kumar, & Singh, 2016b) (Rodriguez, Mexicano, Bila, Cervantes, & Ponce, 2015) (Surekha & Patil, 2014) (Padhy, Sharma, & Dandapat, 2016) (M. M. Abo-Zahhad, Mohamed, & Hussein, 2015) (Mahajan & Bansal, 2014) and method based (Brás & Pinho, 2015) (Brás & Pinho, 2015) (Chidean, Barquero-Pérez, Zhang, Jacobsen, & Caamano, 2016) (Alam & Gupta, 2014) (A. Singh, Sharma, & Dandapat, 2016) (Craven et al., 2017) (Craven et al., 2016). Based on the foregoing, we include Table 2.6 summary articles classification based on Analytical study.

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Table 2.6

Classifying the Articles Based on the Type(Analytical Study)

	Author	Categories of paper	Motivation	Challenges	Recommendation
1	A. Sokołowski.et al-2014	Analysis and compare various images based on statistical techniques	The results show that the algorithms highly adapted to the algorithms must eliminate certain particular spatial frequencies, which must also be added the algorithms extracted from specific color distributions during the study of the images, as well as the statistical techniques used to analyze them. and compare several images.	A challenge in the classification of melanoma images required the analysis of the distributions of some carefully selected colors.	For skin cancer lesions, images should be taken under identical terms, like distance to target, lighting, and camera lens
2	Alexey Balakin-2014	Analysis of the THz tissue	THz tissue images based on the multiband color technique show that the technique is effective for the analysis and diagnosis of skin cancer .	The recorded experiments of the radiation reflected by the object were the image of the entire surface of the sample or the spectrum obtained by the detection of a signal from a point in the sample, then averaged to reduce the noise.	The generation of THz wave and detection field offers the possibility of making THz spectral response measurements of various materials, including biological tissues.
3	Bao C. Q. Truong. et al-2014	Analytic study paper	The combined double parameters of Debye have resulted in promising values of AUC, sensitivity, and specificity, which confirm the remarkable potential of using these parameters to detect a skin tumor.	There is no important correlation between each Debye parameter and the percentage of BCC in the skin samples. They are significantly dependent on the content of the tumor with the corresponding Pearson correlation up to r = 92%.	The remarkable results of the classification are based simply on a very simple technique that uses threshold values. The application of more complex classifiers, such as the support vector machine, promises an important improvement in accuracy.

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	Author	Categories of paper	Motivation	Challenges	Recommendation
4	Dawei Nie-2011	Analytic Study	Two sets of tumors (melanoma and in situ) with characteristics and characteristic values important for the classification rate are sufficiently similar to be considered as a class of tumors that differ significantly from Clark Nevus.	The misclassification of melanomas and melanomas in situ for an expanded training set suggests that there is considerable overlap between the two melanoma categories.	As a result, some additional features are needed to automatically differentiate these types of melanoma.
5	Fritzi Topfe.et al-2013	An analysis study of 2-dimensional scanning	They presented a resolution of two-dimensional scanning of the micrometric wave micro-field near-field probe to combine high resolution and high sensitivity, which is important for the diagnosis of small early-stage skin tumors.	The differences between the measurements of a sample are influenced mainly by the operations and due to insufficient contact between the sample and the tip of the probe.	It is required to use the micro-machined conical tip probe with a two-dimensional scanning resolution at least as small as 1/6 of the normalized wavelength of the medium.
6	Kajsa Møllersen.et al-2015	Analysis study	An insensitive characteristic can make a valuable contribution to a classifier if the melanomas detected by the new characteristic are those that are misclassified by the existing classifier.	The selection of characteristics independent of the classifier indicates that the proposed characteristics are not strongly correlated with the existing characteristics.	The increase in sensitivities and specificities when g new features to an existing classifier shows interest in detecting melanoma.
7	Mutlu Mete and Nikolay Metodiev-2014	Analysis study using three selection techniques	They presented 90 images of dermatoscopic skin lesions used to determine the characteristics that offer the best classification accuracy for the malignant and benign classes.	It has been reported that a classification problem in two classes determines the most important characteristics of the disease using three selection techniques.	We found that the five functions selected by SVMRFE offer the most accurate readings: 100% of the model, 84% absence - absence and 89% cross-validation by 10 (10xCV) than the other two techniques.
8	Nikhil J. Dhinagar .et al-2011	An analysis study using Otsu thresholding	This study describes a technique that helps to detect tanned or precancerous skin under the sun by means of the segmentation of transversal image and the drawing of limits to locate three layers in the human skin tissue.	Additional research is required to analyze the segmented layers of skin samples to detect and differentiate the types of abnormalities present in the three layers of skin.	Otsu segmentation is used effectively to differentiate the three regions of various skin samples representing the normal, tanned and early stages according to the ABCDE melanoma forms.

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	Author	Categories of paper	Motivation	Challenges	Recommendation
9	Sankaran Srinivasan and Gopalakrishnan-2013	Analysis study using Six Sigma thresholds	Quantification of the degree of malignancy by the quantifier Asymmetric index of malignant melanoma. Six Sigma thresholds were used as a preprocessor to segment the return on investment of the rest of the image.	Many practical segmentation problems require more information than those contained in a spectral band. Color images are natural examples, in which the information is encoded in three spectral bands.	In segmentation approaches based on multispectral thresholds, approximations are determined by determining thresholds independently in each spectral band and are combined into a single segmented image based on the color variability in each spectral band.
10	Wiesław Paja and Mariusz-2013	Analysis study to apply feature selection techniques	By presenting the methodology and techniques as useful and effective in the medical approach, it could be treated as a useful technique to define a set of the most important characteristics, such as a genetic disease, lung cancer and other elements difficult to detect. recognize.	According to the importance review, all functions could be limited by eliminating some less important features.	The original set of less important attributes has been phased out and a classification error has been calculated. Therefore, these results show that the error rate is changing.
11	Asta Juzeniene-2014	An analysis study of annual UV levels in Europe	Around 89 to 95% of annual CD cases, approximately 99.8% of SCC cases and 99.4% of CBC cases are caused by exposure to the sun's UV rays.	MC rates are expected to increase more slowly now than before and have doubling periods of 20 to 80 years.	The prevention of UV rays could reduce the incidence of skin cancer in the fair skin population.
12	Bich Tran-2013	Analysis study between UVR and pancreatic cancer.	This study suggests that people with light skin color or who are born or live in areas with high ambient UV radiation have a lower risk of pancreatic cancer.	Ambient UV radiation seems to be more related to the risk of skin cancer than individual sun exposure behaviors.	The ambient UV radiation is strongly associated with circulation 25D, regardless of the time spent outdoors. The results of environmental UV rays are, therefore, consistent with the protective role played by a higher vitamin D status.

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	Author	Categories of paper	Motivation	Challenges	Recommendation
13	Fang Wang-2014	Analysis study abut UV risk	This study, which is referenced in the UV index report, always represents the maximum daily value based on the appropriate recommended protection measures.	This study suggests that the period of the high risk of skin lesions of the three monitored anatomical sites is not at 12 o'clock, unlike WHO, which showed that the period at noon was the period of the high risk of skin lesions caused by lightning. UV	In countries with high levels of ultraviolet radiation, it is considered important that the public is aware and avoid overexposure to UV rays.
14	J. Bernat-2014	Analytic study	The high incidence of NMSC in our patients and the important role played by immunosuppressive therapy in the etiology and pathogenesis of these tumors.	Although the use of mTOR inhibitors is associated with a reduced risk of malignancies after transplantation, it remains to be determined whether the change to these drugs can alter the biological behavior of tumors in patients with recurrent BSEC.	These patients should undergo periodic skin examinations and various clinical and environmental factors should be evaluated in the context of transplant follow-up.
15	Nicholas L. Berlin .et al-2015	Analysis and evaluation of family history of skin cancer	Pigment gene variants, MC1R, represent a small proportion of the risk, and this pigment-related phenotype explains an increased risk of early CBC, due to a family history of skin cancer.	Often, the evaluation of the family history of skin cancer has not been verified by objective techniques; therefore, some of the self-reported family history data may be inaccurate.	Although the role of the DNA genotype is important, some simple questions about the family history of skin cancer can be a surprising predictive tool for assessing the risk of early CBC.
16	Zhaoguo Liu-2015	Analytic study	The inflammation, Erk and P38, collectively played a critical role in the carcinogenic effect of capsaicin on skin cancer induced by carcinogens in mice.	Numerous studies have also shown that the consumption of food, especially some spicy or exciting seasonings such as ginger, garlic, pepper, pepper, and curry, was associated with the risk of skin cancer or even exacerbate the symptoms in people who They already have skin cancer.	It is essential that patients with skin cancer pay more attention to their daily diet.

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	Author	Categories of paper	Motivation	Challenges	Recommendation
17	Z. Al-Dujaili -2015	Analytical study to a variety of preventative measures of the skin cancer for women	They discussed several specific preventive measures for women that could reduce the risk of skin cancer, as well as current screening techniques and treatment options.	Time constraints during a doctor-patient visit and lack of self-confidence in the examination of skin cancer are some of the obstacles.	A recommendation as a preventive strategy to reduce some forms of skin cancer in women through a healthy lifestyle, such as reducing the consumption of tobacco and alcohol and a diet rich in antioxidants and compounds. Phytochemicals in the form of vegetables.
18	Andrew B. Seidenberg -2015	Analysis and evaluation of youth tobacco	Anti-smoking actions among young people have helped to change the norms and behaviors of society. By adopting a comprehensive and multiple approaches, they have significantly reduced youth tobacco use for many years.	Indoor tanning beds are unique because they are not the only source of damage since young women are also exposed to UV rays from outdoor tanning.	Therefore, it may be necessary to develop innovative strategies that are not mentioned here to help denormalize the practice of UV skin tanning, indoors and outdoors.
19	Chante Karimkhani-2015	Analytical study and comparing for melanoma and lung cancer	Cigarettes are considered the most common source of lung cancer and tanning beds are concentrated sources of UV rays, further increasing the risk of skin cancer.	The increase in the number of moles, atypical or dysplastic nevi, personal or family history of melanoma is correlated and exposure to UV radiation carries a risk of melanoma.	There are additional risk factors that create a state vulnerable to UV radiation to trigger the genesis of the tumor.
20	Christopher M. Doran.-2016	An analytic study of skin cancer in NSW	An analytical study of CINSW skin cancer awareness campaigns on skin cancer provides the community with a positive return on investment in prevention in NSW.		The analysis also provides a benchmark against which future campaigns can be judged to establish their relative economic costs and benefits, or estimate the economic efficiency of new forms of social marketing techniques in relation to television advertising and TV. traditional radio

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	Author	Categories of paper	Motivation	Challenges	Recommendation
21	Hasan Khosravi-2015	An analytical study of NMSC in children and young adults	Specific immunosuppressive agents may increase the risk of non-metastatic cancer, so these cumulative effects could lead to the development and uncontrolled growth of skin cancer in children and young adults.	The data showed associations between SCC and prolonged immunosuppression and BCC with radiotherapy; the exact pathogenesis of these processes could not be determined.	Physicians should be aware of the risk factors that predispose a child or young adult to skin cancer so that timely advice, supervision, recognition, and treatment can be provided.
22	Hildur Helgadottir-2015	An analytical study of CDKN2A wt melanoma families	We present this study that estimates the risks of melanoma and non-melanoma cancer in melanoma families of CDKN2A wt.	Mutation status of CDKN2A wt has been confirmed in all families; only a subset of these families has been evaluated to detect other known high-risk mutations associated with melanoma.	Members of CDKN2A families affected by melanoma need counseling and screening for the prevention and early detection of skin lesions.
23	Jerry D. Brewer - 2015	An analytical study of NMSC patients	The current study confirms the high incidence and relatively lower recurrence rates of non-metastatic breast cancer in patients with a history of lymphoma, even after Mohs micrographic surgery.	For patients with a history of NHL, recurrence rates and SCC are high, even after Mohs micrographic surgery.	Usually, attention, quick attention. proper management; and frequent follow-up is necessary to reduce the risk of recurrence and the possibility of subsequent metastasis.
24	Jianhua Zhao-2016	An analysis of variability-sized windows of the wave numbers in Raman spectroscopy	They explored the selection of the wave number based on the analysis of windows of various sizes in Raman spectroscopy for the in vivo diagnosis of skin cancer.	Diagnostic specificity is still limited to high levels of sensitivity. Therefore, from the point of view of the clinical diagnosis, it is very important to improve the specificity at high sensitivity levels in order to reduce unnecessary biopsies.	It can also be easily used for other spectroscopic techniques or for the diagnosis of other types of cancer.
25	Jung Hyun Han-2016	An analytic study of LIBS in the real skin melanomas	The use of LIBS for melanoma discrimination from the surrounding dermis could be very beneficial in the real-time detection system.	Several obstacles, such as beam and detector position problems and space limitations, have yet to be overcome for the practical use of LIBS in clinical settings.	The application of LIBS in a clinical setting will be best achieved through procedures involving the skin.

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	Author	Categories of paper	Motivation	Challenges	Recommendation
26	Leah M. Ferrucci - 2014	An analytical study about Indoor training of skin cancer risk	In some provisions that require indoor tanning salons to meet exposure limits, tanning companies have been associated with an increased risk of melanoma and skin cancer other than melanoma.	This risk of indoor tanning indicates that indoor tanning is an important part of the total indoor tanning session attributable to the risk of skin cancer.	Indoor tanning, regardless of its location, is detrimental to your health and the proliferation of indoor tanning equipment should be discouraged in all areas.
27	Monica Enamandram-2015	An analytical study of NMSC in routine dermatology	In general, the analysis emphasizes the importance of regular care for the population of patients in medical dermatology and the value of the dermatological examination in this context.	In medical dermatology, patients who regularly attend medical care are exposed to a risk of skin cancer.	Often, the optimization of detection in this enriched environment can reduce both the morbidity of undiagnosed cancer and the harms associated with diagnosis and treatment.
28	Reyk Hillert-2016	An analytic study of tumor cells CD8 T lymphocytes	They applied imaging microscopy to analyze the immune structure in various multiprotein sets associated with the cell surface and human skin cancer.		
29	Suchitra Khunsap-2016	Analytical study to explore the pharmacological properties of a dssPLA2 on human melanoma cells.	They reported that the enzyme strongly inhibited migration and cytotoxicity and showed important negative regulation of the N600 and BRAF V600E mutation genes in SK-MEL-28 cells that could cause cell damage and death.	Like vemurafenib and dabrafenib, inhibitors of the BRAFV600E mutation gene have a limitation due to the frequent and rapid onset of resistance.	The effect of dssPLA2 on melanoma should be evaluated in several ways, particularly the resistance mechanisms that focus on the BRAF V600E mutation gene and the BRAF protein that would prevent the recurrence of the disease.

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2.3.4.1 ECG Classification-Based

It is understood that the ECG digital signal processing developed and the necessity to preserve and convey the ECG signal data is uninterruptedly growing.

Pandhe & Patil (2014) introduced an analysis of an improved ECG decompression and compression technique. This technique was assessed on the basis of diverse compression and quality parameters such as CR, SNR, PRD, and QS. The described method achieves compression of ECG signal with lower computational complexity as equated with other multi-faceted methods, and this method can be simply applied to rooted or ambulatory systems. Chen et al. (2017) presented an innovative technique for the ECG beat classification according to a mixture of predictable and vibrant features. During processing, the algorithm results showed that the upraised technique has superior performance, as compared with the state-of-the-art automated heartbeat classification structures.

2.3.4.2 Hybrid Method-Based

Jha and Kolekar (2015), presented an analysis of compression performance built on crossbreed transform techniques which give higher CR than sole stage transform technique. In this performance analysis, the crossbreed transform technique provides a better and improved compression ratio than the sole stage transform technique.

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R. Kumar et al. (2016b) suggested a crossbreed compression system grounded on SVD and EZW by means of zero p gs, average period length and interpolation methods. The method proved its effectiveness and flexibility With various kinds of ECG signals for compression and controls quality of reconstruction. Rodríguez et al. (2015) introduced a new method for QRS detection of ECG signals by using the adaptive threshold technique and Hilbert transform. The QRS complex feature was extracted by using PCA. Surekha and Patil (2014) presented a compression method for ECG signals and in this technique, a DCT phase is joined with 1D or 2D DWT respectively. This technique is appropriate for a broad ECG signal and the QRS complex.

Padhy et al. (2016) presented a low multi-faceted multi-scale SVD compression scheme for WBSN applications. The distortion measures of the suggested method and the compression performance are assessed by calculating the average CR as well as the various distortion measures. The results are equated with prevailing compression methods. The storage effectiveness has been improved 19 times more than the other methods.

In a related development, M. M. Abo-Zahhad et al. (2015) offered a crossbreed compression system built on DWT, DPCM and decreasing the relationship between beats methods and signal samples. The performance of the suggested algorithm has been verified and simulation findings demonstrate the outstanding quality of reconstructed signals with %PRD less than 1.5% and CR greater than 20.

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Additionally, an effective hybrid ECG signal compression system that was founded on parameter extraction, frequency transformation techniques involving DCT and FFT, was introduced by (Mahajan & Bansal, 2014). It was created and evaluated through the utilization of bradycardia and tachycardia ECG rhythm that were extricated from the MIT-BIH Arrhythmia dataset. The justification of the creation and adoption of hybrid techniques in ECG signal compression is substantiated through its effectiveness, demonstrated by the great compression ratio, the small reconstruction error, and reduced computational complicatedness.

2.3.5 Other Studies

2.3.5.1 Method-Based

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Brás & Pinho (2015) proposed a degree that permits the comparison and assessment of two or more ECG segments devoid of following the traditional and conventional methods that need heartbeat segmentation (labeled as greatly inclined by internal or external intrusions. For the compression of data, the authors relied on information-theoretic data models, in addition, they have also utilized similarity metrics linked to the approximation of the Kolmogorov complexity, towards the efficient attainment of the goal. In the database utilized, the classifier was able to adequately determine the entire participants to a 99% preciseness.

Chidean et al. (2016) introduced to completely exploit the wavelet capability to function at varying stages of signal detail at different timescales. The objective of the existing work is to importantly increase the quality of the reconstructed ECG by

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using WT with different stages and bases at high or great CR. High and extraordinary quality ECGs from 50 healthy patients are employed to statistically to illustrate that the diagnostic quality preservation is possible notwithstanding that the compression rates are high.

Alam and Gupta (2014) performed a DPCM based data compression method with thresholding for real-time telemonitoring applications. The algorithm is computationally simple and accomplishes an upright and blameless compression ratio.

The computational plainness of the algorithm gave a chance to execute the coder by means of a low-cost microcontroller. On the other hand, A. Singh et al. (2016) presented a combined PCA-CS approach for MECG signal compression. PCA over MECG signal expedites the use of CS structure in eigenspace. PCA was employed to disassociate the mutually-correlated 12-channel ECG signal and capture their clinical structures in reduced-dimension eigenspace signals. The graphic signal superiority and quality of the reconstructed MECG signal are authenticated using Mean Opinion Score (MOS) and found to be 6.66%, which indicates very upright quality signal-construction.

Craven et al. (2017) presented a new adaptive Dictionary (AD) reconstruction system to increase the routine of CS with the ECG signals. The technique is built on the use of various dictionaries produced by means of Dictionary Learning (DL) methods for CS signal reconstruction. The performance of the proposed approach compares favorably with SPIHT in areas of signal

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reconstruction quality. Additionally, an examination of the whole power consumption of the recommended ECG compression structure as would be used in a Body Area Network (BAN) shows progressive outcomes for the recommended CS method when equated with the prevailing CS methods and SPIHT.

On the other hand, Zhang et al. (2015) advocated for a CS design that joins a new redundancy elimination pattern with AES (Advanced Encryption Standard) coding and quantization to successfully increase the CR. The new CS operation for ECG compression present CS techniques in relation to signal reconstruction quality for all CRs are verified.

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2.3.5.2 Discrete Wavelet Transform-Based

R. Kumar and Kumar (2015a) presented a manuscript of twin tree discrete wavelet transform built on ECG signal compression realized by means of the zero run-length coding methods. The findings of the suggested work have been assessed with three varied parameters, these provide facts about the quantity of compressed data, degradation of signal and relationship between the reconstructed and original signals. As the results of these parameters, the planned work is superior to the enumerated previous works.

Ranjeet et al. (2013) presented an ECG3 signal data compression algorithm that gives an upright and better volume of compression with a limited signal quality degradation by means of two dissimilar methods elucidate on behalf of a 1D ECG

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signal to the 2D array by means of CAB3 method. It was found that the average compression performance of the algorithm is 65% and the correlation score is 0.999.

On the other hand, Abdelmounim et al. (2014) offered a novel method built on four successive blocks for ECG signal compression and they are:

1. 6 to 12 Leads Converter
2. Mean and Baseline Removal
3. DWT and Thresholding
4. ADBC and Encoder

This method is applicable to all forms of ECG signal, be it normal or abnormal. Therefore, this process permits a cardiovascular physicians to carry out an accurate analysis.

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2.4 Open Issues and Challenges

In spite of the significance of signals compression in different fields, still, the main key to providing integrated healthcare for cardiovascular disease through ECG compression and pass these signals via physician in order to faster medical condition assessments. Previous studies showed that authors are bothered about the various challenges connected to CR and the noise-related to the signal compression and using these signals in healthcare. The challenges are classified under the following grouped depending on their nature:

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1. Concern on Storage Capacity and Requirements.
2. Concern on Telemedicine, Bandwidth, and Transmission.
3. Concern on Cardiovascular Disease.
4. Concern on Patient Tracking and Monitoring.

2.4.1 Concern on Storage Capacity and requirements

Probably the utmost untiring and critical challenges are those connected to the requirements of storage capacity. The main issues include concerns about low storage capacity which do not match the increased storage requirements for ECG signal as a result of continuous monitoring for collection and transmission.

Ranjeet et al. (2013) described a difficult to continuous monitoring and tracking the health situation of a patient living in an isolated place real-time inside and outside the hospital to health analysis because it will lead to power consumption. R. Kumar et al. (2016b) confirmed reducing the quantity of data due to the restriction of storage and analysis of computerized ECG signal real-time to use in the ambulatory system for Telemedicine, and loss the essential ECG signal information via compression.

R. Kumar and Kumar (2015a) explained a compression of biomedical signals with maintaining the signal quality due to a huge amount of different sampling rates data in order to remote monitoring based treatment to increasing telehealthcare

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services for Cardio-vascular Remote ambulatory and treatment. But, there is a limitation of signal database storage. M. M. Abo-Zahhad et al. (2015) explained the storage limitation of continuous ECG sampled signals.

2.4.2 Concern on Telemedicine, Bandwidth, and Transmission

The key objective of ECG compression is to decrease the amounts of ECG signal in order to transmit these signals to the server for remote diagnoses, such as (Craven et al., 2017) explained the rationale behind reducing the energy costs connected with wireless transmission and relieve the effect of wireless transmission.

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Mahajan and Bansal (2014) described a highly data-intensive due to high resolution because of longer time periods of continuous acquired and long-term ECG signal recording and analysis. This is leads to a big database construction and storing capacity, and more transmission bandwidth for isolated ECG signal analysis.

2.4.3 Concern on Cardiovascular Disease

Many authors highlighted the problems in cardiovascular disease due to prevalence between communities. Chidean et al. (2016) proposed a completely exploit the wavelet capability in order to function at different explained compression of ECG signal in wireless environments, with a lack of diagnostic quality and absence or deficiency in quality storage by means of Wavelet Transform (WT). Rodríguez et

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al. (2015) provided cardiovascular diseases, detection of QRS complex and ECG signal extraction for diverse forms of arrhythmias. Further, ECG signal faced the effects of motion artifacts, muscle noise and baseline drifts variations and modifications.

2.4.4 Concern on Patient Tracking and Monitoring

Probably, the greatest stubborn and critical challenges are those connected to the security and privacy of the patients tracking and monitoring. Brás and Pinho (2015) proved by means of ECG signal to ascertain and/or validate persons and this necessitates liveliness and contact for acquirement these signals.

So, these ECG signals are potentially useless, if changes under stress and rendering or acquired under threatening.

Surekha and Patil (2014) explained a long patient monitoring system and accurate QRS complex detection in real-time. Alam and Gupta (2014) described the capacity of ECG data in Halter monitoring, problematic to store and convey as well as well-organized ECG data compression methods reduce the volume of these data in real-time. A. Singh et al. (2016) described compressed sensing for the MECG signal.

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2.5 Theoretical Background about Compression Techniques

Here, the diverse compression methods which are utilized for the applications of ECG signal processing and their fundamental background theories are offered. DWT and PCA are several of the well-known methods. There are several reasons led to select DWT technique for ECG signal compression:

1. A powerful and influential method in the compression process.
2. It's a lossy method but this lossy has little impact on the ECG signal data
3. By this method we can compress the ECG signal to several levels.
4. DWT is perfect for non- stationary signals compression (i.e. ECG signals that cut up data into different scale-shift components).
5. ECG compression methods based on DWT have been shown to perform well.
6. Basically it gives multiple resolution decomposition of a signal.
7. DWT is faster and maps quickly to the sub-band coding of signals.

On the other hand, there are several reasons that led to the select PCA technique:

1. PCA is applied over the MECG data to preserve diagnostically important ECG features.
2. PCA has been previously used as dimensionality reduction tool to achieve MECG data compression.
3. The treatment of heart signals by PCA helps to and remove redundant information by exploit the spatial link across channels.

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4. The basic component analysis (PCA) is one of the most successful techniques used in image recognition and image compression.
5. A technique used to summarize and summarize data. It converts the large number of interrelated variables implicitly (albeit partially) into a much smaller group of independent variables. They are usually called major components and are mainly calculated from the original variables in percentages and increments that increase or decrease depending on the role and impact of each, ultimately describing as much information as possible in the original set of data we have.
6. Take the effective properties of the signal coming out of the DWT.
7. The PCA used to represent the digital signals within a partial low - dimensional space.

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2.5.1 Discrete Wavelet Transform (DWT)

DWT which is a fast algorithm and also an invertible algorithm, utilized for computation in machines; is a linear operation that functions of a data vector. It alters the data vector into a dissimilar vector possessing equal length. The primary functions of DWT entail a hierarchical set of wavelet functions which fulfill specific mathematical standards (Daubechies, 1992; S.G. Mallat, 1989b) consisting of the mutual translations and scaling in entirety.

The recommendation of the wavelet transform was as an optional technique for stationary biomedical signal analysis, which is a signal expansion to the primary functions. The wavelet technique has an omnipresent mathematical ability to be able

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to have a universal inspection of the diverse signal components through the mere manipulation of the focus.

In addition, the typical wavelet techniques applications dedicated to the medical wavelet processing utilize a wavelet transform in accordance with the implementation of a single wavelet, in contrast to the utilization of a primary set constructed from family mathematically associated wavelets. Reiteratively, it is critical for the favorable performance of the wavelet to choose a wavelet that possesses features that are apt to the physical signal that is taken into consideration.

The one dimension DWT can be shown in Figure 2.7.(Soni et al., 2018) (S. Mallat, 1999) (Mallat, 1989):

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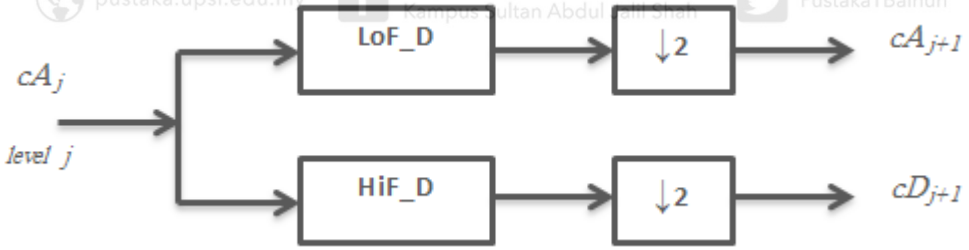


Figure 2.7 One-Dimensional DWT

The implementation of DWT in cardiology research could be utilized in various ways alongside fascinating applications like de-noising and medical signals compression. It also comprise feature extraction and ECG segmentation, the examination of heart rhythm variability and the examination of various types of cardiac arrhythmias (Cervigón, 2011).

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In general, DWT have the following features:

1. A powerful and influential method in the compression process.
2. It is a lossy method but has little impact on the ECG signal data.
3. DWT can compress ECG signal to several levels, due to wavelet-based methods provide a good performance in terms of compression.
4. DWT is suitable for non-stationary signals compression.
5. DWT founded on the compression of ECG techniques has demonstrated excellent performance.
6. DWT offers myriad solutions for signal decomposition.

   It expedites the functioning and mapping operations to the signal sub-band coding (Cervigón, 2011).

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2.5.2 Principle Component Analysis (PCA)

Generally, in course of analyzing a data or analyzing a problem, there is need to reduce the dimension of a problem which is a vital step before any analysis of data is carried out. The common standard for reducing the sizes or dimensions is to store the important facts and materials from the original data according to some optimality standards. The explication of the variance-covariance structure of a set of variables via the linear combinations of the variables is the main focus of PCA (Jolliffe, 1986).

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Given that a broad spectrum of clinical check-ups engages the utilization of ECG signals, an enormous quantity of data is generated for instant inspection, in addition to the repository of the database for the purpose of extraction and review in the forthcoming period.

The feature extraction process enables the transformation of the data space into a different and current feature space, that may be rendered in a decreased quantity of features. Thus, whilst the feature space is created, the initial data space experiences a decrease in dimensions. The prevalent speed of transmitting data that are not compressed is extremely sluggish, thus endowing it unsuitable with the compulsion for instantaneous interactions that are associated with a majority of ECG applications. An eminent impetus that underlies the progression of techniques in the compression of data is the ability of ECG signals to be transmitted transversing public telephone networks, cellular networks, networks external to the hospital and communication systems without wires (R. Jain, 2015).

PCA is amongst the beneficial methods that utilises statistical means to identify patterns within high dimension and low dimension data from the dataset, keeping the related data intact. The following are the primary aims of PCA:

1. Take the effective properties of the signal coming out of the DWT.
2. Utilized in reducing data whilst keeping the maximum conceivable data in the initial data. Applied to multi-channel ECG data (MECG) for the purpose of maintaining the important cardiac signaling characteristics of the diagnostic area.

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3. Used as a tool to reduce the dimensions of data for the purpose of achieving compression.
4. The heart signal processing by PCA assists in the exploitation of the spatial link transversing conduits and eliminating redundant data.
5. Utilized as an instrument to decrease dimension in order to attain a multi-channel ECG data (MECG) data compression.

Furthermore, PCA aims at reducing the dataset dimensionality. This is accomplished by changing a new set of variables such as PCs that are not unconnected, structured as well as arranged (Castells, Laguna, Sernmo, Bollmann, & Roig, 2007).

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2.6 Literature Survey

This chapter provides some background information about the ECG signal. The following Table 2.7, provides a complete analysis of the reviewed articles on ECG signal compression in different techniques in terms of their strengths and weaknesses.

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Table 2.7

A Complete Analysis of the Reviewed Articles on ECG Signal Compression in Different Techniques

Article No.	Author / Year	Brief Description	Method	Strength and Weakness
9	(Brás & Pinho, 2015)	The recommended measure permits the comparison of two (or more) ECG parts, without following conventional or traditional methods that need heartbeat segmentation, the recommended technique shown to be a realistic approach.	Displays an advanced and strong solution for identification and authentication of ECG signal for a person who depends on information-theoretic data models for data compression and on similarity metrics connected to the estimate of the Kolmogorov complexity.	- Using ECG signal ECG to ascertain and/or validate persons. - It involves contact and liveliness for acquisition - It modifies under compression, making it theoretically unusable if developed under intimidation.
10	(Chidean et al., 2016)	Recommend to completely exploit the wavelet capability to function at diverse stages of signal detail at different time scales in order to fix the problem of quality preservation lack.	The PRD is not a suitable method or technique to assess the performance or routine of an ECG mHealth solution. Towards the attainment of this objective, we have executed experimental endeavors onto the real ECH records, of which the entirety are classified as stemming from patients who are in good health. Our observations demonstrated that even in patients who are in good health will produce worthy outcomes with high dispersals.	- Compression of (ECG) in wireless environments, with diagnostic quality. - Lack of quality preservation, using Wavelet Transform (WT). - Cardiovascular diseases

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Article No.	Author / Year	Brief Description	Method	Strength and Weakness
52	(Alam & Gupta, 2014)	Suggest a DPCM based data compression technique with thresholding for real-time Telemonitoring applications	Implementation of a frame in real-time with one original sample followed by 64 first diverse elements. The non-QRS regions of an ECG data stream were compressed by the coder, via stages of the first difference, joint sign and magnitude coding and the run-length encoding. The enhancement of the RLE effectiveness was implemented through the application of hard thresholding posited at the equipotential regions.	- The volume of ECG data in Halter monitoring, ambulatory patients or in central ECG monitoring is so large and very problematic to store and transmit. - Real-time implementation. - Efficient ECG data compression method and decrease the volume of data.
5	(Alam & Gupta, 2014)	A joint PCA (Principal Component Analysis)-CS (Compressed Sensing) approach was suggested for MECG signal compression.	Firstly, the PCA is implemented on the MECG data to conserve significant ECG features in several principal eigenspace signals constructed on maximum variance. Next, the projection of the significant eigenspace signals is executed in a random manner over a sparse binary sensing matrix to obtain the abridged dimension compressive measurement vectors.	- Compressed sensing for MECG signals
56	(Craven et al., 2017)	Suggested a new reconstruction structure or framework for CS-based ECG compression by combining dictionary learning (DL) with compressed sensing (CS)	The core of the methods is pivoted on the utilization of diverse dictionaries, generated through the Dictionary Learning (DL) methods towards the reconstructing of CS Signal. The enhanced and altered reconstruction structure entails a pair of methodology phases that influence data pertaining to the signal, since the beginning of the initial signal reconstruction phase.	- Reducing the costs of energy connected to wireless transmission. - Reduce the effect of wireless transmission

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Article No.	Author / Year	Brief Description	Method	Strength and Weakness
72	(Craven et al., 2017)	The suggested CS implementation was verified against state-of-the-art CS implementations. Energy-based distortion metrics and QRS detection metrics were examined for increasing CR.	The proposed Compressed Sensing (CS) method provides a greater performance to the most recent state-of-the-art CS implementations in terms of signal reconstruction quality across all CR confirmed and verified. Furthermore, a comparison of the QRS detection technique preciseness was made against the well-known lossy SPIHT compression technique.	- The limited performance potential of compressed sensing in terms of total energy efficiency. - Device size, cost and computational performance for healthcare for BAN implementations. - Minimizing system power consumption.
26	(Ranjeet et al., 2013)	The recommendation of an ECG signal data compression algorithm was executed towards the provision of a worthwhile and sufficient quantity of compression with limited deterioration of the quality of the signal.	The construction of a 2D array of 1D ECG signal utilized two varying techniques through the cut and align (CAB) method, where the decomposition of the ECG 2D array occurred with the utilization of 2D DWT, with the resultant of the additional quantity of irrelevant coefficients.	- Storage capability and communication channel bandwidth - The storage of computerized ECG - Limitation of storage

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Article No.	Author / Year	Brief Description	Method	Strength and Weakness
45	(R. Kumar & Kumar, 2015a)	An ECG compression technique is described based on DT-DWT and zero run-length codings.	DT-DWT grounded on ECG signal compression is exploited by means of zero run-length coding methods	- Compression of the biomedical signal. - Increasing of telehealthcare services and - Remote monitoring based treatment. - Cardio-vascular Remote ambulatory and treatment. - The limitation of signal database storage. - A huge amount of different sampling rates data. - An ECG signal compression with maintains the signal quality.

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Article No.	Author / Year	Brief Description	Method	Strength and Weakness
63	(Abdelmounim et al., 2014)	The ECG signal compression entails a new technique based on 4 consecutive blocks: -(i) 6 to 2 Leads Converter, (ii) Mean and Baseline removal, (iii) Discrete Wavelet Transform and Thresholding, (iv) Adaptive Decimal to Binary Converter and Encoder	Utilized the up-to-date robust DWT signal processing linked to its thresholded coefficients alongside the Adaptive Decimal to Binary Converter (ADBC).	- Capabilities of conventional storage systems and transmission

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2.7 Summary of Technical Issues

Designing an ECG compression system requires several considerations. The technical challenge is at the forefront, under varying and demanding conditions (B. Huang et al., 2013). For example, some systems are employed in particular places such as hospitals, houses, or game fields. Other systems can be engaged throughout explicit period of time, as while sleeping, in periods of high risk, or at the time of exercise. Whereas each case has its own technical requirements.

Several authors mentioned in their articles to various ECG signal compression techniques in order to transmit these signals to a physician for proper diagnosis. These techniques differed according to their efficiency and speed in addition to the amount of data transferred. The technical issues depending on the specific characteristics of the application.

Ranjeet et al. (2013) mentioned in their article some of the technical issues related to the increase in the different sampling rates of signals, a number of channels, and time. Hence, data compression has a crucial part in the processing of data capacity, providing actual and practical resolution to the challenges linked with transmission and the bandwidth of storage issues.

R. Kumar and Kumar (2015a) referred to the role in managing storage and transmission speed of real-time ECG signals.

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In Abdelmounim et al. (2014), the authors expounded about the conventional ECG techniques, and high-resolution ECG techniques. Pertaining to the high-resolution ECG, a 24-hour duration file that has been recorded with a 12 bits/sample resolution that requires an average of above 100 megabytes per channel for the storage capacity. Hence, the values demonstrate a marked extensive capacity that exceeds typical transmission and systems of storage.

Brás and Pinho (2015) they mentioned to ECG signal acquired under threat are changed due to stress, rendering it potentially useless, which makes identify and/or authenticate persons difficult. The author used a method of Kolmogorov theory to define a relationship measure between binary objects, but major drawback (problem/limitation) of the Kolmogorov complexity (or algorithmic entropy) is that it is not quantifiable. The author referred to the proposed method is discarding more efficiently than accommodating. Consequently, there is a need for improvements so as to increase the acceptance percentage, and the technique should be authenticated taking into account data (ECG) gathered from a number of days as well as recognizing external variability conditions (such as stress).

In Chidean et al. (2016), the authors stated that derived from outcomes, they noted the narrowing of the y-axis to PRD = 20, implicating that the greater values do not provide crucial data and influence the dynamic components. They noted the possible distinctions amongst the various gauged CR, which are; the greater the CR will lead to the reduction in the quality of the recovered signal. Additionally, the inadequacies of the technique in averaging the PRD in assessing the ECG mHealth solution performance was discovered, where the quality outcomes of associated

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ECG records demonstrated high variance. The tests executed on the real ECG records derived from patients in good health were experimental in nature, which may result in quality outcomes with disseminations.

Alam and Gupta (2014) referred to the recommended compression method no compression is accomplished in the QRS region where the First Difference (FD) elements are either zero or very small. The authors also referred to as the algorithm suffer from high computational complexity. And also referred to CR that can further be improved by incorporating the original sample, however, the error will increase.

A. Singh et al. (2016) they mentioned that the current work examines some practical concerns in executing the combined PCA-CS for MECG signal. Also, they referred to the computational burden at the encoder. Recovery the compressed sensing (CS) also mentioned by the authors. Eigenspace MECG signals have moderately low sparsity in eigenspace itself (54.1%), which costs higher reconstruction error (APR= D 8.219 at CR = 5.96).

Craven et al. (2017) have referred to the restrictions connected with the application of standard orthogonal wavelets the basis for CS-based reconstruction, mainly for reducing the number of compressed measurements M, when signals represent additional variability and a more challenging reconstruction problem for the suggested algorithm. Also, the authors mentioned an impending concern here is the manifestation of a QRS complex at the borderline between two frames. Also, they referred to the remaining portion of the high energy in the ECG signal when the QRS detection algorithm determines the sample position of the complex, still, the

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neighboring frame may still have a portion of the QRS complex. Craven et al. (2016) mentioned to the optimization problem of ECG reconstruction signals quality.

Overall, by referring to the details of what the authors mentioned in their articles, no author had mentioned to use a method-based and discrete wavelet transform-based. In this thesis, we need an integrated hybrid method consists of PCA and DWT.

2.8 Conclusion

This chapter discusses the various techniques used for the lossy, lossless and controlled compression of ECG signal in the literature. The researcher carefully carried out a search for every article on:

1. ECG compression or ECG compression or EKG compression.
2. Telemonitoring or telemedicine or telehealth, in three main databases: IEEE Xplore, Web of Science and Science Direct. These databases are considered comprehensive sufficient to reflect both technical and medical literature. The search figured out 95 articles. Most literature (15/95) are surveys and reviews that refer to real methods or the literature to explain algorithms and methods of ECG signal compression to give an overall overview of the technology. A different group (18/95) consists of several studies, from an assessment and comparative studies of algorithms and methods of ECG signal compression to

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the examination of preferred features when developing them. A small number of authors (45/95) demonstrated real attempts and efforts to the development and design studies of algorithms and methods of ECG signal compression. The final portion (18/1) proposed analytical studies of all various methods and algorithms of ECG signal compression.

In this research, we have relied on the analytical study. All methods and algorithms utilized for ECG signal compression have been studied for storage size reduction in order to achieve higher transmission speed, and evaluate the quality of the reconstructed signal were considered as necessary in the patient's medical assessment process. So, the research gap was defined based on subsection method-based, and discrete wavelet transform-based subsection. These two subsections are two branches of the analytical study section. Based on published literature, none of the above authors have even merged a methods-based and discrete wavelet transform-based based. A hybrid compression methods for ECG compression using PCA belong to methods-based and DWT belong to discrete wavelet transform-based has been designed.

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CHAPTER 3

METHODOLOGY

3.1 Introduction

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The course of this research is presented in this chapter and an outline of the technique utilized onto ECG signal compression via the utilization of DWT and PCA accordingly. The illustration of the recommended technique framework is depicted in Figure 3.1.

The first phase described the ECG signal compression by using DWT and PCA respectively in Section 3.2. In the second phase, the transmitted data was explained in Section 3.3. The third phase, telemedicine for patient's sides, gateway side, and the recipient side was illustrated in Section 3.4. The proposed method was introduced in the fourth phase in Section 3.5. Finally, the fifth phase described the equipment of ECG data in section 3.6.

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3.2 Research Methodology

In this research, a hybrid compression method, DWT and PCA are researched. The research work was implemented in Microsoft Visual C# Android application (Xamarin) programming language is a powerful package for designing a complex mobile App. The work is done by building an application for heart rate compression, it is installed on a mobile phone (at the patient's side), and the other application is installed on the server (at the physician's side). Both applications contain COMDEC of the sent and received heart signals.

For the recommended techniques performance appraisal, the MIT-BIH arrhythmia dataset records are utilized in the work. The MIT-BIH arrhythmia dataset is favored and extensively utilized dataset sets, as individual record has the annotations of doctors, with the assured labeling of the entire signal anomalies and normal beat events. The ECG signals were attained from the PhysioNet service (http://www.physionet.org) from the MIT-BIH arrhythmia dataset. It entails an independent dataset and is showcased in the major part of literary publications.

This dataset contains 48 records with two channels in each record of heartbeats. The duration of each record is slightly more than 30 minutes. Each record is sampled at 360 Hz with a resolution of 11 bits. The recordings were done at BIH Arrhythmia Laboratory between 1975 and 1979.

The data flow is received from the target patient through a set of electrodes connected to the patient's body directly to record the patient's heartbeat (24/7). This

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data is compiled into the Holter machine. Sent to another device or computer that performs the preprocessing of the signal, which includes the ECG signals denoising by utilizing various filters designed for this purpose (such as HPF, PBF, and SBF), as well as normalization and threshold. Once the data is ready, it is compressed using the proposed hybrid algorithm (DWT and PCA methods), illustrate the methodology of the presented work with a specific ID for each compressed signal, ID indicates to a specific patient where each patient there is a private ID. Encodes the ECG signal file to protect the patient's privacy and then sends wirelessly to the server-side (physician). All these operations are done in the client part. On the server part, the compressed file is received by the physician. They are sent to the laptop designed for this purpose to be decrypted by using a private key. Then decompressed file to be analyzed by the physician and sends the appropriate diagnosis to the patient directly. The following Figure 3.11 illustrates the methodology of the presented work. The records in the MIT-BIH dataset are cleared and denoising organized according types, length, and duration.

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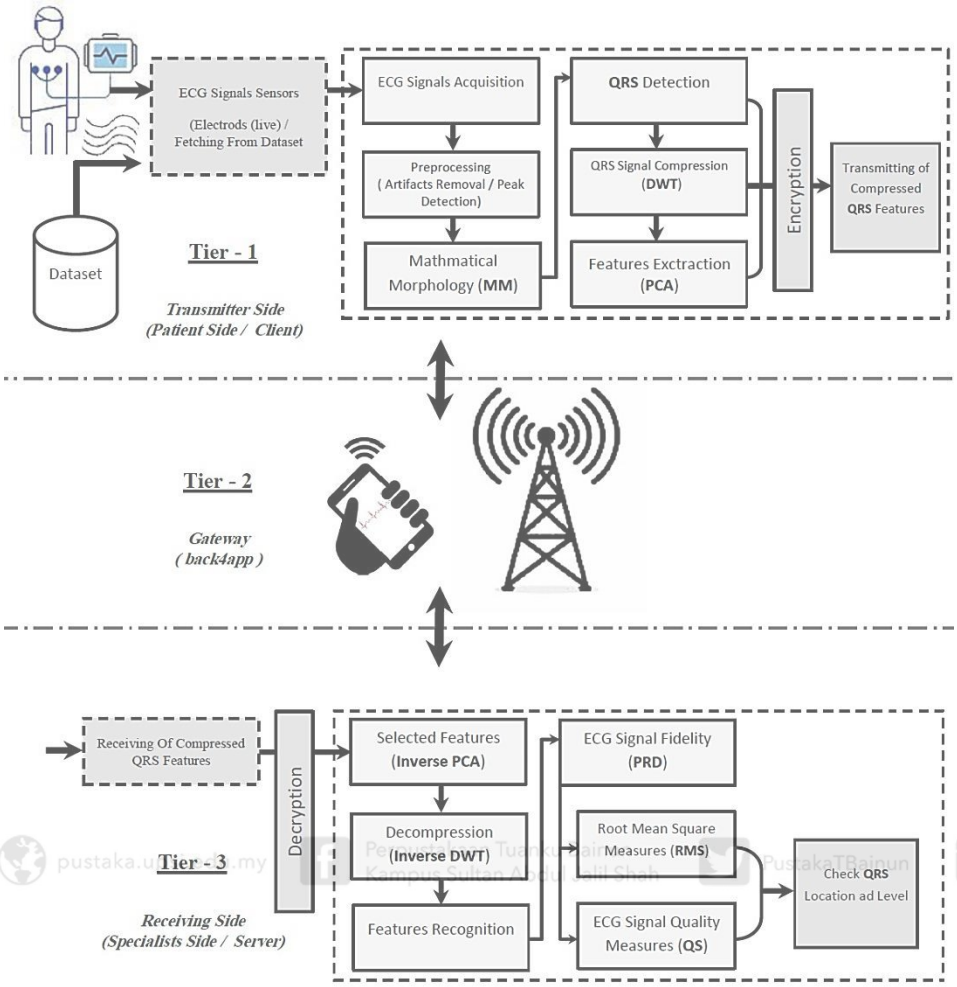


Figure 3.1 The Methodology of the Research

3.3 Preliminary Analysis Phase

The preliminary analysis stage includes the problem identification stage as follows:

3.3.1 Phase Assignment

The main aim of the phase assignment stage is to detect QRS peak in the ECG signal and then to assign the phase to each sample of the signal according to the detected

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QRS peak. In this stage, a mathematical morphological (MM)method is applied to detect QRS peak the ECG. The concept of R peak detection of the ECG as explained in our proposed method above was used. The phase to each sample of ECG was assigned by using QRS-peaks of ECG (Blaya, Fraser, & Holt, 2010)(Bhalerao et al., 2019).

3.3.2 Problem Identification

The main goal of the ECG signal compression is to signal compression with adequate size with preserving the most valuable clinical information in these signals, additionally, provide a minimal loss in signal fidelity while maximizing the compression ratio(CR).

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In order to evaluate the patient medically, there is data that the physician must obtain. These data are collected via aggregation devices such as Holter machine and sent at once to the physician to give an opinion in the case of the patient who has been monitored (24/7) after analyzing this data. This is done in Modula 1 and 2, which described in Section 3.6.

These data, as a natural result of their continuous storage, increase in size and become regular data. This leads to needing to high storage capacity, sufficient memory, as well as the time of data transmission and large bandwidth required.

So data compression has become a necessity to get rid of all the above problems. In general, factors leading to the size of ECG data grow:

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1. Increase the no. of channels (single-channel and multi-channel).
2. Increase the sampling rate per second (125 Hz – 500 Hz).
3. Increase recording time, and,
4. Increase Sample accuracy: pure high-resolution samples from the dependent or reliable medical center or dependent dataset.

In order to identify the gap between the current and existing work in the research field related to ECG signal compression, various research papers that originate from IEEE, Web of Science and Science Direct, were chosen and examined.

From the examination of documented research works, it is noted that an extensive study has been executed on the techniques of compression, and its effects on the ECG signal. However, there is a dearth of studies executed on ascertaining the quality of the reconstructed ECG signal towards the offering of the appropriate orientation for forthcoming signal compression quality research. Further challenges that were not stated by the authors through the examination of prior articles are:

1. The need for a technique to perform the compact digital representation for effective storage and better transmission, because uncompressed ECG digital signals need to sufficient memory.
2. Use the minimum number of bits beside the optimum signal quality in order to represent uncompressed ECG signals.
3. Slow data transmission and incompatible with the protection systems, are the main problem of current compression systems

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3.4 Design a Framework Phase

ECG COMDEC specified for the Telemedicine system comprise QRS sending by the patient from the patient, and reconstructing these signals after receiving by the physician. Figure 3.2 illustrates a conventional ECG signal processing system.

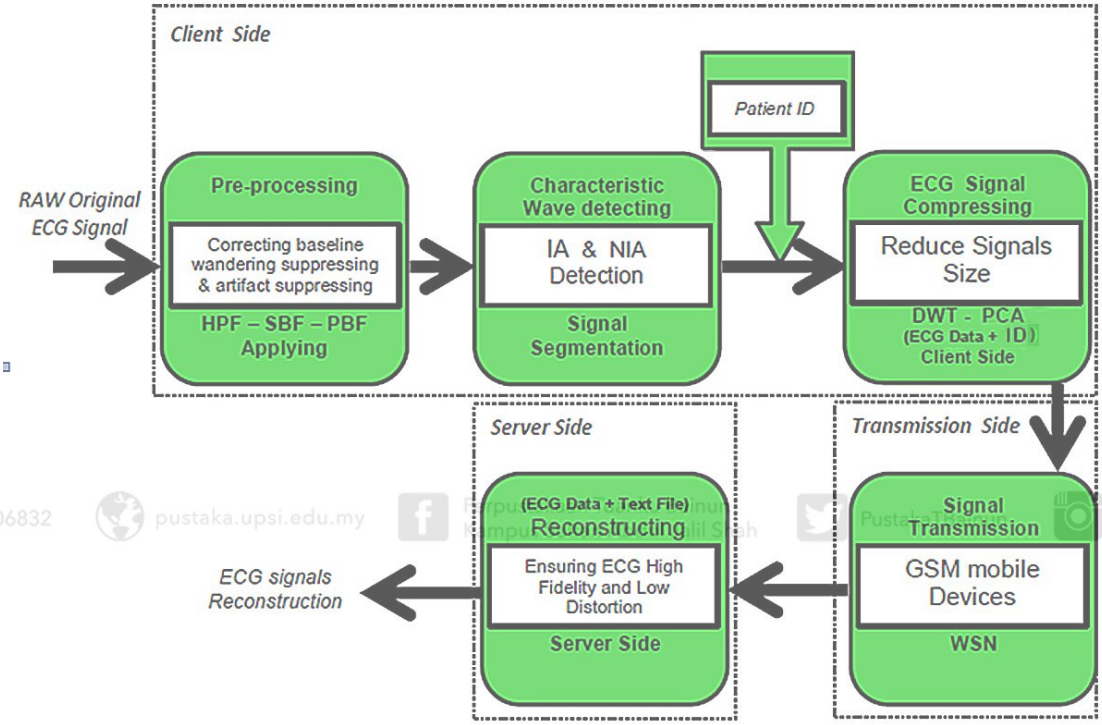


Figure.3.2 A typical ECG COMDEC Framework for a Telemedicine System

3.5 The Implementation of the Proposed Method Scenario

The compression algorithm is constructed of preprocessing of original ECG signal ensued by DWT and PCA, wavelet coefficients energy calibration, in addition to appropriate coefficients thresholding. The ECG data comprising a distinct period of time is initially segregated into blocks, where individual block comprising length N

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samplings. Every individual block is next preprocessed to ready the raw ECG data for additional processing. Next, the discrete time-series data outcome is wavelet transformed into an additional group of arrays.

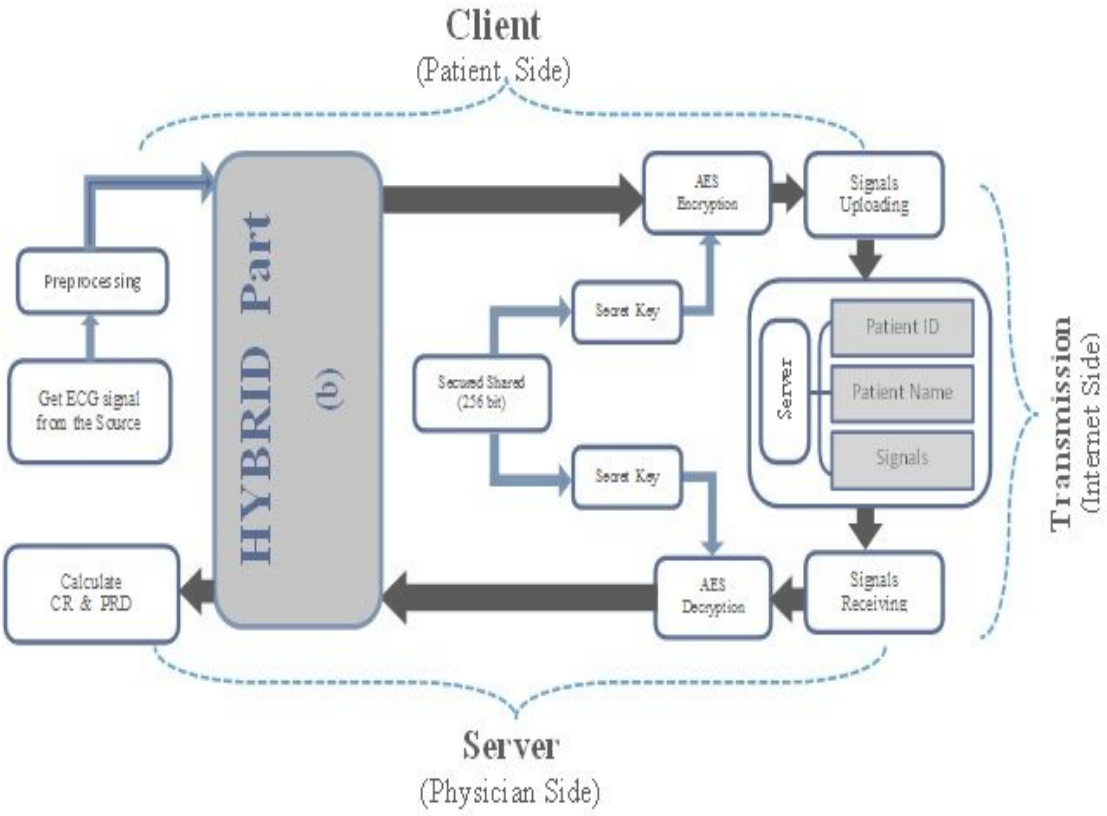
There is a pair of functions executed by the transformation process, it undoes the correlation of the greatly correlated ECG samplings, in addition to assisting in the determination of the degree in the threshold for every individual frequency band according to the energy composition. Ensuing the ECG signal wavelet transformation of the individual block, the degree of the threshold for the individual band is decided according to the wavelet coefficients energy dissemination among the bands. Then, the wavelet coefficients undergo thresholding process with the set threshold level for the varying sub-bands.

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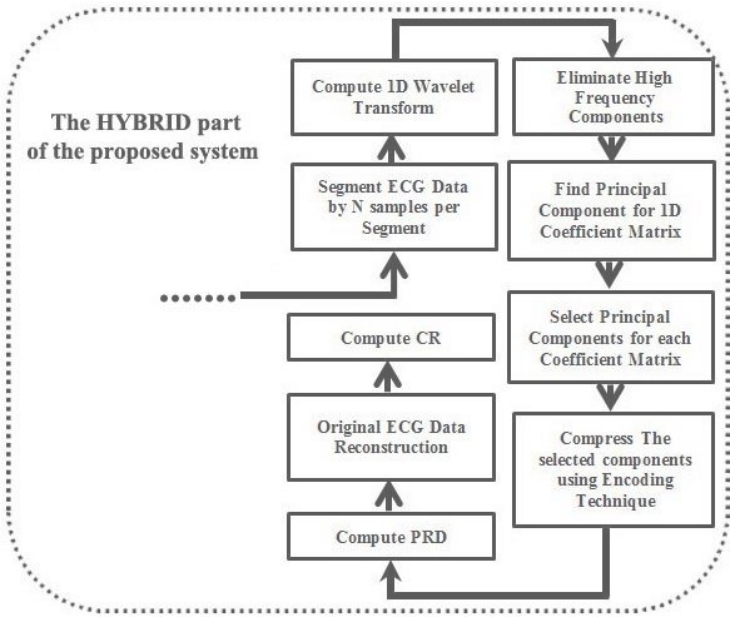
During the ECG signal processing, it is permissible to relinquish several redundant data. It influences the signal's reconstruction quality. The execution of the recommended method scenario stages and the hybrid part are shown in Figure 4.5.

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(a)



(b)

Figure 3.3 (a) The Proposed Method (b) The Hybrid Part

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The recommended compression method's effectiveness may be gauged according to a pair of parameters. The compression ratio (CR) entails the measures which show the ratio betwixt the original is to the ECG file size that has undergone compression. The other parameter entails the PRD, which is utilized for the distortion measures among the original ECG signal and the ECG signal that has undergone reconstruction.

Based on the methodology of the proposed method, the compression algorithm makes use of wavelet and scaling function for decomposition of ECG signal up to level 1. Approximate and detail coefficient obtained at first decomposition level is put for in the second level of decomposition. Thus, ECG signal is decomposed upto 4 levels. The approximated coefficients are represented as the cA1 cA2 cA3 and cA4 and detailed coefficients with cD1 cD2 cD3 and cD4. Approximated coefficient cA4 and detailed coefficient cD4 are stored and inverse discrete wavelet transform (IDWT) is carried out to reconstruct the signal. The computation of DWT and IDWT is done using decomposing low and high pass filters. The reconstruction process is exactly opposite of decomposition. The output of 4th level is input to synthesis filters and IDWT is computed and the process is repeated. Thus, perfect reconstruction of data can be achieved with minimum loss of signal. Signal components with strong characteristics outside of DWT enter the PCA for more compression. And finally, IPCA was applied to reconstruct the signal.

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3.5.1 ECG pre-processing:

The main aim of the pre-processing stage is to remove the baseline wander and power line interference from the ECG signal. Baseline wanders noise is one of the common noise present in a typical ECG signal. It fluctuates the baseline from the reference axis of the ECG signal(Arican & Polat, 2018).

Filters can be used to remove baseline wander noise such as, Haar filter, bandpass filter (BPF), low pass filter(LPF), and High pass filter (HPF) to eliminate various signals artifacts. So I have used two-stage median filter for this particular problem (Ramachandran & Bashyam, 2017). At first, the ECG signal is passed through a median filter with a window size of 200 ms which removes the P waves and QRS complexes. The filtered signal represents the baseline wander which is then subtracted from the ECG recording to get the baseline wander removed ECG signal (Huang et al., 2018).

The filtering of power line interference, high-frequency noise, and baseline wandering is the primary focus of ECG pre-processing. (Hargittai, 2008) (Christov, Dotsinsky, & Daskalov, 1992) indicated that in the initial days, the techniques in noise suppression were founded on band-pass filters. Nonetheless, the characteristic of the band-pass linear filter which possesses constant cut-off frequency, will inevitably result in serious ST-segment distortion and QRS complex.

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Additionally, it is not able to adhere to the time-variant characteristic of ECG signals in an adaptive manner. The utilization of adaptive filter methods is implemented in order to attain noise suppression. In addition, the core algorithms are founded in accordance to the least mean square (LMS) or interactive least square) RLS) (Ferrara & Widrow, 1981). The problems faced in attaining the suitable reference signals have restricted the utilization of these types of techniques.

The expeditious advancement of Wavelet Analysis methodology has resulted in its extensive application in the field of ECG pre-processing, due to favourable achievement in time-frequency characteristic (Khan, Aslam, Zaidi, & Khan, 2011) (Khan et al., 2011). However, it is hard to segregate baseline wandering or high-frequency noise from baseline wandering. It will result in a weak performance in suppressing noise or waveform distortion.

The adoption of techniques founded on Mathematical Morphology (MM) is implemented as an effective nonlinear filter (Khan et al., 2011). The essential notion in rectifying baseline wandering is through the utilization of linear segment element (SE) and high-frequency noise suppression via triangular SE. Nonetheless, the needs of high fidelity cannot be fulfilled by the block effects resulted from the SEs (Qian & Chun_hui, 2002) (Huang et al., 2018).

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3.5.1.1 Building the Normalized Matrix

The normalization of each constituent of matrix A is through the division of each constituent within a column via the total summation of the constituents in the same column in order to generate a normalized pairwise comparison matrix A_{norm}. A_{norm} is the normalized matrix of A(1), where $A(x_{ij})$ is given by Equation (3.1), A_{norm} (aij) such:

$$a_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} xij} \tag{3.1}$$

$$A_{norm} = \begin{pmatrix} a_{11} & a_{12} & \dots & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & \dots & a_{nn} \end{pmatrix}$$

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3.5.1.2 Filtering (Artifact Suppression)

The existence of noise in heart signals might result in inaccurate or erroneous signal categorizations, thus it necessitates measures in suppressing noise. In order to suppress noise, the extensive utilization of classical filters like Gaussian filter, Chebyshev filter, Butterworth filter, and Weiner filter has been implemented. This is due to the fact of the similar disposition for satisfaction fulfillment, where the heart signals occupy within the 20–500 Hz frequency band, and the mentioned filters are capable of suppressing noise that occupies within the chosen frequency band (less than 20 Hz and over 500 Hz). However, the suppression of noises that coincide with the heart signal spectral constituents from the signals is difficult.

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Thus, the recommendation of elaborate filters was forwarded in documentations in order to suppress the aforementioned sort of noises (in-band noise) (Almasi, Shamsollahi, & Senhadji, 2013) (Debbal & Bereksi-Reguig, 2008). Wavelet transform was utilized for the development of filters (Almasi et al., 2013). The transformation signals into wavelet coefficients were generated in the filters. The application of threshold was executed through the elimination of coefficients that are related to noises in order to attain noise suppression. The threshold values still hold a critical part of this approach, even though the wavelet-based filters are capable of suppressing the in-band noise. In the event of the threshold, selection is high, the signal data will be gone, on the other hand, if it is of minor value, there will be insignificant impact towards the signal.

For the purpose of attaining optimum denoising parameter for denoising based on DWT, Messer et al. (Messer, Agzarian, & Abbott, 2001) conducted experiments and discovered that in acquiring the finest outcome, the utilization of level 5 for decomposing signal and soft thresholding with threshold selection rule is the aptest.

The principal purpose of this phase is to boost the signal to ECG signal noise ratio through the emphasis of the QRS complex. The band passes FIR Butterworth filter with pass band frequencies of 5-15 Hz was utilized to dispose of interference of power line and noises of high frequencies from the initial signal. The 5-15Hz is the estimated popular pass band utilized for the maximization of the QRS energy (Tompkins, 1993).

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There are mainly three filters are utilized in this research for artifacts removal, High Pass Filter (HPF) (utilized to remove Baseline Wander Artifact (BWA), Stop Pass Filter (SPF) (used to remove Powerline Interfaces Artifacts (PIA)), and Pass Band Filters (PBF) (used to extract QRS-Complex, improve signal-to-Noise-Ratio (SNR), and attenuate the noise). ECG Raw data are filtered by applying several filters for signal artifacts removals. There are many noise-related with heart signals called artifacts which are:

1. BWA: This artifact removed by HPF.
2. PIA: This artifact removed by SPF.
3. MCA (Muscle Contraction Artifacts): This artifact removed by PBF.
4. PECA (Poor Electrode Contact Artifacts): This artifact removed by PBF.
5. PMA (Patient Movements Artifact): This artifact removed by PBF.

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3.5.1.3 Cardiac Cycle Extraction

The Cardiac Cycle entails a quasi-periodic signal, of which the normal period is within the array of 0.4 to 1.2 seconds. The presentation of certain extraction methods can be found in (Yaniv Zigel, Cohen, & Katz, 2000) (W.-S. Chen, Hsieh, & Yuan, 2004) (Paggetti, Lusini, Varanini, Taddei, & Marchesi, 1994).

The description of a method can be found in (Cohen, Poluta, & Scott-Millar, 1990) for the identification of QRS complex in ECG signal, that is able to offer the detection of a cycle through the utilization of PCG signals due to the characteristics

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of the PCG signal quasi-periodic. The measures to be taken to execute the method are stated by (Mammen & Ramamurthi, 1990)as the following:

Step 1: The extraction of a three-second PCG sample

Step 2: The Cardiac Cycle is within the range of 0.4 to 1.2 seconds. A lag index is constructed within the array of 0.4 to 1.2 seconds with the step of 0.005 seconds.

Step 3: The total sum of the Autocorrelation of the sample with the said lag indexes is ascertained.

Step 4: The location of the maximum peak of this autocorrelation sum is ascertained.

Step 5: The related lag time of the ascertained lag index is the ascertained cardiac cycle.

Step 6: The entire sample is segregated into cycle blocks.

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3.5.1.4 Thresholding

The original signal thresholding decreases data through the retention of the larger amplitude coefficients while inducing a drop in the smaller amplitude coefficients according to the hard or soft thresholding regulations. Additionally, the hard and soft thresholding utilize the ‘kill or keep’ and ‘kill or shrink’ methods accordingly. The methods of hard and soft thresholding are found in (3.2) and (3.3) accordingly.

$$djk = \begin{cases} djk & |djk| \geq T \\ 0 & |djk| < T \end{cases} \qquad (3.2)$$

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$$djk = \begin{cases} sgn(djk) * (|djk| - T), |djk| \geq T, \\ 0\ , \qquad\qquad\qquad |djk| < T \end{cases} \tag{3.3}$$

The selection of the thresholding methods is dependent upon the utilization. According to each strategy, the hard thresholding conserves the amplitudes of the wavelet coefficient on the condition that the dissemination is dense proximal to the threshold whilst, the soft thresholding decreases its amplitude. In the document, the global and local thresholding techniques are prevalent. The majority of signal energy is contained in the approximation coefficients within the wavelet decomposition. The identification of the optimal threshold determination is essential to reassemble the signal as similar as possible to the initial signal. The CR is dependent upon the chosen threshold. Precautionary measures must be adhered to in an ECG signal compression, so as to conserve the pertinent data that are related to diagnostics.

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3.5.1.4.1 The Criterion for Threshold Selection

Towards the achievement of the necessary signal reconstruction, having a threshold guideline is eminent. Configuring the threshold manually is admissible, however, it is not suitable due to the lack of direct relationship with the threshold, in addition to the deficits resulting from it (Manikandan & Dandapat, 2014). Certain threshold criteria choices are:

1. Criterion-1 Keep exclusively the wavelet coefficient that possesses magnitude higher than the threshold.

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2. Criterion-2 The decision of retaining the wavelet coefficient depends on the mediation between the retained coefficients and the distortion measure.

The decisive criteria for ECG signal wavelet-based compression threshold and their limitations (Rajoub, 2002) (R Benzid, Marir, Boussaad, Benyoucef, & Arar, 2003) are the following:

1. The definition of retained energy (RE) as in (Baby, Manikandan, & Soman, 2011) or energy packing efficiency (EPE) in (Rajoub, 2002) are explicated as the following: It entails the energy ratio in the reconstructed signal as to the original signal energy in a specific subband. This is a beneficial criterion for expeditious as well as sluggish wavelet coefficient decay; albeit it is susceptible to noise (Huang et al., 2018).
2. The Fix Number of Coefficients (FNC) or the Percentage Wavelet Coefficients to be Zeroed (PWCZ) (R Benzid et al., 2003) is explained as the following: In this instance, the preservation of the wavelet coefficient are determined in quantity for normal and abnormal signals, thus this might inject distorted reconstructed signal.
3. The measurement of distortion is conducted through the utilization of quality metrics such as PRD and RMSE (Redha Benzid, Marir, & Bouguechal, 2007) (Blanco-Velasco, Cruz-Roldan, Godino-Lorente, & Barner, 2007): Additionally, it is vulnerable to noise.

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In favor of the normal, abnormal and noisy signal, it is essential for a threshold which is robust or not vulnerable to noise. The potential resolution for this is a threshold that is adaptive to the signal(Alam & Gupta, 2014).

3.5.1.5 Segmentation

Let x(n) is the first heart cycle block. The segmentation process can be described as follow:

Step 1: find y(n) = x2(n).

Step 2: Take a window of 50. We place the window at the beginning of the y(n). Take the mean of the window. Place it in Z(k). We slide the window by one sample and do the same operation. This will remove if any spike is present in the sample. If the size of y(n) is m then the size of Z(k) will be

Step 3: Bring a 400-sample window. Position the window at the outset of Z(k). Bring the maximal value and position it into an (i). The 400-sample window is slipped onto the zero overlaps.

Step 4: Bring a 0.07 threshold. The threshold intersecting spots is operated on the mathematical multiplication of 400, in order to obtain the outset and terminal side of S1 and S2.

Step 5: Considering that the entire blocks are in line, with similar size, the blocks in line are wholly segmented.

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3.5.1.5.1 ST-segment analysis of ECG

Variations in the T-wave and ECG ST-level result from Myocardial ischemia. The alteration events on the St-level are helpful in detecting ailments and for diagnosis.

A majority of medically beneficial data are discovered in the gaps and ECG wave amplitudes. The ECG specific traits are in the identification of the peak, in addition to the estimation of the period span.

A typical ECG possesses an S-point that has the initial inflection point following an R-peak. The identification of the S-point is the identification of the modifications in the slope. The role of the ST-slope forms a significant trait in the ECG signal for the purpose of investigating myocardial ischemia. The provision of essential characteristics by the ST-segment elevation and depression have enabled the myocardial ischemia identification.

Commonly, the identification of the ischemic episodes is utilized in the ST-level. The ST-segment elevation and depression alongside the modifications in the T-wave amplitude are able to show the ischemic disease.

The measurement of the ST-level deviation is ascertained through the isoelectric level. The illustration of standard different wave range and segments entailing ECG can be found in Table 3.1.

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Table 3.1

Different Waves and Segments Explanation in the ECG Cycle.

ECG Futures	Amplitude (mV)	Duration	Explanation
P-Wave	0.1-0.25	60-80	It is an ECG wave, as a representation of the activation in sequence, of the left and the right Atria.
PR-Segment	-	50-120	It is the leveled PR-segment that is generally the isoelectric segment betwixt the terminal side of the P-wave and the beginning of the QRS-Complex.
PR-Interval	-	120-2	It is the time span from the start of the P-wave to the start of the QRS-Complex.
QRS-Complex	1	80-120	It is a representative of the concurrent left and right ventricles activations.
ST-Segment	-	80-120	It ensues the QRS-Complex. The spot that it is initiated is known as the J-Junction point.
T-Wave	0.1-0.5	120-160	It is a representation of the time duration for Ventricles recuperation.
ST-Interval	-	320	Its measurement entails the J- point up to the T-Wave terminal side.
QT-Interval	-	300-430	Its measurement entails the initial side of the QRS-Complex to the terminal side of the T-Wave.
RR-Interval	-	600-1200	It entails the period betwixt a pair of sequential R-Waves in the electrocardiogram.

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3.5.2 QRS Complex detection

The accurate division of cardiac cycles is ensured by the pre-processing correcting baseline wandering and noise-suppressing characteristic wave that detects QRS. Additional characteristic wave detection compression decreases the consumption of sources. Reconstruction will ensure that the fidelity will be high and that the distortion will be kept to a minimal of the initial ECG signals. Ensuing the reconstruction 7, it is the initial step prior to compressing of the ECG. It has a significant influence on the usage of the relationship between cardiac cycles or different leads.

For the objective of QRS identification, numerous algorithms were created. Prior to the adoption of Wavelet methods, ECG derivatives and its associated data are principally utilized for the identification of QRS., due to the fact that it can gain entry into the R waves deep slope (Pan & Tompkins, 1985) (Bereksi-Reguig & Slimane, 2000). These types of techniques possess features of reduced calculation with uncomplicated execution, however with reduced favorable rate and invulnerability from noise. The utilization of the QRS detection algorithms founded on Wavelet Methods was the favorite choice in the last ten years. QRS Complex possesses analysis elements that vary between the levels, thus through the selection of level with the local maximum, discerning modulus maximum is simpler which are associated with QRS Complexes (Gautam & Sharmar, 2010) (Chouakri, Bereksi-Reguig, & Taleb-Ahmed, 2011). Nevertheless, QRS Complex that has a steep slope, Wavelet-based methods are incorporated with EMG or additional noise, with a resultant of identification of leak. During the 1980s, Mathematical morphology (MM) methods

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were initiated into the ECG signal processing field (Zidelmal, Amirou, Adnane, & Belouchrani, 2012).

In majority cases, algorithms founded on Mathematical Morphology techniques are implemented prior to the processing to attain a robust nature, and autonomous flexibility for the extraction of morphological data (Chu & Delp, 1989). Consequently, the implementation of the Mathematical Morphology-based QRS identification technique was executed through the utilization of triangle structure elements (SE) (Sun, Chan, & Krishnan, 2002). Goutsias et al. recommended in 2002, a non-linear multi-resolution signal decomposition scheme founded on MM (Trahanias, 1993), that enables the attainment of favorable ECG signals execution, particularly prior to the processing of ECG (P. Zhang, Zhang, Akutagawa, Kinouchi, & Konaka, 2013). The identification of the QRS complex is enabled through a multi-resolution decomposition scheme founded on MM (MDMM) (Goutsias & Heijmans, 2000). Nevertheless, the identification techniques that utilize QRS complex founded on Mathematical Morphology which ascertain steep R peaks readily over gradual slopes.

3.5.3 ECG Signal Compression and Reconstruction

The limitation of power consumption is enabled by an uncomplicated compression algorithm, with a small perversion in the Telemedicine system. It may be categorized into three categories; the first category is the direct compressing technique, like the turning point technique, fan algorithm, and amplitude zero phase encoding method

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and others. However, this technique is unable to attain the appropriate compression ratio (CR) and limited distortion performance of Percentage Root-mean-square Difference (PRD) (Ebrahimzadeh & Azarbad, 2010).

The second category entails the linear transforming domain techniques such as by the utilization of Fourier, Walsh, Kahunen Loeve, discrete cosine, in addition to the wavelet transform in evaluating ECG signals in other domains, where the compression is achieved. The great computing complication at the transmitter, with the added difficulty in achieving equilibrium between CR and PRD, forms the drawbacks (B. R. S. Reddy & Murthy, 1986) (McAuliffe, 1993)

The third category is the parameter extraction method, where ensuing the analysis of the ECG signals is the extraction of the characteristic values and waveform patterns, to be treated as compression outcome. The execution of the reconstruction is for the retrieval of the ECG signals through the said characteristics. However, it is difficult to be executed into the Telemedicine system as the complication in computation is great (Madhukar & Murthy, 1992) (Y Zigel, Cohen, Abu-Ful, Wagshal, & Katz, 1997).

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3.6 The Proposed Techniques for ECG signals Processing

3.6.1 Discrete Wavelet Transform

It is a technique of analyzing a TD signal along with the frequency domain and offers the signal's multi-resolution decomposition. The decomposition of a signal is through the DWT, executed at various *n* levels in varying frequency bands (M. Abo-Zahhad, Ahmed, & Zakaria, 2011).

The decomposition of a signal to become approximation coefficients (low-frequency band processing signal) occurs at the individual level and detailed coefficients (high-frequency band processing signal).

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DWT is operating in signal processing and widely recognized. DWT break-down the signals at several levels for high pass filters and low pass filters (R. Kumar, Kumar, & Pandey, 2013). DWT has turned to a solid technique in biomedical signal processing.

In general, the form of DWT can be described in the as Equations 3.1, and 3.2 respectively, and this equation is called refinement equation, multi-resolution analysis equation, and it depends what kind of filter is used(R. Kumar et al., 2013).

$$\emptyset(t) = \sum_n h[n]\sqrt{2\emptyset}\ (2t - n) \qquad (3.1)$$

$$\varphi(t) = \sum_n h[n]\sqrt{2\emptyset}\ (2t - n) \qquad (3.2)$$

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where:

n: $no.of\ levels$

$\emptyset$: $input\ signals$

h: $filter\ used$

t: $an\ internal\ variable\ counter\ inside\ the\ program$

The crucial task of DWT and inverse DWT (IDWT) are breakdown and restoration of the signals respectively. The breakdown and reconstruction or restoration of the idea is the low pass filtering and high pass filtering additional to the down-sampling and up-sampling utilization respectively. The wavelet breakdown outcome is hierarchically structured breakdowns.

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The breakdown level can be selected based on the preferred cutoff rate (Khorrami & Moavenian, 2010).

The decomposing procedure of a signal x into the approximation and particular components may be materialized to form a filter bank, ensued by a factor with the value of 2, as illustrated in Figure 3.3. The impulse responses h[n] (low-pass filter) alongside the g[n] (high-pass filter) are obtained through scaling function and mother wavelet. The production of a novel wavelet decomposition interpretation manifested in the form of the signal x which is split into frequency bands. The hierarchical decomposition entails the output from the low-pass filter h, which comprise the input to a novel pair of filters. The resultant outcome is a multilevel decomposition (Abdelmounim et al., 2014). The optimal decomposition levels are dependent on the extent of the signal. In the instance of an N-sized signal, the

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maximum decomposition level is log2(N). The decomposition procedure of signal x is reversible, on the condition that the approximation in addition to the detailed information is available, the reconstruction of x is then possible.

The materialization of procedure entails the Up-Sampling (by a factor of 2), ensued by the filtration of the resulting signals, plus the addition of the filter results. The impulse responses h' and g' are obtained from h and g. Provided that the bands utilized in the decomposition exceed the quantity of two bands, the structure is required to be cascaded. (Khorrami & Moavenian, 2010)

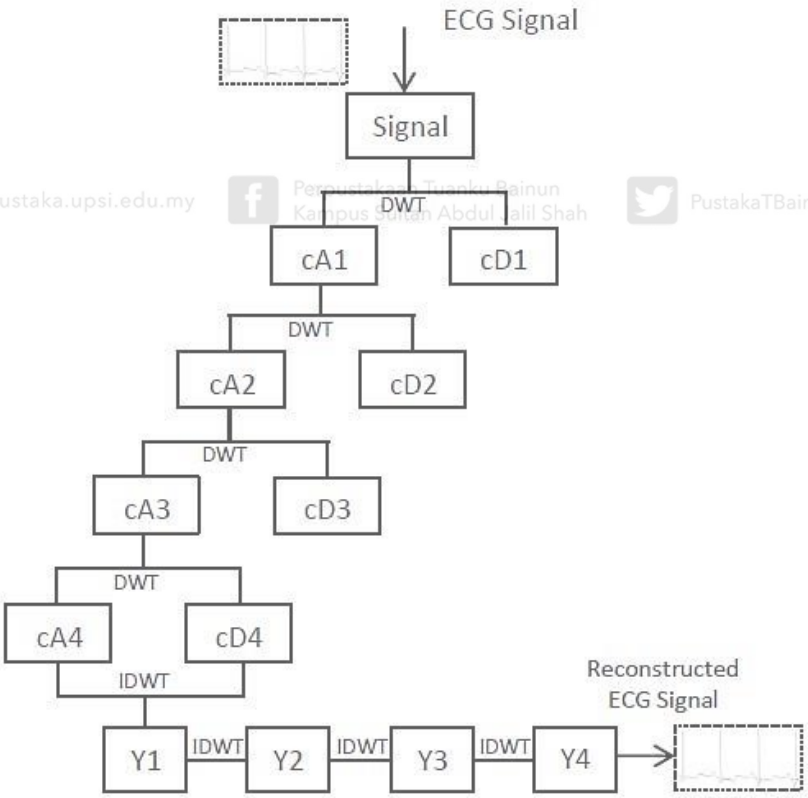


Figure 3.4 DWT Based Compression and Reconstruction.

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3.6.2 Principal Components Analysis (PCA)

The core aim of the PCA is to recapitulate the autonomous variables into a lesser set of consequential variables so that the early component has the highest variance, then the subsequent component as well as followed by the third component continuously. The first numerous Principal Components (PC) display the data information. Therefore, even if a few components are lost, the original data will be well remodeled (Candès, Li, Ma, & Wright, 2011).

PCA explicates the variance-covariance structure belonging to a set of variables via the linear compositions of the said variables.

Take into consideration a random vector Y= (y1, y2,……..,yp) the covariance matrix of Y is C, with eigen values as λ1, λ2, λ3…..... λp of which λ1 ≥λ2≥…….≥ λp in addition the eigenvector and eigen values pairs to be (V1,λ1),(V2, λ2)…(Vp, λp). The PCs are linear combination (x1,x2,…xp) with the changed coordinate system of p random variables (y1, y2,……Yp) (Jolliffe, 1986).

The first PC x1 is a linear combination of (y1,y2,……yp), that is

x1 = (a11y1+a12y2+……..+a1pyp x1=(a11y1+a12y2+.....a1pyp)

$$x1 = \sum_{j=1}^{p} a1jyj\, a_1^T y \qquad (3.3)$$

PC x1 has its variance maximized with the condition that the constraint is a1Ta1= 1. PCA finds the optimal weight vector (a11,a12,…….a1p) and associated

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variance of x1, and is denoted as λ1. The second PC entails ascertaining a second weight vector (a21,a22,……,a2p) such that the variance x2 is maximized, and that a2Ta2 = 1 with associated value denoted by λ2.

The continuation of the procedure may proceed up to the required number of components as variables are configured. The total of the variance of the principal component is equivalent to the total of the original variables variance (Sharma, Danadapat, & Mahanta, 2012) such that

$$\sum_{j=1}^{p} \lambda j = \sum_{j=1}^{p} \sigma_j^2 \qquad (3.4)$$

$$1 = \sum_{j=1}^{p} a1jyj\ a_1^T y \ldots\ldots\ldots\ldots Xp = a_{p1}^{j} yj \qquad (3.5)$$

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The ensuing simplified steps are implemented onto the PCA based ECG compression analysis (Castells et al., 2007):

Step 1: Obtain ECG data MIT-BIH Arrhythmia data base.

Step 2: The mean of ECG data is calculated.

Step 3: The mean is subtracted from ECG data.

Step 4: The covariance matrix of subtracting data is calculated.

Step5: The eigenvectors and Eigenvalues of the covariance matrix are calculated.

Step 6: The Eigenvalues and Eigen vectors are sorted, on the basis of the highest Eigenvalues.

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Step 7: Principal components are chosen and form ECG feature vectors = [eig1;eig2;eig3;……eigL].

Step 8: The new ECG data are derived, i.e. New data =[Row Feature Vector]T*[Row data adjust].

Step 9: The compression ratio (CR) is calculated.

Contrarily, for the purpose of analyzing the Principal component (Castells, Laguna, Sornmo, Bollmann, & Roig, 2007):

1. The covariance matrix of the data is calculated.
2. Ascertain the eigenvalue
3. Ascertain the eigenvector
4. The projecton of the data points is obtained in the direction of the Principal Components.

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PCA is a technique that utilizes statistics, where the extraction of the principle linear factors that form the fundamentals of the motion of a respective multivariate data series are implemented as specific vectors. PCA aims to reduce the dimensions that do not compromise of precision significantly. Its objectives are to attain the summary of the data alongside numerous independent variables into more minor derived variable sets in which case, the first component possesses maximum variance, ensued by the second, and then by the third and continuously after that. Hence, the initial couple of principal constituents exemplify the data information. Thus, the reconstruction of the initial data can be superbly, notwithstanding the eventuality that the last couple of constituents are missing.

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3.6.3 DWT Method-Choosing Reasons

Wavelet transform is used to eliminate these noise artifacts. A discrete wavelet transform (DWT) is any wavelet transform, for which the wavelets are discretely sampled. The reason behind using discrete wavelet transform is ECG signal can be decomposed without any loss of information and energy. results in approximate coefficients (CA), and detailed coefficients (CD). Li represents the length of first approximate coefficient and all detailed coefficients. The sampling frequency of the ECG signal from PTB database is known i.e. 1000Hz [5]. By substituting in Nyquist Criterion, the maximum frequency of the ECG signal is calculated to be 500Hz. The levels of decomposition are restricted to 10, since the 10th level decomposition gives an approximate coefficient of 0-0.48; this frequency range contains the baseline wandering frequencies (0-0.48) [5]. The important features of the ECG signal are within 60Hz and the baseline wandering frequencies are within 0-0.48Hz [3]. Hence coefficients containing these frequencies are forced to zero and then the coefficients are reconstructed back to obtain filtered signal. Figure 3 shows the preprocessed signal. There are many reasons to recruitment PCA in ECG signal compression:

1. A powerful and influential method in the compression process.
2. It's a lossy method but this lossy has little impact on the ECG signal data
3. By this method we can compress the ECG signal to several levels.
4. DWT is perfect for non- stationary signals compression (i.e. ECG signals that cut up data into different scale-shift components).

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5. ECG compression methods based on DWT have been shown to perform well.
6. Basically it gives multiple resolution decomposition of a signal.
7. DWT is faster and maps quickly to the sub-band coding of signals.

3.6.4 PCA Method-Choosing Reasons

PCA is an important tool used in many fields of ECG signal analysis. The most common PCA applications include: ECG compression, heart rate detection, artifact noise suppression, classification, obtaining indications, signal separation and others [89,90,93–95].PCA has also been used to derive orthogonal leads. There are many reasons to recruitment PCA in ECG signal compression:

8. PCA of multiscale multivariate matrices of multichannel signals helps reduce dimension and remove redundant information present in signals.
9. A comprehensive technique for dimensionality reduction applied on multivariate analysis.
10. Optimal and linear scheme for compressing a set of high dimensional vectors into a set of lower dimensional vectors and then reconstructing.
11. Utilized to computes the model parameters directly from the data, for example by diagonalising the sample covariance.
12. Utilized in many applications that include data compression, image processing, visualisation, exploratory data analysis, pattern recognition and time series prediction.

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13. Conventional PCA has been applied for data reduction, noise elimination, beat detection, classification, signal separation, and feature extraction, for physiological signals.
14. PCA is a statistical method designed to compress information from many correlated variables into a smaller number of linearly non-correlated principal components.

3.6.5 Hybrid Method Based DWT and PCA (COMDEC)

The following steps illustrate the hybrid method of ECG signal compression which based on DWT and PCA:

Algorithm 3.1: The Hybrid algorithm of DWT and PCA
Goal: Cardiac Signals Compression Input: Original ECG Signals (Input the target signal) Output: Compressed ECG Signals (Getting the desired signal)
Initial Step: Get ECG Data from the Source (Real-time or Dataset). Normalize the ECG Signals (Normalization means: capacitance change) Normalize the signal to compare with other signals) (Normalization means scaling the signals at identical levels). DWT Stages Applying DWT Transform on ECG Signals. DWT transform the Signals to Four Bands (HH, HL, LH, and LL).

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Element the High-Frequency Components (Applying various filters).

Low-Frequency Components (In LL band) adopted as the samples for the PCA Stage.

PCA Stage

Compute the mean of all samples.

Subtract the mean from all samples.

Compute the covariance matrix.

Compute the eigenvectors ∨ and eigenvalues ≺ of the covariance matrix.

Sort eigenvectors according to their corresponding eigenvalues

Select the eigenvectors that have the largest eigenvalues.

Forming Principal Components.

The final data obtained.

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Figure 3.5 Hybrid Algorithm of DWT and PCA

Based on the previous algorithm, the following steps show the pseudocode for the proposed method (COMDEC) based on DWT and PCA.

PsedoCode 3.1 DWT and PCA COMDEC
Goal: Steps for Cardiac Signals Compression Based on DWT and PCA Input: Original ECG Signals (Input the target signal) Output: Compressed ECG Signals by DWT and Forward to PCA

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```
Initial Step:
/* Pseudo-code for the Computation of the DWT*/
Load Signal File();/*input signal file */
Initialize Input matrix (); /* Input matrix */
Convolution with scaling vector ();/* FDWT */
Down sample by_2 ();
/*Thresholding */
Initialize threshold value ();
Calculate dead value ();
Perform thresholding on the transform
matrix();
Up sample by_2 ();
Convolution with wavelet vectors () ;
/*IDWT*/
Next;
/* Pseudo-code for the Computation of the PCA*/
sig_data = ReadFile();
sig_data = Math.Round(sig_data, 2);
haar.Forward(sig_data);
for I = 0 to sig_data.length / 2
        dwt_data[I] = sig_data[I];
end for
convert dwt_sig to 2D array
pca = new PrincipalComponentAnalysis(2D_dwt_sig);
pca.Compute();
components = pca.Transform(2D_dwt_sig, Threshold);
/*IPCA*/
```

Figure 3.6 Psedocode Steps of Hybrid Method DWT and PCA

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3.7 Other ECG Signal Compression Techniques

The collection of an ECG signal is implemented through the internet database, which is utilized in this research pertaining to compression performance. Being a component of the assessment, a sample of the heart in 333 Hz was acquired, where the signal sampling rate is 333 Hz. The ensuing table 1 illustrates the performance comparison of the data compression metrics utilized. It should be noted that the compression ratio is advisable to be high, whereas the PRD is advisable to be low, towards the attainment of improved outcomes, which is signal fidelity dependent. Quality DWT is offered by CR, however, it has low PRD value. Thus, in this respect, DWT demonstrates the optimal compression method. The description of FFT, DCT, DCT-II, DST, and DWT transformations for ECG data compression is covered in this section.

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3.7.1 Fast Fourier Transform (FFT)

The attainment of frequency – amplitude of a represented signal is realized through the utilization of a Fourier transform.

$$X(K) = \sum_{n=0}^{N-1} x(n) e^{-j\pi nk/N} \qquad (1.1)$$

where k=0,1,2,3,4,5,…..N-1, X(K) is the FFT of a signal (x).

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The FFT compression algorithm entails:

1. The separation of the ECG constituents into three constituents x, y, z.
2. The seeking of the frequency and time between the two samples.
3. The ascertainment of the FFT of ECG signal and determination of the FFT coefficients (before compression) =0, increment the counter A, in the event that it is between +25 to-25 and assign to index=0.
4. The checking for FFT coefficients (after compression) =0, increase the Counter B.
5. The calculation of inverse FFT and decompression error is plotted.
6. The calculation of the compression ratio CR and PRD.

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The failure to provide data pertaining to the precise position of the frequency component in time. Forms the constraints of FFT.

The diadvantages of FFT can be summarized as follows:

1. The FFT technique also has limitation in its performance. FFT is a complex transform which requires operating on an imaginary number and especial algorithm.
2. It is a complex exponential that defines a complex sinusoid with frequency.

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3.7.2 Discrete Cosine Transform (DCT)

The restoration of the signal data is enabled by DCT compression in a limited number of DCT coefficients. The definition of a DCT of a discrete signal f (u), u=0, 1. , N-1 is as follows:

$$F(U) = w(u) \sum_{x=0}^{N-1} f(u) \cos(^{\mu(2u+1)x}\,)/2N \qquad (1.2)$$

where u = 0, 1, 2…N-1,

and , w (u) = √1/N, for u= 0 ; = √2/N, for u ≠ 0

The algorithm of DCT Compression is:

1. The separation of the ECG constituents into three constituents x, y, z.
2. Ascertaining the frequency and time between two samples.
3. Ascertaining the DCT of ECG signal, in addition to detecting DCT coefficients (prior to compressing procedure) =0, increment the counter A in the event that it is between +0.22 to -0.22 with the allocation to Index=0.
4. Ascertaining DCT coefficients (ensuing compressing procedure) =0,
5. Increment Counter B.
6. Calculating the inverse of DCT and plotting the decompression, error.
7. Calculating the compression ratio CR and PRD.

The occurrence of distortion in a majority of the reconstructed signal forms the constraints for DCT(Pandey et al., 2016).

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The major disadvantage of DCT is that the basic functions are very long. If a transform coefficient is quantized, the effect is visible throughout the signal. This does not create much problem for the low-frequency coefficients that are coded with higher precision. However, the high-frequency coefficients are coarsely quantized, and hence the reconstructed quality of the signal at the edges will have poor quality.

3.7.3 Discrete sine Transform (DST)

DST, as part of Fourier-relate transform, is akin to Discrete Fourier Transform (DFT), however, it is strictly a genuine matrix. DST is identical to the DFT imaginary parts, and of an estimation double the length, functioning on real data that has odd symmetry (considering the Fourier transform of a real and odd function as imaginary and odd), in which case certain variations of the input and/or output data are moved by half a sample.

Similar to other Fourier-related transform, DSTs specify a function or a signal in the form of a sum of sinusoids possessing varying frequencies and amplitudes. Comparable to the DFT in similarity, a DST runs on a function in a limited quantity of discrete data points scope. There is an apparent difference between a DST and a DFT. Discrete Sine Transform utilizes sine functions solely, whereas DFT utilizes uses both cosines and sines (in complex exponentials manifestations).
Nevertheless, the perceptible distinction is the result of different boundary conditions than the DFT or other related transforms as implicated by a DST.

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$$X(K) = \sum_{n=0}^{N-1} x_n \, sin\left\{\frac{\pi}{N+1}(n+1)(k+1)\right\} \qquad (1.3)$$

The algorithm of DST compression entails :

1. The separation of the ECG constituents into three elements x, y, z.
2. Ascertain the frequency and time between the two samples.
3. Ascertain the DST of ECG signal, and identify the DST
4. Coefficients (prior to the compression procedure) =0, increment the counter A if it is between +15 to-15 and allocate to Index=0.
5. Identification of the DST coefficients (ensuing the compression) = 0, increment the Counter B.
6. The calculation of inverse DST and the plotting of the decompression error.
7. The calculation of the compression ratio CR and PRD.

3.7.4 Discrete Cosine Transform-II (DCT-II)

The pervasive discrete cosine transform variant is the type-II DCT. It is customarily a real, orthogonal (unitary), linear transformation defined by the ensuing equation.

$$C_k = \sqrt{2 - \delta k/N \sum_{n=0}^{N-1} X_n} \cos\left[\frac{\pi}{n\left(n+\frac{1}{2}\right)K}\right] \qquad (1.4)$$

For N inputs and N outputs.

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It is perceived as a unique DFT with real inputs of specific symmetry. All FFT algorithm for the DFT heads directly to a respective fast algorithm for the DCT-II seamlessly through the rejection of redundant operations.

The algorithm DCT-II compression entails:

1. Partitioning of the data sequence x in Nb consecutive blocks bi, I =0, 1, ¼, Nb-1, individually with Lb samples.
2. The computation of DCT computation per individual block.
3. The quantization of the DCT coefficients.
4. The Lossless encoding of the quantized DCT coefficients(Pandey et al., 2016).

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3.8 ECG Data COMDEC

The proposed algorithm COMDEC is divided into the following main sections:

1. Data compression Protocol Based on System Infrastructure.
2. Data Encryption
3. Data Transmission and Reception Protocol.
4. Data Decryption
5. Data reconstruction Protocol Based on System Infrastructure.

The explanations for the compression, transmission-reception, and reconstruction algorithms are in the enduing sections in sequential order.

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3.8.1 Data Compression Protocol Based on System infrastructure

Our recommended algorithm as we had suggested in (Jalaleddine et al., 1990) can be seen in its implementation here, in the compression of the ECG data. The extraction of eight ECG samples from the digitized input ECG data file are implemented and kept in an array.

0.060	0	0.007	-0.001	0.007	0.020	0.15	-0.040
e[0]	e[1]	e[2]	e[]	e[4]	e[5]	e[6]	e[7]

Each of the elements is examined for its sign in this array. Thus, for each positive numeral, a binary zero (0) is allocated, and for each negative numeral, a binary (1) is appropriated as sign byte for the comparable ‘Voltage’ value.

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The corresponding decimal of the binary string is utilized as the sign byte of the respective 8 -‘Voltage’ values. Adhering this order of principle, thus the constituents from the array (e[]), a string such as ‘‘00010001’’ may be attained, of which having the decimal equivalence of 17. It will be regarded as the sign byte of those comparable respective eight ‘Voltage’ values.

Henceforth, the conversion of the sign byte is executed into its related respective ASCII character, ensued by the output file printing it. The following phase entails the ascertainment of the maximum numeral from the array. By utilizing the maximum number, the generation of a common amplification factor for the eight voltage values is implemented in a manner that ensures that following the

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multiplication operation, the integer portion of the voltage values will individually be either less than or equals to nine (9). As an exemplar, when the maximum number is 0.060, the amplification factor will be 150 (9/0.060). The amplified voltage values (solely the integer part) will be kept in an array. Ensuing the amplification, the numbers of e [ ] array are expected to be as indicated in the table below and kept in another array c [ ].

9	0	1	0	1	3	2	6
c[0]	c[1]	c[2]	c[3]	c[4]	c[5]	c[6]	c[7]

The aggregation of the 8 amplified 'Voltage' values into merely four only are due to the ensuing rationale:

Each number at the c[i] location is multiplied by 10, and added with the number at the c[i + 1] location, in addition, the printing of the corresponding ASCII character of the aggregated integers will occur. The counter, ''I'' (which is at the beginning is configured to zero) will be incremented by 2. Hence, at this point the entire 8 integers are grouped into merely four.

9	0	1	0	1	3	2	6
90		10		13		26	

In the event that any of the grouped integers turns into 10 or 13 or 26, they will be transformed into 11, 14 and 27 accordingly, due to the fact that during the data reconstruction, the compiler will consider the features as End of File (EOF), thus the program will be ceased.

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Thus, specifically, the printing of 90, 11, 14 and 27 will be printed in the output file in their corresponding ASCII character will occur. In accordance with the specified exemplars in the compression technique, a string like ◄Z♂♫←û will appear in the output file as shown below.

17	90	11	14	27	0	150

◄	Z	♂	♫	←	space	û

The printing of each group of 4-clustered integers, in addition to additional related data such as ‘sign-byte’, ‘Amplification factor’ and others, in their relative ASCII characters by retaining the format as follow:

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Sign Byte	Four Grouped integer	rs	Amplification Factor

Each group of characters is segregated relative to the other by an ‘ENTER’ character. In instances when there merely exist eight-time values and eight voltage values which are segregated by TAB delimiter, within the initial ECG data file, the file size turns into 102 bytes (minimal).

Meanwhile, there exist just 7 ASCII characters (8 bit) in the compressed file. Hence, the compressed file size is only 7 byte. Thus, the minimum compression ratio attainable through the utilization of this algorithm is 14.57. The continuous repetitive implementation of the aforementioned algorithm will be maintained up to the point when the entire ECG samples are compressed.

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The Data Compression Protocol is segregated into three sections:

1. The detection of the R peak
2. The Lossy compression in the QRS regions (LCQRS), and
3. The Lossy compression in the nation-QRS regions (LCNQR).

The descriptions of all of the parts are done individually in the ensuing sections.

3.8.1.1 R-peak Detection Algorithm

During the time of acquiring a signal, the ECG samples are influenced by numerous high-frequency noise sources. Inclusive of power-line interference and electrosurgical noise.In order to eliminate these high-frequency noises, the utilization of standard filtering software preceding additional processes.

Initially, the utilization of low pass filter or the removal of noises above 100 Hz (Khorrami & Moavenian, 2010), After that, in order to eliminate the disturbances in the power line, a 60 Hz notch filter is utilized. The development of the R peak detection algorithm id a traditional differentiation based methodology. The subtraction of all ECG sample is operated on all that is before them, acting as a high pass filtering. The sample voltage difference will be proximal to zero in the flat or zero regions entailing P wave, T wave, ST segment, and others, meanwhile, the production of higher differences will occur in the QRS regions, due to the regions being in constant maximum slope.

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The enhancement of high-frequency regions is executed through the squaring of the differentiated voltage values. The specific samples are marked, in which case the square of the difference turns into maximal value within a window size 0.25 s. Here, the assumption is that the rate of the heart will remain below 240 and not surpass. Pertaining the original ECG signal, the maximal amplitude is sought within 160 ms (the maximal QRS time span) (Lee, Kim, & Lee, 2011). In addition, the maximum squared location produces a true R peak. Figure 3 illustrates the identified R peaks of specific ECG data files. On the correct detection. At the instance when R-peaks are accurately identified, the detection of QRS regions will be effortless, through the extraction of of160 samples near the R-peak (eighty samples prior to and subsequently following the R-peak). Seeing that the maximal QRS time span is 160 ms (Lee et al., 2011), it is compulsory that the Q and S point to be found within this duration. Hence, contrary to the detection of Q and S points apart from the entire 160 samples surrounding individual R peak are taken. The development of numerous techniques for the detection of ECG peaks (Miaou & Yen, 2000) (Miaou & Chao, 2005). It is the norm in the T-peak detection algorithm for combining differentiation and squaring methods.

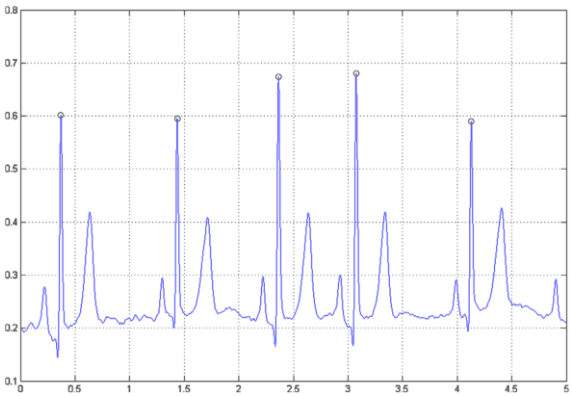


Figure 3.7 Detected R-Peaks of file S0305, Lead I, Normal (first 5000 Samples).

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3.8.1.2 Lossy Compression with QRS Regions (LCQRS)

The algorithm that we recommended can be found in (Bendifallah, Benzid, & Boulemden, 2011) who utilized it in the compression of the ECG data of QRS regions in a lossless way. The 'Voltage' values of the QRS region are solely the ones extracted from the ECG data input. In gaining lesser numbers, which in turn will result in enhanced compression, the alternative array is created that possesses the difference of every voltage and those before it. The identification of each constituent in the array is examined. A binary zero() is designated for each positive number, and a binary (1) is designated as a sign bit for the associated 'Voltage' value for each negative number. The utilization of the decimal that is equal to the binary string will be executed as sign byte of the associated 8 'Voltage' values. However, challenges will surface, in the event that the matching ASCII of whatsoever sign byte turns into certain unique characters such as 10 (line feed), 13 (carriage return), 26 (substitution) or 255 (blank).

During the reconstructing of the data phase, values 13, 26 and 255 are perceived as 'End of File (EOF)' by the compiler, the termination of the program is executed. Hence, the numbers are substituted with alternative appropriate numbers, on the condition that an additional bit such as 'rs' is transmitted with the sign byte.

Henceforth, every individual number in the array undergoes a mathematical multiplication operation with 1000, as within the standard ECG database, in addition to the PTB-DB, the documented voltages are until three decimals points. The integers that had gone through amplification will be normalized, retaining certain logical

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conditions and normalization constant is situated in a variable such as 'ii'. Lastly, the printing of 'rs' and 'ii' in character form are executed. In order to mark the location of the crucial numbers 255, 10, 13 and 26 in the amplified integer values, 3 variables are extracted such as q, r, and s.

The amplified integers are clustered in order to retain certain crucial logical criteria. Three kinds of grouping are taken into consideration, which is the following:

(1) Forward Grouping,

(2) Reverse Grouping,

(3) No Grouping.

The 3 variables that denote the locations of the groupings are k,z and u. The printing of an individual set of clustered or not clustered as a group 'Voltage' values in addition with alternative needed data such as sign byte, k, z, u, and others in the output file in the character version in the following manner:

Sign-Bit	Grouped/Ungrouped Integers	k	z	u	r	s	q	rs+ii

Each character set is segregated mutually via the 'ENTER' character. The repetitive execution of the afore-mentioned LCQRS algorithm, till the entire ECG QRS region samples, undergo compression.

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3.8.1.3 Lossy Compression with Non-QRS Regions (LCNQRS)

In attaining a lossy compression that is acceptable, the recommended algorithm that we suggested can be found in (Nunes & Nait-Ali, 2005), is executed in a differed manner.

On observation, the sixteen ECG samples are derived from the non-QRS section. It is an established knowledge that typical clinical bandwidth is 0.05–100 Hz for the 12-lead clinical ECG (Khorrami & Moavenian, 2010), although the 1 kHz sampling frequency utilized in PTB-DB is adequate. Hence, prior to the compression of the samples, the sampling frequency of the regions is decreased to one and a half (500 Hz).

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The Nyquist principle will not be breached by this. Thus, from amongst the 16 samples, just eight other optional samples such as 1st, 3rd, 5th, and others are derived for processing at a later stage and kept in an array. The generating of Sign-byte procedures is similar for the 8 voltage values as explicated in Section 2.1.2. The ensuing stage is the derivation of the maximum number from the respective array. The generation of a common amplification factor for those eight voltage values is enabled through the utilization of the maximum number, such that ensuing the multiplication, the integer portion of every individual voltage values shall be smaller than or equals to nine (9).

An appendix is appended to the algorithm. Here, the 8 amplified ‘Voltage’ values are clustered to only four groups. In the event that whatsoever grouped integer

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turns into 10 or 13 or 26, their transformation into 11, 14 and 27 will be executed accordingly, as an aversion endeavor from the aforementioned issues. The printing of their associated ASCII characters of the entire set of four grouped integers, in addition to alternative related data such as ‘sign-byte’, ‘rs’, in addition to the ‘Amplification factor’ will be executed retaining the ensuing forms. Each individual character set is segregated by an ‘ENTER’ character.

The execution of the aforementioned LCNQRS algorithm shall be done recurrently up to a point where the entire non-QRS region ECG samples have undergone the process of compression.

Sign-bit	Four Grouped Integers	rs	Amplification factor

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3.8.2 Advanced Encryption Standard (AES Encryption)

The employment of a symmetric key encryption method is recommended by the suggested model, in which case, the encryption and decryption of the secret key are executed. The deployment of the chosen algorithm of this scheme is AES, for the signals.

Prior to the signal encryption, the 256-bit key was utilized by us as an encryption key. At the initiation of the Cipher, the copying of the input is implemented onto the state array through the utilization of conventions. Ensuing the start of a spherical Key expansion, the transformation of the state array is

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implemented via the actualization of a spherical function 10, 12, or 14 instances which are contingent upon the key lengths 128, 256, 256 bit, the recommended application utilized the 10 rounds function using a 128-bit key time span. The final spherical hardly different from the first Nr -1 rounds, The entire Nr rounds are equal except for the last spherical, which is inclusive of the Mix Columns() transformation. This is ensued by the replication of the last state onto the output.

The parameters of the round function are created through the utilization of a key schedule consisting of a single dimension array that has 4-byte words determining the usage of the Key Expansion customary practice. In the expansion of the AES key and encrypting process, the ensuing pseudo-codes are implemented.

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Algorithm 3.2: AES Key Expansion
Goal: Generate a series of round keys from the cipher key Input: key Output: round_key (,)

Initial Step:
Nb ← 4 (data blocks are about 128 bits)
Nk ← 4 (number of double words in the cipher key)
Nr ← number of rounds in the cipher (Nr=10 for AES-128)
temp← temporary value
Step 1:
For all i do where{0 ≤ i<Nk}
w[i] = word(key(4*i), key(4*i+1), key(4*i+2), key(4*i+3))
End for
Step 2 :
For all i do where{Nk ≤ i <(Nb * (Nr+1))}
temp = w[i-1]
If i mod Nk = 0 then
temp = SubWord(RotWord(temp)) xorRcon(i/Nk)
End if
w(i)= w(i-Nk) xor temp
End for
round_key ← w
Step 3 : Return (round_key)

Figure 3.8 AES Key Expansion Algorithm

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Algorithm 3.3: AES Encryption
Goal: Text Encryption Input: plaintext Output: ciphertext
Initial Step: Nb ← 4 (data blocks are of 128 bits) Nr← number of rounds in the cipher (Nr=10 for AES-128) Step 1: State ←plain_text AddRoundKey(state, w(0, Nb-1)) Step 2: For all round do where{1≤ round <Nr} SubBytes(state) ShiftRows(state) MixColumns(state) AddRoundKey(state, w (round * Nb, (round+1)*Nb-1)) End for Step 3: SubBytes(state) ShiftRows(state) AddRoundKey(state, w[Nr*Nb, (Nr+1)*Nb-1]) cipher_text ← state Step 4: Return (cipher_text)

Figure 3.9 AES Encryption Algorithm

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3.8.3 Data Transmission and Reception Protocol

There are solely ASCII contained in the compressed data file. Hence, the Data file system that is founded on GSM is utilized in the transmission of the data that has undergone the compression process. Towards achieving this end, an ‘i-300’ GSM transmitter is utilized.

The transmission of a mobile messaging system (MMS) is able to transmit just 7-bit ASCII characters (0-127), however, the compressed file possesses 8-bit ASCII characters (0-255) only.

Hence, each compressed file character is transformed into a pair of appropriate 7-bit ASCII characters. Even though 7-bit ASCII characters are supported by mobile message, however, not every single one are supported. The transmission of certain particular 7-bit characters is not able to be executed via the GSM modem. As an exemplar, the entire characters between 0-31, 91 ([ ), 92 (\), 93 ( ]), 96 (`), 127 (⌂) in addition to several others are not transmittable via the GSM modem.

Hence, it is imperative to avert the respective mentioned characters. The description of the rule to be adhered to tansform the 8-bit to 7-bit ASCII character is extremely easy, and its description is below. A pair of variables is taken and termed as ‘MSB’ and ‘LSB’. In instances when any 8-bit ASCII is less than or equals to 31, the MSB is determined to be 32, in addition, the LSB is determined to be ’32 + that 8-bit ASCII’.

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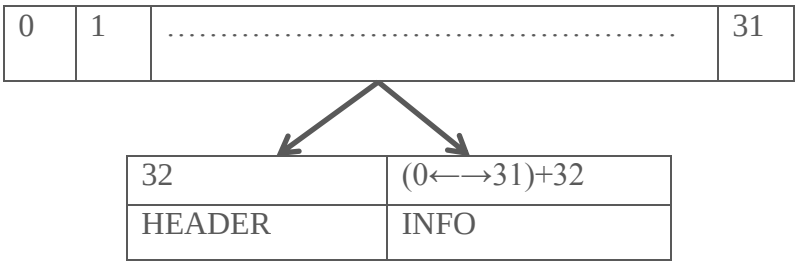


Figure *3.10* ASCII Byte with Details

Hence, the MSB and LSB maintain its value of greater than 31 constantly, which in turn enables its transmission via the data file. An alternative varying method is utilized for the numbers ranging from 32 to 126. The MSB is fixed in number 33, in addition to the retention of LSB is similar to the initial number, for the aforementioned numbers.

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---

X= any 8-bit ASCII (0-255)

if X <= 31

'MSB'=32 and 'LSB' = X+32.

If X > 31 and X<= 127

'MSB'=33 and 'LSB' = same as original.

A nearly similar rule is adhered to for the remainder of the 8-bit ASCII (128-255). Notably, it is imperative that not only MSB but also LSB are obligated to be located under valid 7-bit ASCII characters, additionally the composite of the pair needs to be specific for each 8-bit ASCII character. Lastly, the printing of MSB and LSB within the output file is executed.

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The development of an algorithm that divides the data file which had undergone compression into several minor data files individually consisting of 140 7-bit ASCII characters. From the 140 characters, the first character is kept especially for the patient ID, the second and third characters are kept for the data file numbers, in addition, the remainder of the 137 characters are utilized for the transmission of the ECG data that had undergone compression.

The transmission of the minor data files via an 'i-300' GSM transmitter connected via the computer's serial port. The utilization of the Standard Attention Commands or AT commands is initiated to interact with the transmitter. The beginning file number and Patient ID is from number 32.

During the embedment of the patient ID and file number within the body of the information, the concurrent transmission of the numerous data from the patient is executed to a specific mobile gadget. Additionally, in the event that certain file is transferred prior to its due time, or due to certain network issues, or due to other circumstances, the data reconstruction is unaffected in these cases. on the recipients side, the transmission of each received data is from the mobile device are implemented to the computer through USB cable, Bluetooth technology or through other methods.

The entire files are linked by a reverse algorithm at the recipient's side in accordance with their file number of a specific patient ID, transforming the 7-bit ASCII characters to 8-bit ASCII characters and creates a distinct file for another patient ID. Every individual file is similar to its initial data file that had undergone

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compression. A transformation of a7-bit to 8-bit ASCII is executed utilizing the reverse algorithm only. Let us say that a variable 'Y' for example, is taken to keep 8-bit ASCII characters. The conversion algorithm is provided below.

---

if MSB = = 32
Y = LSB – 32
if MSB = = 33
Y = LSB
if MSB = = 34
Y = LSB + 6.

3.8.4 AES Decryption

Additionally, on the decryption side, we used the key (256 bit) period. The inversion of the encryption process entails the decryption process. The decryption procedure of an AES cipher textual content is just like the encryption procedure inside the opposite order. Each spherical consists of the 4 procedures (InvShiftRows, InvSubBytes, AddRoundKey, and InvMixColumns) except the final round that not carry out the InvMixColumns. For the reason that sub-processes in every round are backward way, the encryption and decryption algorithms have to be independently performed, despite the reality that they are closely related. The following algorithm shows the AES decryption.

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Algorithm 3.4: AES Decryption
Goal: Decrypt cipher text Input: cipher_text Output: plain_text
Initial Step: Nb ← 4 (data blocks are of 128 bits) Nr← number of rounds in the cipher (Nr=10 for AES-128) Step 1: State ←cipher_text AddRoundKey(state, w(Nr*Nb, (Nr+1)*Nb-1)) Step 2: For all round do where{ Nr> round ≥1}decrement round by 1 InvShiftRows(state) InvSubBytes(state) AddRoundKey(state, w(round*Nb, (round+1)*Nb-1)) InvMixColumns(state) End for Step 3: InvShiftRows(state) InvSubBytes(state) AddRoundKey(state, w(0, Nb-1)) plain_text← state Step 4: Return (plain_text)

Figure 3.11 AES Decryption Algorithm

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3.8.5 Data Reconstruction Protocol Based on System infrastructure

Ensuing the procedures of transmitting and receiving, there is a necessity to retrieve the original ECG signal for the adoption of the resolution process pertaining to the status of the patient's heart. The entire data reconstruction algorithm is segregated into two sections:

1. Lossy data reconstruction in the QRS region (LRQRS) by applied IPCA, and
2. Lossy data reconstruction in the non-QRS region (LRNQRS) by applying IDWT.

The development of the reconstruction algorithm through the utilization of the reverse logic of compression only. A set of character is derived from the data file that had undergone compression, consecutively. Characters with equal values as ASCII are kept in an array, with the ensuing of the application of the reconstruction algorithm onto them in the restoration procedure of the original eight 'Voltage' values.

The 'Sign byte' of the 8-voltage values are contained in the first ASCII value. The ensuing 4 ASCII values are the integers that have undergone the grouping process, and the 6^{th} and 7^{th} ASCII values are 'rs' with the 'Amplification factor' accordingly. The sign byte', 'rs', and 'Amplification factor' are kept distinctly apart in varying variables from the seven ASCII values, where the grouped integers are ungrouped through the utilization of the reverse logic of grouping.

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The entire ungrouped number undergo division by the 'Amplification factor' and after that is kept within another array. Next, the conversion of the sign-byte into its related 8-bit binary equivalent is executed. On the occasion that there is a bit that is '1'in the binary string, hence the related ungrouped integer will undergo a multiplication of (-1).

The reconstructed ECG voltage values are contained in this array. Let us say that variable 'x' is declared and is initialized with zero (0). The original ECG signal sampling frequency is 1kHz for PTD-DB ECG the database. Hence, the sampling interval is 0.001 second. Thus for every iteration, the incrementation of 'x' will be executed by the sampling interval and the printing of the reconstructed ECG samples is implemented.

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3.8.5.1 Lossy Data Reconstruction in QRS Region (LRQRS)

The development of the LRQRS algorithm is implemented through the utilization of the LCQRS reverse logic.

A single set of ASCII characters of the ECG data file that had undergone compression is taken and the equivalent ASCII values are kept in an array, which is ensued by the application of the decompression algorithm onto the ASCII values.

The 'Sign-byte' is altered according to the value stored in 'rs'. The generation of the original eight 'Voltage' values occurs from the remainder of the ASCII values.

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The location of forward, reverse, no grouping, accordingly is defined by the variables ‘k’, ‘z’, and ‘u’. The utilization of the reverse logic grouping is executed for the ungrouping. Hence, ‘r’, ‘s’ and ‘q’ variables are being considered.

The indication of the location of the critical numbers 10, 13, 26 and 255 within the ungrouped data is through the mentioned variables. Thus, the retrieval of original values is implemented. The modification of ungrouped integers is aptly executed through the utilization of the variable ‘ii’. The ensuing phase entails the conversion of the sign-byte into its related 8-bit binary equivalence. On the occasion that a binary string is ‘1’, the related ungrouped integer will undergo a multiplication of (-1). Here, each number undergoes a division of 1000. In order to obtain the original, every individual number undergoes an addition to the prior value. The storage of the new values is executed in another array. The array is equivalent to the original ECG voltage values. Let us say that the declaration of a variable ‘x’ is done and is initialized with zero.

3.8.5.2 Lossy Data Reconstruction in Non-QRS Region (LRNQRS)

The development of the LRNQRS algorithm is implemented through the utilization of the reverse logic of LCNQRS. A set of character is derived from the data file that has undergone compression, sequentially.

The values that are equal to ASCII of the 7 characters are deposited in an array. The ungrouping of the Grouped integers is executed by utilizing the reverse

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logic of grouping in the Section 2.1.3 description. Here, all the ungrouped number undergo a division by the 'Amplification factor' and kept in an array, let us say d [] array. The procedure of the sign byte regeneration is similar as explained in Section 2.3.1. The sampling frequency was decreased to one half in Section 2.1.3,

Here, the generation of a 16 'voltage' values are executed from the eight, in order to monitor the reconstructed ECG signal sampling frequency with its original. Towards the achievement of this end, the average of each pair of neighboring numbers is inserted in between. The illustration of the function can be viewed below. Once again, the incrementation of 'x' will be executed by the sampling interval with the printing of the reconstructed ECG samples.

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3.9 Telemedicine Definition

Briefly, telemedicine entails healthcare-related services delivery for example examination, therapy, and remedy advice, in addition to distance-learning for professionals, utilizing Information and Communication Technologies (ICTS) to connect the distance between patients and healthcare providers that is physical in nature. Within the industrialized world, the increasing perception towards telemedicine as a feasible instrument for healthcare services delivery in the countryside, non-urban and distant areas (Bagchi, 2006).

Taking into account the wellbeing delivery constraints in developing countries, the notion of the probability of remote medical services delivery is an

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appealing notion. Additionally, the idea of telemedicine usage in developing countries has been disseminated for an extensive period of time (Wright, 1998). Findings from several pilot studies have revealed the possibility of telemedicine for supporting health care providers in developing countries. Nevertheless, there are negligible exemplars of telemedicine networks that are consistent external of a pilot project and which have incorporated additional pilot sites (Blaya, Fraser, & Holt, 2010)(Bhalerao et al., 2019).

3.9.1 Telemedicine Tiers

The current generation of personal health monitoring systems goes beyond earlier generations in performing sensing, data collection and standalone data analysis using companion software on a personal computing device. Now, personal health monitoring devices in the so-called ―telemedicine [4] are often but a part of a more comprehensive ―disease management system. A typical disease management system augments the sensing and data collection functions of earlier generation devices with an array of on-line services, including data aggregation, data visualization and analysis functions for users' personal physicians, and alerting functions which are able to notify caregivers of emergent conditions detected in the telemetry from a patient. This type of telemedicine system can, thus, be represented in three-tier architecture (Marcolino, 2019).

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3.9.1.1 The Patient-Related Tier

The cardiac signals on the patient's side are collecting, compressed, and transmission via mobile device openly linked with a patient and allotted continuously for a heartbeat:

1. The ECG signal from the patient or arranges an uncompressed signal can be captured from the database.
2. Where the signals are acquired from patients, unpolluted these signals from the artifacts, and take away the signals mean and stabilize them. In the course of selecting the signals from a database, take away its mean and stabilize the resulting mean-removed signals. All the measured signals are removed from a live database.
3. Divide the signal into the interesting-area (IA) (QRS-complex and possibly P-T-and U-waves), and the non-interesting-area (NIA) (the remaining parts representing the difference between the original ECG signal and IA).
4. Compress the area of IA using DWT lossy compression technique and adopting appropriate thresholding and quantization.
5. Use the AES algorithm to encode the quantized residuals resulting from into binary stream.
6. Use PCA lossy compression technique in order to compress NIA with the appropriate thresholding applying as well as quantization.
7. Encode the resulting quantized wavelet coefficients into a binary stream by the AES algorithm .

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8. Data packetize (data collection process in packets according to a particular protocol), and provide to data header (data header is a binary structure that may be present at the beginning of a short message in the GSM short message service and does not contain any text, but specifies how the message is formatted and processed) (Marcolino, 2019).

3.9.1.2 The Gateway-Related Tier

The heart signals in the gateway side are gathered to be delivered through one of the obtainable wireless networks:

1. Guarantee network connection by using the internet and wireless transmission services.
2. Move the data header, the binary stream of IA and that of NIA respectively.

3.9.1.3 The Recipient-Related Tier

On the server-side, open the compressed cardiac signals, analyzed and examined by the physician, and send the decision of the physician unchanged as received.

1. Depacketized the gained binary stream is into the header, for both IA and NIA respectively.

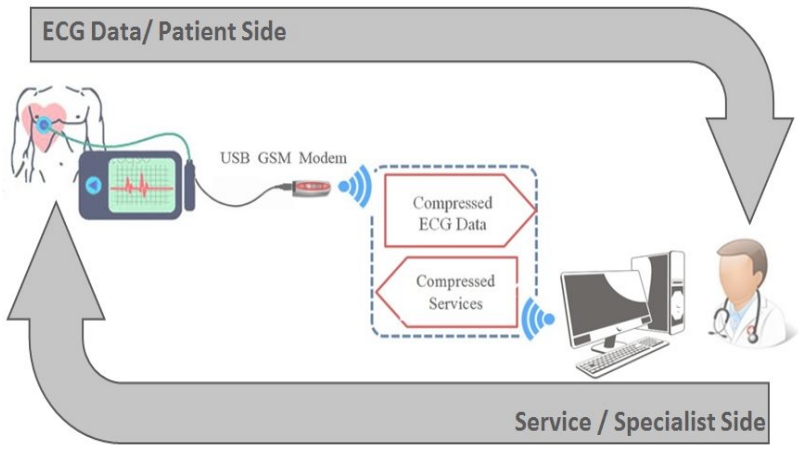
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2. Binary streams of the header are converting to essential information important to reconstruct the ECG signal (like, IA stream length, NIA stream length wave start and wave end in both IA and NIA).
3. The IA and NIA binary streams parts are converting to the comparable decimal numbers.
4. Apply inverse DWT for the IA part and apply inverse PCA transform for the NIA part.
5. The resulting time-domain IA and NIA are decomposing into QRS-waves, T-waves, P-waves, U-waves, and isoelectric-waves.6) Use the obtained data in the above steps to reconstruct the ECG signal.
6. Compute CR and the error measures for comparison and evaluation.
7. Produce the reconstructed ECG signal for medical investigation (Marcolino, 2019).

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Figure 3.11 gives a brief explanation for the patient side and physician side and how the ECG signal moves from client to server with remotely processing.



A Figure 3.12 COMDEC Signal Transmission Between Client / Server

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3.9.2 Client-Related Side

Cardiac signaling is the vital signal in the human being through which the patient's chronic heart disease is evaluated. Consequently, the compilation of RAW ECG signal on the patient's end is executed via a Holter machine (that is immediately linked to the mobile gadget), is a kind of mobile electrocardiography appliance, that is portable for the examination and tracking of cardiac electrical activities and cardiovascular conditions round-the-clock daily, via the ECG data that are compiled constantly. These raw heart signals are transferred to the mobile device in order to send to the physician after preprocessing that including artifacts removal, signals normalization, and signals encoding. The denoising of the ECG signal is performed during the preprocessing stage (Marcolino, 2019).

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Then the signals are normalized and encoded. When the ECG signal is ready for transmission, compress the ECG signal by using the proposed method DWT and PCA sending wirelessly to the server-side.

3.9.3 Server-Related Side

At the second side (server-side), the compressed ECG signal is received, ECG signal decompression and decryption. The signals sent to the appropriate physician for the patient assessment. After the physician evaluates the patient's condition through the received cardiac signal, The physician sends the appropriate procedure

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to the patient by sending a compressed service describing the patient's correct procedure according to the patient's health status (self-assessment of the patient). The proposed method consists of three tires according to the Figure 3.12, namely:

1. Patient tier.
2. Gateway (transmission) tier.
3. Physician tier.

The procedure of compression passes in two directions with four modules. The modules are arranged as Figure 3.13 works well, and any halt in any unit of these modules will lead to the system completely halted.

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The framework of the research consists of three main tiers: the first called the patient tier, the second is the gateway tier, and the third is the physicians' tier. The patient's tier (also called Client), is the main tier from which the system begins. They are closely related to the patient's life. The patient sends ECG signals constantly by collecting them in a device (Holter machine) designated for these purposes to the physician after preprocessing.

There are several problems related to this part which patient needs to continue monitoring the state of health (24/7), and this monitoring is increasing for a chronic diseases patients which require a continuous and uninterrupted transmission of ECG signal from the patient to the physician. The gateway tier also called (mobile part) or any dedicated device designed ECG signal transmission from the patient to the physician. This part has a strong relationship with the bandwidth. Bandwidth is the

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space on which mobile devices operate to transmit digital signals from source to destination. Slow is the main problem of bandwidth, due to increasing requests of patients upon the server, which requires expansion bandwidth continuously to accommodate the huge volume of these increasing requests. The last part is the physician part (also called the server part), which is receiving requests from patients to obtain a better medical service from the physician.

The patients' requests increasing leads to the accumulation of those requests inside the server (the data become big data), which impede physicians' work and delayed medical services accessible to patients, especially critical and urgent cases. To overcome these problems, the better solution is to build an efficient algorithm for ECG signal compression sent from the patient to the server to ensure patients get medical services as soon as possible without delay. The framework in figure 3.12 explains what mentioned above.

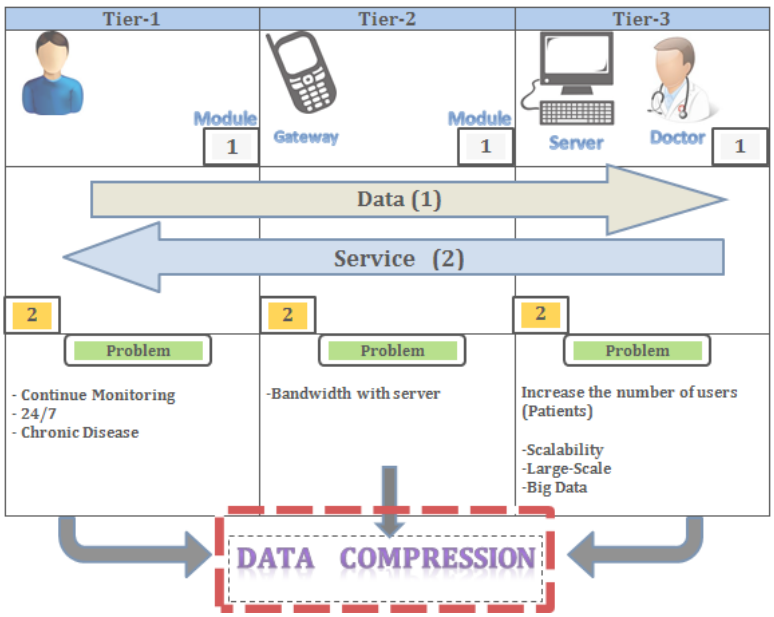


Figure 3.13 Framework of ECG Signal Compression via Telemedicine

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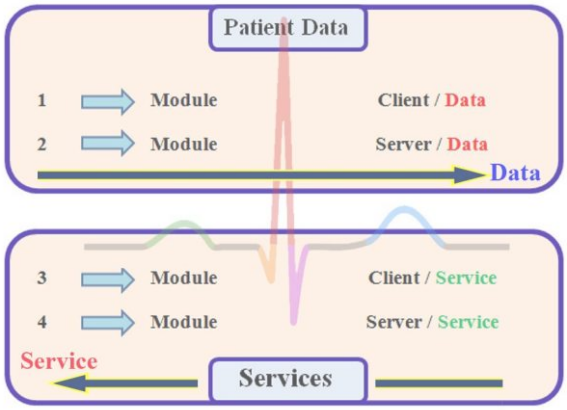


Figure 3.14 Four Modules of the Proposed Compression System

Based on Fig. 3.13, the proposed compression system modules can be described as follows. Any of these four units will stop functioning and cause the system to stop completely.

1. The first direction: Patient's Data
    A) Modules (Client/Data): The client (patient) send data as a compressed file consists of ECG data with a text file to the server (physician) in order to get service.
    B) Modules (Server/Data): The server (physician) received the compressed file from the client (Patient), decompressed file, analysis content, and prepare to send service to the client (Patient).
2. The second direction: Services
    A) Modules (Client/Service): The client (patient) received the service as a compressed file coming from the server (physician) based on the data sent to the server (physician).
    B) Modules (Server/Service): The server (physician) sends service to the client (patient) based on received data from the client (patient).

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3.10 The Client / Server Model

There is a possibility for the concurrent initiation of a pair of network applications, however, it is unrealistic in necessitating it. Hence, it is logical to construct a transmission network applications utilized for exchanges to carry out sequential complementary network operations, instead of concurrently. Firstly, execution is carried out by the server, which then pauses to accept; the user or customer carries out the second move, and transmits the first network packet to the server. Ensuing the initial communications, the client or the server can, either way, is enabled in transmitting and accepting data (Toll, 1995)(Raeiatibanadkooki et al., 2016).



Figure 3.15 A Client Initiate Communications to a Server

3.10.1 Outline of a TCP Server

Step 1: Constructing a socket: Constructing a socket in a certain manner is the same as creating a file. It constructs a file descriptor and reverts it from the function call. This file descriptor is later utilized for reading and writing, in addition to usage with alternative socket functions

int socket(int family, int type, int protocol);

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Step 2: Binding an address and port number: The association of an IP address and port number to our application is needed. A user/customer who wishes to link to our server requires the aforementioned details for the purpose of connecting to our server. The distinction betwixt this function and the connect () function of the customer should be noted. The connect function defines a remote/distant address which the customer wishes to connect to. In this instance, the server is sending specification to the bind function a local IP address belonging to one of its Network Interfaces alongside a local port number.

*int bind(int socket_file_descriptor, const struct sockaddr * LocalAddress, socklen_t AddressLength);*

Step 3: Listening for incoming connections Binding is akin to expecting a particular phone to ring.

int listen(int socket_file_descriptor, int backlog);

Step 4: Accepting a connection. The accept() function reverts a new socket file descriptor in order to read and write to the customer. The utilization of the original file descriptor is frequently for listening to new incoming connections. The discussions of servers will be explicated more in an ensuing lab later.

*int accept (int socket_file_descriptor, struct sockaddr * ClientAddress, socklen_t *addrlen);*

3.10.2 Outline of a TCP Client

Step 1: Construction of a socket: similar to the server.

Step 2: Binding a socket: This step is not needed for a client, as the function of a bind (and will be discussed in detail in the server section) linking a port number to

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the application. In the event that this step is omitted with a TCP client, the automatic assignment of a non-permanent port number occurs, thus it is advisable to omit this step for the client.

Step 3: Connecting to a Server:

*int connect (int socket_file_descriptor, const struct sockaddr *ServerAddress, socklen_t AddressLength);*

After the creation of a socket and the address structure of the server that needs to be connected have been filled, the ensuing step is the connection to the server. The execution with the connect function is as listed previously to this.

Step 4: The discussion on Reading and Writing to the socket will ensue soon

Step 5: The closing of the socket will ensue soon

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3.11 Signals Converted Process

Generally, a digital filter system consists of an analog to digital converter (for input signal sampling), microprocessor (specialized digital signal processor for signal processing), and for converting digital signal back to analog, a digital-to-analog converter.

After initialization is over, the program will generate start pulse After cardiac signal initialization is over, the program will generate a start pulse for ADC to take a signal. The data available from the ADC requires filtering of high-frequency noise like artifacts and low frequency 50 Hz line frequency noise from the signals.

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First, the output of ADC is passed through the function subprogram of low pass filter to filter the line frequency noise. The attenuation of the signal is improved in this filtering to have signal amplitude to have a desire level. Then the output data of low pass filters are passed through high pass filter to remove muscular artifacts noise. The digital filter can easily be implemented in software by providing a filter coefficient in the lookup table of the program. The digitized data from the high pass filter is then transmitted to start the compression phase.

The function of DAC is described as:

1. Processed digital signal y[n].
2. Continuous signal representation ya(nT).
3. Low-pass filtered continuous signal y(t).

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3.11.1 Analog to Digital Signal Conversion

To capture and analyze the signals, the general processing steps are required. First, the signal must be captured. Since the signal is electrical in nature, electrodes are used to capture the same. The signal from the electrodes is usually very small in amplitude, an ECG range from 10 micro-Volts to 5 milli-Volts. Amplification is necessary to bring the amplitude of the signal into the range of the analog to digital converter. The amplification should be done as close to the signal source as possible to prevent any degradation of the signal. If there are several input signals to be converted, an analog multiplexer is needed to route each signal to the A/D converter. In order to minimize

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aliasing, a low pass filter is often used to band-limit the signal prior to sampling. A sample and hold circuit is required at the input to the A/D converter to hold the analog signal at a constant value during the conversion process. Finally, the A/D converter changes the analog voltage stored by the sample and hold circuit to a digital representation.

3.11.2 Digital to Analog Signal Conversion

A digital-to-analog converter (DAC or D/A) is a system that converts a digital signal into an analog signal. An analog-to-digital converter (ADC) performs the reverse function. There are several DAC architectures; the suitability of a DAC for a particular application is determined by figures of merit including resolution, maximum sampling frequency, and others.

Digital-to-analog conversion can degrade a signal, so a DAC should be specified that has insignificant errors in terms of the application. DACs are commonly used to convert digital data streams into analog signals. They are also used in televisions and mobile phones to convert digital video data into analog video signals which connect to the screen drivers to display monochrome or color images. These two applications use DACs at opposite ends of the frequency/resolution trade-off. A DAC converts an abstract finite-precision number (usually a fixed-point binary number) into a physical quantity (Murmann, B, 2008).

In particular, DACs are often used to convert finite-precision time series data to a continually varying physical signal. An ideal DAC converts the abstract numbers into

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a conceptual sequence of impulses that are then processed by a reconstruction filter using some form of interpolation to fill in data between the impulses.

A conventional practical DAC converts the numbers into a piecewise constant function made up of a sequence of rectangular functions that are modeled with the zero-order hold. Other DAC methods (such as those based on delta-sigma modulation) produce a pulse-density modulated output that can be similarly filtered to produce a smoothly varying signal. A DAC can reconstruct the original signal from the sampled data provided that its bandwidth meets certain requirements. Digital sampling introduces quantization error that manifests as low-level noise in the reconstructed signal (Murmann, B, 2008). Figure 3.15 illustrates a general form for analog to digital (A/D) signal and digital to analog conversion (D/A) system.

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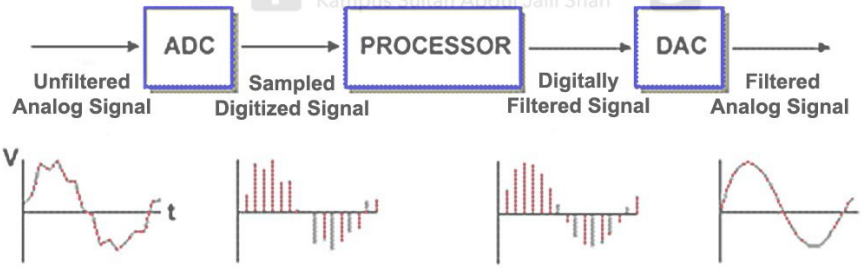


Figure 3.16 A General (A/D and D/A) Signal Conversion System

3.12 The Equipment of ECG Data

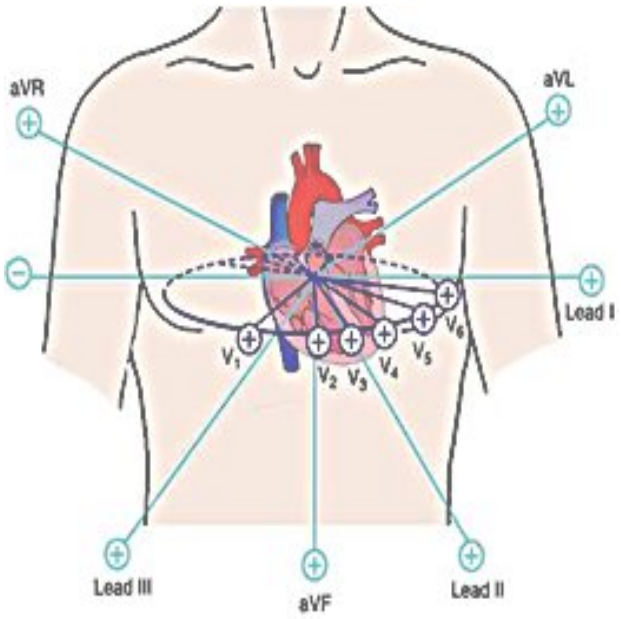
3.12.1 ECG lead placement

A conventional clinical ECG consists of twelve varying vectors termed as leads. A lead is a particular cardiac electrical activity view. The acquisition of the electrical

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perspective is derived from a couple of electrodes positioned at varying orientations on the exterior of the body; generating numerous ECG vectors. The ensuing Figure 3.16 illustrates examples of the orientations of 12 ECG leads.



A *Figure 3.17* The 12 ECG Leads Directions on Patient Body

Out of the twelve leads, six leads are situated on the parallel plane of the human torso. Meanwhile, the remainder six leads are situated in perspective of the heart, at the vertical plane of the body. A typical 12-leads ECG consists of six-chest leads, three-bipolar limb leads and three-unipolar limb leads.

3.12.2 Bipolar Limb Leads

Leads I, II, and III are part of this group. (Gertsch (2004) espoused that the acquisition of leads is through the electrodes with opposing polarity (+ve and -ve).

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1. Lead I: the distinction betwixt the left arm (LA) electrode potential and right arm (RA) electrode potential (LA-RA).
2. Lead II: the distinction betwixt the left leg (LL) electrode potential and right arm (RA) electrode potential (LL-RA).
3. Lead III: the distinction betwixt the left leg (LL) electrode potential and left arm (LA) electrode potential (LL-LA).

3.12.3 A Unipolar Limb Leads

The unipolar limb leads are inclusive of Augmented Vector Left (aVL), Augmented Vector Right (aVR) and Augmented Vector Foot (aVF). Gertsch (2004) noted that the acquisition of these leads through a unique positive electrode, in addition to the reference point that situated at the core of the heart's electric field. The aforementioned listed unipolar limb leads are explicated as the following:

1. aVR: The potential difference between the Right Arm Electrode and the core of the heart's electric field.
2. aVL: The potential difference between Left Arm Electrode and the core of the heart's electric field.

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3. aVF: The prospective difference between the Left Leg and the core of the heart's electric field.

3.12.4 ECG Sensor

ECG is the representation of the contracting activity of the heart over time. It is utilized for the short-term evaluation of cardiovascular diseases, especially in patients with chronic heart problems. The ECG signal provides valuable information about the regularity and frequency of the heartbeat. These signals are used in the diagnosis of heart disease . The user can use the 3 or 12 derivation system. The ECG 3 lead system is proper for patients in nursing homes because of their ability to wear.

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However, the telecardiology services provision to the cardiologist experts for clear, rapid and efficient interpretation enabling purpose is still a major challenge. The analysis of the ECG signal is studied and widely utilized due to it reflects an important indicator of the diagnosis of many heart diseases.

According to , the detection of the ECG device plays a key role in the diagnosis of heart disease. The cardiac cycle on an ECG contains P-QRS-T waves. The performance of the heart can be determined by the interval values and the amplitude of the P-QRS-T segment. There are many proposed schemes based on signal analysis techniques to detect characteristics of the ECG signal. In this section, we also analyze the type and number of ECG functions that can be used in the remote prioritization and classification method, as explained below:

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1. QRS complex: considered as one of the most significant characteristic waveforms of the ECG, it can be used as a reference for the cardiac cycle . The QRS wave group indicates the rapid depolarization of the left ventricle. As the atria develop in the tissues of the left and right ventricular muscles, the QRS complex is much higher than the amplitude of the P wave . The QRS normal value varies from 0.06 s to 0.12 s and all values outside that range. The beaches are considered abnormal
2. PR Interval: determines if a range is regular or irregular.
3. ST-segment: the section between the QRS complex end to the T wave end is called the ST interval . The section from the QRS complex end until the T wave beginning is called the ST segment. Elevation in the ST segment is considered an abnormal value . Azmi0
4. Rhythm: demonstrate the importance of using this function in the monitoring and diagnosis of heart disease in all ECG studies.

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3.13 ECG Signal Dataset

The experimental ECG database In our research work has been used namely MIT-BIH Arrhythmia database.

MIT-BIH Arrhythmia Database is one of the major contributions of cooperative work of Bostonos Israel Hospital Laboratory and MIT laboratory. This database was introduced in 1980 and the main contents of this database are standard material for evaluation of arrhythmia detection. This database consists 48 half hours

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two-channel ECG recording obtained from 47 subjects studied by the BIH Arrhythmia Laboratory. The sampling frequency of the digitized ECG signal is 360 samples per second per second with 11-bit resolution over a 10 mV range.

The extensive utilization of ECGs is due to the cheap and nonintrusive ways of examining the physiological aspects of the heart. The MIT-BIH arrhythmia dataset records are utilized in the work for the recommended techniques performance appraisal. The MIT-BIH arrhythmia dataset is favored and extensively utilized dataset sets, as individual record has the annotations of doctors, with the assured labeling of the entire signal anomalies and normal beat events. The ECG signals were attained from the PhysioNet service (http://www.physionet.org) from the MIT-BIH arrhythmia dataset. It entails an independent dataset and is showcased in the major part of literary publications.

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This dataset contains 48 records with two channels in each record of heartbeats. The duration of each record is slightly more than 30 minutes. Each record is sampled at 360 Hz with a resolution of 11 bits. The recordings were done at BIH Arrhythmia Laboratory between 1975 and 1979 (George B. Moody, 2010).

The proposed method works effectively on live cardiac data that are taken from the patient directly. We have actually tried it on a special Holter Machine to collect cardiac signals directly from patient. However, due to the high prices of these devices, it prevented continuing to take live signals directly, and we were satisfied with examining this system on the cardiac signals taken from the website.

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The created dataset with ECG signals is described below:

3.13.1 MIT-BIH Arrhythmia Dataset (middle)

Selected input: record mitdb/117 (MLII), annotator atr, from [0:00.000] to [0:10.000].

3.13.2 Sudden Cardiac Death Holter Dataset (side)

Selected input: record sddb/30 (ECG), annotator ari, from [12:00:00.000] to [12:00:10.000].

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3.13.3 MIT-BIH Noise (Artifacts) Stress Test Dataset (nstdb)

Selected input: record nstdb/118e00 (MLII), annotator atr, from [0:00.000] to [0:10.000].

3.13.4 Non-Invasive Fetal ECG Dataset (nifecgdb)

Selected input: record nifecgdb/ecgca102.edf (Thorax_1), annotator QRS, from [21:49:00.000 16/11/2003] to [21:49:10.000 16/11/2003].

3.13.5 PTB Diagnostic ECG Dataset (ptbdb)

Selected input: record ptbdb/patient001/s0010_re (i), from [0:00.000] to [0:10.000].

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3.14 The Normal ECG Waves, Time Intervals, and its Normal Variants

A typical cardiac cycle is portrayed by a typical ECG signal. The typical ECG of a single cardiac cycle together with its constituents and features is depicted in Figure 3.17.

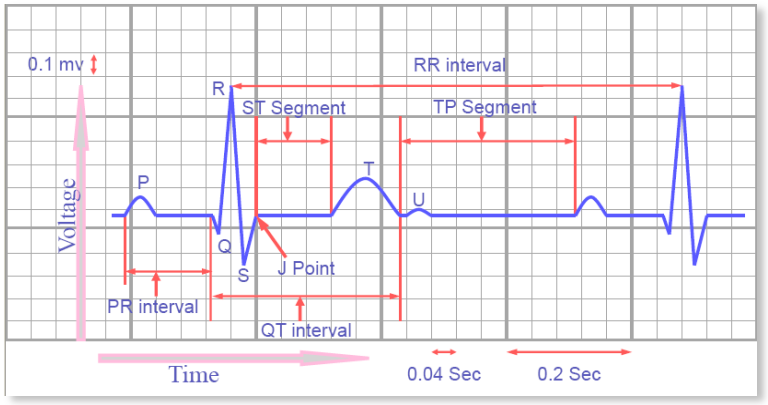


Figure 3.18 Typical ECG Wave Comprising its Constituents and Features.

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The customary waves variations and features, time span and a period of time and intermissions are explicated as the following:

3.14.1 The P Wave

The registration of the P wave within the ECG entails the atria depolarization. The P wave time span must not be above 0.12 sec in chest leads or 0.10 sec in limb leads. The average of its amplitude is 0.1-0.3 mV.

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The P wave found in limb leads is customarily positive, excluding in a VR lead, as it is constantly negative there. In lead II, it is prominently obvious (N. Saxena & Shinghal, 2015).

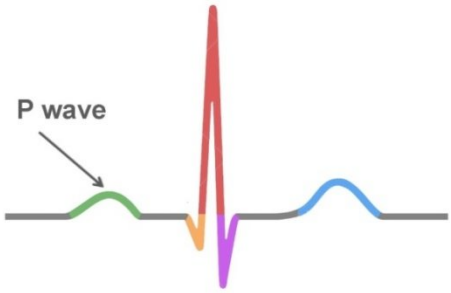


Figure 3.19 The Characteristics and Fformation of the P wave.

Positioned on the left of the precordial leads, the P wave is constantly positive. It is frequently positioned on the right chest wall and is biphasic. The morphology of the varying P Wave is significantly impacted by the autonomous nervous system. On the occasion that the sympathetic tone is raised, the P wave amplitude has the probability to rise tremendously, exceeding the entire leads in II, III and a VF. Contrarily, in the event that there is a rise in the parasympathetic tone, then in leads II, III, and a VF, the P waves will turn flat. It is the norm that the typical P wave spectral characteristics to be perceived as low in frequency, of lesser than 10-15 Hz (N. Saxena & Shinghal, 2016).

3.14.2 The QRS Complex

The start of the ventricular depolarization is represented by the ventricular complex. The Q, R, and S waves are customarily contained in it. Each individual wave that is

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positive is known as R.The initial negative wave prior to R is often known as Q. Additionally the initial negative wave ensuing R is known as S.

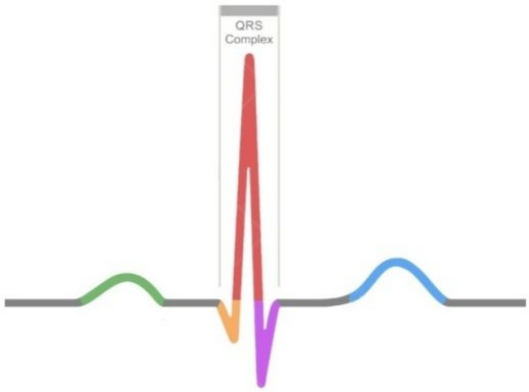


Figure 3.20 Characteristics and Formation of the QRS Complex

Figure 3.19 illustrates that there are another probable R number 2 and number 3, which are known as R' or R''. On the occasion of numerous present, this situation entails a split ventricular complex. The indication of each ventricular complex wave entity varies in conformity to the amplitude through the utilization of minute or big letters (N. Saxena & Shinghal, 2015).

3.14.3 The PR or PQ Interval

Its measurement arises from the beginning of the P wave up to the beginning of the ventricular complex. It must not be lesser than 0.12 second, and must not exceed 0.20 second. The extended time for AV conduction at rest is customary and not a mark of irregularity (N. Saxena & Shinghal, 2015).

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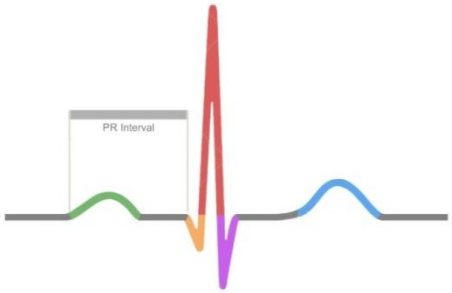


Figure 3.21 The PR segment

3.14.4 The T Wave

Ventricles repolarization is manifested by the T Wave. The consideration of its amplitude is in relation to the R Wave. In lead I and II, and in aVR lead, it is constantly positive and is consistently negative (N. Saxena & Shinghal, 2015)

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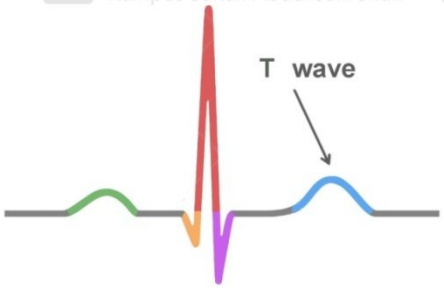


Figure 3.22 Characteristics and Formation of the of the T wave

3.14.5 The U Wave

Ensuing the T wave, a U wave may occasionally be demonstrated by the ECG. It possesses a similar T Wave deflection and has a formation that is akin to the P Wave.

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It is perceived to be a representation of the delayed repolarization of Purkinje fibers in the ventricles (N. Saxena & Shinghal, 2016).

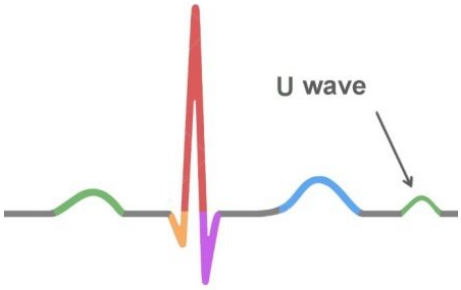


Figure 3.23 The Positions and Appearance of the U wave

3.14.6 The PP Interval and the RR Interval

The atrial cycle span established the PT interval. It assists to gauge the atrial rate. At the same time, the RR interval entails the gap in m-second between a pair of two consecutive waves. The ventricular rate is indicated by it, to represent the ventricular cardiac cycle length. Furthermore, the characterization of the various arrhythmias and the examination of the fluctuations in the heart rate is eminent (N. Saxena & Shinghal, 2016).

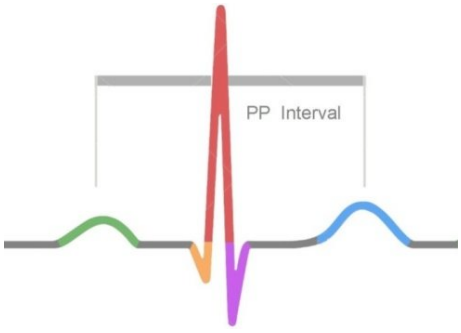


Figure 3.24 The positioning of the PP segment

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3.14.7 The ST Segment

The termination time when the ventricular is depolarized up to the initiation time when the ventricular is repolarized is illustrated by the ST segment. The location of the ST segment is betwixt the QRS complex terminal end and the beginning of the T-wave that was deflected and is typically isoelectric. There is the great clinical significance of its elevation or depression state, which could indicate the mark of ischemia and hyperkalemia (N. Saxena & Shinghal, 2016).

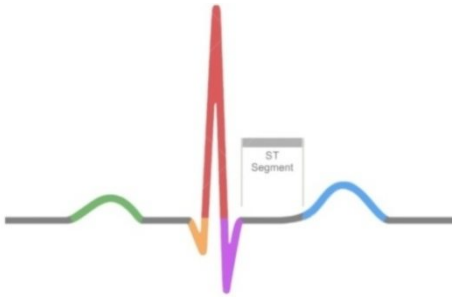


Figure 3.25 The ST segment

With a view of the precise ST segment interpretation, the exact localization of the J point should be implemented. The exact point of time of the curvature of the QRS into the ST segment defines the J point. Table 3.2 describe various waves and segments in the cycle ECG signal.

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Table 3.2

Description of Various Waves and Segments in the Cycle ECG Signal.

ECG Features	Amplitude (mV)	Duration (ms)	Description
P-wave	0.1 - 0.25	60 - 80	The P wave is the first wave of the ECG and represents the sequential activation of the left and right atria.
PR-Segment	-	50 - 120	The PR segment is the flat segment, generally isoelectric, located between the end of the P wave and the beginning of the QRS complex.
PR-Interval	-	120 - 200	The PR interval is the time between the beginning of the P wave and the beginning of the QRS complex.
QRS-complex	1	80 - 120	The QRS represents the simultaneous activation of the right and left ventricles.
ST-Segment	-	80 - 120	The ST segment follows the QRS complex. The point where it begins is called the point J- (union).
T-wave	0. 1 - 0.5	120 - 160	The T wave represents the recovery period of the ventricles.
ST-Interval	-	320	The ST interval is measured from point J to the end of wave T.
QT-interval	-	300 - 430	The QT interval is measured from the beginning of the QRS complex to the end of the T wave.
RR-Interval	-	600 - 1200	The time that elapses between two consecutive R waves in the electrocardiogram.

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3.15 Identification of Performance Measures

The objective of any compression scheme is to exclude extraneous and inact information in order to preserve vital information without losing by decreasing data volume. Distortion performances and compression are important factors to assess the effectiveness and productivity of the compression system. The aspect of compression is achieved by decreasing the data size. Rebuilding the potential of the compression system is assessed and gauged by the distortion parameter (Bali, Nandi, & Hiremath, 2018).

The statistical analyses are carried out in order to measure the performance and efficiency of data compression systems. These analyses are operational and active indicators of intimacy between the repaired signal from the original signal and compression. The subsequent indicators are used to assess the effectiveness of compression system productivity (S. Huang, Li, Zhang, & Zhang, 2018).

The linkage between the original and remodeled signals is called compression ratio (CR) and it is illustrated in the following Equation 3.1:

$$CR = \frac{\text{Uncompressed File Bits Size}}{\text{Compressed File Bits Size}} \qquad (3.1)$$

The fidelity of reconstructing signal compared with the original signal is commonly defined in the following Equation 3.2:

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$$PRD = \sqrt{\frac{\sum_{n=1}^{N}(x(n)-x\prime(n))^2}{\sum_{n=1}^{N}x^2(n)}}\,x\,100 \qquad (3.2)$$

Where *x (n)* represents the original data whereas x'(n) represents the sequence of remodeled data.

The Normalized Cross-Correlation Coefficient (NCC) of the fidelity is demonstrated below:

$$NCC = \frac{1/N\sum_{n=1}^{N}(x(n)-\mu o)\sum_{n=1}^{N}(x'(n)-\mu o)}{\sqrt{\frac{1}{N}\sum_{n=1}^{N}(x(n)-\mu o)2\frac{1}{N}\sum_{n=1}^{N}(x'(n)-\mu o)2}} \qquad (3.3)$$

Where μ represents the average of the original signal and μ_r is the average of the remodeled signal.

The power P_{org} of the original signal is demonstrated below:

$$P_{org} = \sum_{n=1}^{N}[Xrec(n)]^2 \qquad (3.4)$$

The power P_{rec} of the remodeled signal is illustrated below:

$$P_{rec} = \sum_{n=1}^{N}[Xrec(n)]^2\ " \qquad (3.5)$$

The Power of Error signal (P_{err}) can be described below:

$$P_{err} = \sum_{n=1}^{N}[x(n) - Xrec(n)]^2 \qquad (3.6)$$

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The Maximum Error (ME) is represented as a following:

$$ME = \max_n | x(n) - y(n)| \quad (3.7)$$

The SER is the mean signal to error ration as amplified in the following Equation 3.8:

$$SER = 10 * \log \frac{\sum_{n=1}^{N}[x(n)]2}{\sum_{n=1}^{N}[n(n)-Xrec(n)]2} \quad (3.8)$$

The function RMSE can be described as Root Mean Square Error in the following Equation 3.9, this equation used for signal assessment:

$$RMSE = \sqrt{\frac{1}{N}\sum_{n=1}^{N}[x(n) - x'(n)]^2} \quad (3.9)$$

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Where *x (n)* is an original signal, and *x' (n)* is an ECG signal improvement.

The Signal to Noise Ratio (SNR) can be described as a following:

$$SNR = 10 * log \frac{\sum_{n=1}^{N}(x(n)-x')^2}{\sum_{n=1}^{N}(x(n)-x'))^2} \quad (3.10)$$

The overall performance of the system through (QS), which is based on the compression ration (CR) and the distortion percentage (PRD) of the signal according to the following Equation 3.11:

$$QS = \frac{CR}{PRD} \quad (3.11)$$

The performance measures guidelines are presented as a following:

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1. CR, SER, and CCC (computational complexity component): High
2. PRD, MSE, ORD, and RMSE: Low
3. P_{rec}: P_{org}

There are numerous standards or ways for testing the effectiveness and productivity of compression algorithms. These standards or ways include Reconstruction Error (RE), Compression Ratio (CR), and Computational Complexity (CC).

Usually, the assessment of Reconstruction Error and Compression is determined by the rate of misrepresentation of the role of the algorithm. CCC is connected with the practical implementation, recommended as little as possible specifically for convenient apparatus. It is essential to get the physician's views from cardiologists at the value of the reconstructed signal so as to know the nonconformity and damage in the key morphological features of the ECG signal.

3.16 Summary

This chapter introduces a transmission technique for ECG signals compression utilizing a wireless medium and also reconstructs the ECG signals from received data. Additionally, it presents the reconstruction of the ECG signal from data that has been received. With regard to the objectives of transmission, the utilization of a USB GSM modem was implemented via a computer to transmit the compressed ECG signal in

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the form of a compressed file. The modem is under the command of AT-command in a personal computer.

The utilized compressed data is resultant from the outcome attained through a hybrid technique founded on the combination between the DWT and PCA.

All the compressed files are received successfully in a mobile device at the receiver section or computer server connect directly with the physician mobile used for this purpose. The compressed files are transmitted to the personal computer through the utilization of the Bluetooth, ensued by the execution of the data decompression algorithm for the reconstruction of the ECG signal. After that, a comparison of the original ECG signal with the ECG signal that has undergone reconstruction is executed, with the discovery of an error signal. The evaluation of this method is executed through the reconstruction parameter CR and PRD. The attainment of a high compression ratio by the compression algorithm has enabled to store a meager repository space.

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CHAPTER 4

RESULTS AND DISCUSSION

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4.1 Introduction

The deliberations and outcomes of assessing the recommended method of compression level standards are contained in this chapter. Measures associated with amplitude disparity between the original signal and the signal that has undergone construction is utilized for the appraisal of lossy ECG compression. The quantitative measurement commonly used is the percent root mean square difference (PRD), in which case, a lesser value of PRD signifies the proximal nearness of the approximation of the reconstruction with the original, thus indicating its more positive attributes. Nevertheless, as the result of the considered perception that the human judgment is more superior in determining the signal details considered to be essential, thus, evaluating things quantitatively is the inevitable utilized method. The results in this chapter depended on the research methodology strength starting from the

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preprocessing, passing through the ECG signal compression of the signal to the patient's condition assessment based on the accuracy of the reconstructed signal. As well as the MIT-BIH approved dataset that we relied upon to obtain accurate results as all records in the dataset are noise-free which collected for the purposes of storage, test, evaluation, and transmission as well. Section 4.1, presented the introduction of the chapter. A brief background of the research components is presented in Section 4.2. Section 4.3 described Performance Evaluation Measures. Section 4.4 displayed a compression measurement in this research. Distortion Measurement is identified and introduced in Section 4.5. The system requirement for running experiments is briefly presented in Section 4.6. Section 4.7, presented developing An Algorithm for ECG Signal COMDEC Based on DWT and PCA. Furthermore, the implementation of the proposed method scenario is explained in Section 4.8. Finally, the conclusion of this research is presented in i n Section 4.9.

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4.2 Background

Due to the absence of noise or aberration that is being injected by lossless algorithms as defined, hence the evaluation executed is solely through the utilization of quantitative standards.

The gauging of the data size, quantity that has been reduced is done through the compression ratio (CR). A better quality of effectiveness in the encoding will give a reduction in the size of the compressed file, hence leading to a greater CR.

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The recommended technique entails a novel 2- DWT and PCA according to the ECG compression technique that results in minimal clinical information that goes missing in the signal which has undergone reconstruction.

The current section puts forward the outcomes from the experiment attained from the recommended compression algorithm. The extraction of the database was from (Physio Bank ATM) and utilized for the assessment of the recommended compression technique.

Every ECG is utilized as sampling at 360Hz, with a resolution of individual sampling to be 11 bits/sampling. The first two thousand samplings from individual records are taken with the objective for experimental purposes. The initial ECG signal undergoes segmentation, forming a 2-Dimension data matrix. After that, the application of a 2-D DWT is executed onto the two-dimensional data matrix. The current study involves the utilization of wavelet decomposition of three levels, with the ensuing application of PCA on every individual respective matrix.

4.3 Performance Evaluation Measures

The ECG compression algorithm of the reconstructed signal must achieve a high compression quality in order to preserve the signal's diagnostic properties and high-compression efficiency.

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The quality of the ECG signal compressed should not be affected by the compression methods in order to preserve the signal's diagnostic properties. The assessment of ECG compression algorithms examination achievement consists of 3 elements: compression effectiveness, reconstruction mistakes and complicatedness in the computation system. The effectiveness of the compression is provided by the CR.

The CR and reconstruction mistakes generally are mutually reliant. The complicatedness of the computation element entails a portion of the feasible execution that has been taken into account.

4.3.1 Compression Measurement

The minimization of the data repository through the reduction of the redundancy is realized by the entire data compression algorithms where it is probable, hence enhancing data ratio.

4.3.1.1 Compression Ratio (CR)

Compression Ratio (CR) entails the ratio of the number of bits signifying the initial signal to the number of needed bits to deposit the compressed signal. CR aspires to be relatively great. An admissible fidelity must be represented by a data compression algorithm during the attainment of high CR. CR and the PRD are usually dependent on each other.

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$$CR = \frac{Original\ File\ Bit\ Size}{Compressed\ File\ Bit\ Size} \quad (4.1)$$

The below table 4.1, illustrates the CR measurement of the ECG signal record 134 taken from MIT-BIH Arrhythmia dataset.

Table 4.1 Comparison between Hybrid Proposed method, DWT and PCA in term of CR for standards ECG records 100,101,and 200.

Below table 4.1 shows how to find the number of bits in the ECG signal file before/after compression.

ECGs Records No.	DWT Compression Based CR	PCA Compression Based CR	Proposed Method Compression Based CR
100	7.32	7.073	9.802
101	7.07	7.241	9.643
200	9.34	8.501	9.182
Average	**7.91**	**7.605**	**9.5423**

The proposed method works well then as illustrated in ECG record number 200 (i.e High CR) .

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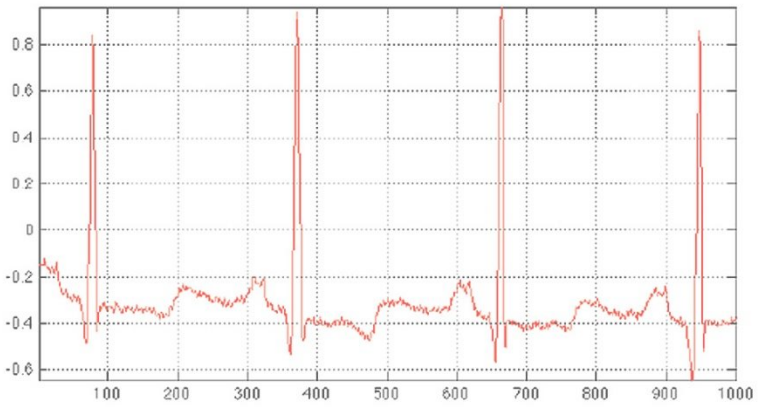
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Table 4.2

Finding the Number of Bits in the ECG Signal file Before/After Compression.

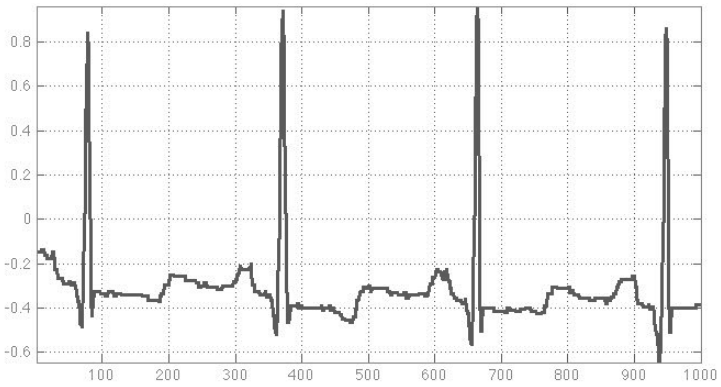
Data Type	Record No.	Before compression (bit)	After compression (bit)	CR
MIT-BIH Arrhythmia	200	12405	1351	9.182
MIT-BIH Noise Stress	nstdb/119e24	12855	1070	12.014
Non-Invasive Fetal	nifecgdb/ecgca410	12887	1060	12.157
PTB Diagnostic	ptbdb/patient008/s0028lre	13773	997	13.814
Sudden Cardiac Death Holter	sddb/50	13055	1848	7.064

The below figures show clearly the ECG signal of the first 1000 samples of Sample No. 100 in MIT- BIH Arrhythmia Database:



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(b) Compressed ECG Signal at CS=9.182

Figure 4.1 (a) The Original ECG Samples of the First 1000 Samples of Sample No.100 in MIT-BIH Arrhythmia Database

4.3.2 Distortion Measurement

Amongst the tough challenges in ECG compression and reconstruction is determining the error criterion which measures the capability of the signals that had undergone reconstruction in maintaining the appropriate data. Varying objective error measurements specifically; a signal to noise ratio (SNR), root mean square error (RMSE), and percentage root mean difference (PRD), is utilized to calculate reconstruction mistakes. Amid the erroneous measurements, the ECG processing is often gauged by the percentage root mean difference (PRD).

4.3.2.1 Percentage Root mean Difference (PRD)

The Percentage Root means Difference specifies the fidelity via point wise comparison with the initial data. In spite of their extensive utilization, the accurate

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quality of signal reconstructions is not shown by PRD, and the evaluation via visual examination has to be executed onto the decompressed signals. PRD is signified as:

$$PRD = \sqrt{\frac{\sum_{n=1}^{N}(x(n)-x\prime(n))^2}{\sum_{n=1}^{N}x^2(n)}}x\ 100 \qquad (4.2)$$

where x(n) and x'(n) x n equates the original and reconstructed samples values accordingly, and N is the window length from which the PRD is calculated. The PRD low value signifies a preferably less error between the original signal and reconstructed signal. The below table 4.3, illustrates the PRD measurement of the ECG signal rec. 134 taken from MIT-BIH Arrhythmia dataset

Table 4.3

Comparison Between Hybrid Proposed Method, DWT, and PCA in term of PRD for Standards Records 100,101,and 200.

ECGs Records No.	DWT Compression Based	PCA Compression Based	Proposed Method Compression Based
	PRD	PRD	PRD
100	1.23	4.50	1.280
101	0.67	4.53	0.869
200	1.96	4.78	1.267
Average	**3.860**	**4.6033**	**3.416**

The proposed method works well then as illustrated in ECG record number 200 (i.e low PRD) .

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4.3.2.2 Root Mean Square Error (RMS)

Root Mean Square offers reconstructed signal error measurements in relation to the original signal. The RMS definition is as follows :

$$RMS = 100x\sqrt{\frac{\sum_{n=1}^{N} X_2(n)-X_1(n))^2}{N-1}} \qquad (4.3)$$

This is the RMS error between the original ECG signal and the reconstructed ECG signal.

4.3.2.3 Signal to Noise Ratio (SNR)

SNR is the peak signal-to-noise ratio in decibels (dB), and can be represented as a following:

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$$SNR = 10xLog\left(\frac{\sum_{0}^{N-1}(X(n)-mean(X)}{\sum_{0}^{N-1}(X(n)-Y(n))^2}\right) \qquad (4.4)$$

The extensive utilization of SNR in ECG data compression literature can be seen in order to measure reconstructed signal quality in comparison to the original signal.

4.3.2.4 Quality Score (QS)

QS is the ratio of CR and PRD which quantifies the overall performance of the compression technique. The high value of quality score indicates high compression performance with less error. QS defined as a follow:

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$$QS = \frac{CR}{PRD} \quad (4.5)$$

4.3.2.5 Normalized Percent Root-mean-square Difference (PRDN)

$$PRDN = \sqrt{\frac{\sum_{i=1}^{N}[x(n)-x\prime(n)]^2}{\sum_{n=1}^{N}[x(n)-avg(x(n))]^2}}x100 \quad (4.6)$$

The below table 4.4, illustrates the QS measurement of the ECG signal record 134 taken from MIT-BIH Arrhythmia dataset.

Table 4.4

Comparison Between Hybrid Proposed Method, DWT, and PCA in term of QS

ECGs	DWT Compression Based QS	PCA Compression Based QS	Proposed Method Compression Based QS
100	7.94	7.721	7.653
101	14.92	9.044	11.086
200	3.22	4.602	7.244
Average	**8.663**	**7.122**	**8.961**

The proposed method works well then as illustrated in ECG record number 200 (i.e High QS) .

Here, the results of the proposed method were compared with the other methods (CR, PRD, and QS), through testing with the same records that were

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indicated in the with previous works, which are the values (100, 101, and 200), as a scientific procedure to detect the accuracy of COMDEC of the proposed method.

4.4 System Requirement for Running Experiments

This section provides a summary of each hardware and software used to run the research experiment.

1. The experiments are executed on a personal computer with the following specifications:
   a) The operating system used is Microsoft Windows 7 /10, service pack one.
   b) The system type X32-based PC.
   c) The processor type is Intel(R) Cor(TM) i7-2450M CPU @ 2.50GHz, 2501MHz, 2 Cor(s), and eight logical processors.
   d) The physical memory is 8.00 GB.
2. The programming language used in this experiment is Microsoft Visual C# Android application (Xamarin).
3. Excel sheets Microsoft office 2017 is used to present the findings in a graphical form.

4.5 The Preprocessing Stage

During the pre-processing stage, the ECG is denoised. Various kinds of noises (artifacts) exist in an ECG signal at the time of the attainment. The prominent noises

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are the high frequency noise; power line interference and baseline wander noise. The occurrence of the power line interference is caused by the incorrect power line grounding. However, the counterbalance of voltages in electrodes, respiration, and physical motion is caused by baseline wander. Hence, for accurate analysis, it is a requirement for the noise to be removed. The result of the ECG compression process is affected by the extent of the noise that exists in the signal.

Consequently, in the event that the noise that exists in the signal exhibits a greater quantity, this will lead to a reduction of the compression ratio. In this case, the probability-based ECG denoising method is utilized for the elimination of noise.

This data processing phase is executed so as to heightened the effectiveness of the transformation processes, which ultimately improve the performance of the compression.

Firstly, the long ECG signal is divided into short divisions, individually of N-samples in length. There are two core techniques in choosing the segment length. Technique number one is the consideration of individual heartbeat as a single segment. The challenge that arises is pertaining to the heartbeat volatility, hence it is essential for the QRS-complex identification, and knowing the RR period is also essential. Nevertheless, this makes the compression process more complex and magnifies the computation strain. Numerous segmentation standards can be found in technical literature according to fixed-length blocks.

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It is critical for the block size N to be ascertained since it establishes the compression ratio, in addition to the related PRD. A huge N value further heightens the variation of the distortions of the sub-band signal. Through the process of experimentation, from this study, a 2000-sampling segment length is identified, where through the experimentation will produce an appropriate compression performance(Saxena & Shinghal, 2015).

The robust artifacts present at the time of the collection stage are influential towards the ECG signals quality for example movement artifact, muscle activity, and baseline wander. For the elimination of the strong noise and artifacts, the original ECG signals will eliminate the low frequency, in addition to the high-frequency noises, whereas it will not alter the core ECG signals framework (Pandey et al., 2016).

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4.6 Signal Processing Filters

Modern ECG monitors offer multiple filters for signal processing. The most common settings are monitor mode and diagnostic mode. In monitor mode, the low-frequency filter (also called the high-pass filter because signals above the threshold are allowed to pass) is set at either 0.5 Hz or 1 Hz and the high-frequency filter (also called the low-pass filter because signals below the threshold are allowed to pass) is set at 40 Hz. This limits artifact for routine cardiac rhythm monitoring. The high-pass filter helps reduce the wandering baseline and the low-pass filter helps reduce 50 or 60 Hz power line noise (the power line network frequency differs between 50 and 60 Hz in different countries). In diagnostic mode, the high-pass filter is set at 0.05 Hz, which allows accurate ST segments to be recorded. The low-pass filter is set to 40, 100, or

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150 Hz. Consequently, the monitor mode ECG display is more filtered than the diagnostic mode, because its pass-band is narrower.

ECG samples are generally affected by various sources of high-frequency noises including power-line interference and electrosurgical noise at the time of signal acquisition. To remove such high-frequency noises, standard filtering software is used prior to any other process. At first, a low pass filter is used to remove all noises above 100 Hz and then a 60 Hz notch filter is used to remove power line interference. The R peak detection algorithm is developed on the basis of the conventional differentiation technique. Every ECG sample is subtracted from its preceding. It is basically a high pass filtering. In flat or low-frequency regions (P wave, T wave, ST segment, etc.), a difference of sample voltages will be close enough to zero whereas higher differences will result in QRS regions because these regions always have the maximum slope. Now, these differentiated voltage values are squared to enhance the high-frequency regions. Those particular samples are noted where the square of the difference becomes maximum within a window size 0.25 s i.e. it is assumed that the heart rate will not exceed 240. Now, returned back to the original ECG signal, the maximum amplitude is searched within 160 ms (maximum QRS duration [45]) about the maximum squared position which gives a true R peak. Detected R peaks of particular ECG data record are shown in Figure 4.2.

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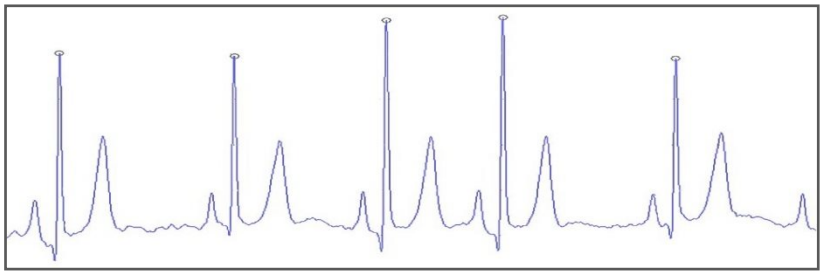


Figure 4.2 Detected R-peaks of Rec 112 MIT-BIH, lead I, Normal

4.6.1 FIR Filters

FIR filters are widely used due to the powerful design algorithms that exist for them, their inherent stability. When implementing in non-recursive form, the ease with which one can attain a linear phase. Equiripple filter, least square method, windowing method for designing of FIR low pass filter is there. A windowing method is used, where Kaiser, Rectangular, Hamming, Hanning and Blackman functions are designed. The basic specifications for the design of filter are:

1. Cut-off frequency 100 Hz
2. Sampling frequency 360Hz (MIT/BIH database sampled at 360 Hz). In the FIR window filters, the cut-off frequency at the 3 dB point is approximately 91.8333 Hz. The window length in case of Rectangular, Hanning, and Hamming is 18 and 16(window length is order plus one). Kaiser window has filter length 14 with phase delay 0.1047 rad/Hz and cut off frequency at 3db is 89.60449Hz.

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Digital filters are very important in many digital signal processing applications. Obtain the coefficients of an FIR lowpass digital filter to meet these specifications:

passband edge frequency	1.625 kHz
passband pk-to-pk ripple	<1 dB
transition width	0.5 kHz
stopband attenuation	>50 dB
sampling frequency	8 kHz

In digital signal processing, an FIR is a filter whose impulse response is of the finite period, as a result of it settles to zero in finite time. At each level, a signal is decomposed into low and high-frequency bands. The detail coefficient is the result of the high pass filter and the approximation coefficient is the result of a low pass filter. In each step of decomposition two outputs are generated such as scaling and wavelet coefficient as given in Equation. (4. 7) and (4. 8):

$$x^{j+1}(n) = \sum_{i=1}^{2n} h(2n-t)x^{j}(n) \qquad (4.7)$$

$$y^{j+1}(n) = \sum_{i=1}^{2n} g(2n-t)x^{j}(n) \qquad (4.8)$$

$x^{j+1}(n)$ is the scaling coefficient, $y^{j+1}(n)$shows the wavelet coefficient, x^0(n) indicates the original signal ,j indicates the scaling number ,*h(n)*and *g(n)* indicates the high pass filter and low pass filter. High Pass filter passes signals with a frequency higher than a particular cut off frequency and signals with frequencies lower than the cut off frequency are attenuated. Low pass filter passes signals with a frequency lower than a particular cut off frequency and signals with frequencies higher than the cut off frequency are attenuated.

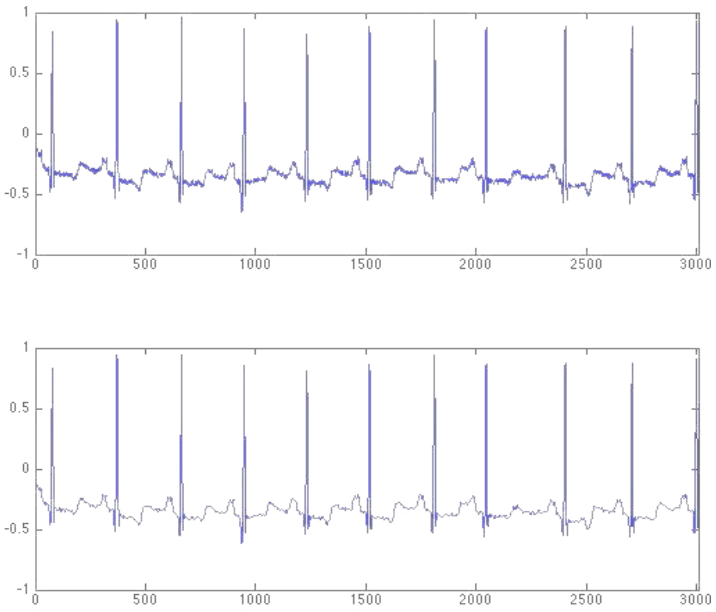
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During the noise removal, it must be careful to preserve the main features of the signal. Perseverance of the signal features is essential for correct diagnosis. The data related to revealing peak P, distance QT, T and S waves are considered as important diagnostic parameters. Thus, ways that have the least amount of change in the actual signal must be chosen to reduce noise from the ECG signals. The frequency range of the ECG signal is between 0.5 to 100 Hz. The baseline noise is often caused by breathing and body movements (Artifacts), which mainly cause deviation at low frequencies, this noise can be removed by a high-pass filter. During the cardiac signal transmission in telemedicine, Gaussian noise is also added to the signal. So, in order to have a better examination of the algorithm, Gaussian noise is also added to the data. Then, the proposed algorithm is tested(Ramachandran & Bashyam, 2017). The low pass filter with a 55 Hz cutoff frequency and 3rd order are used for Gaussian noise canceling. By choosing a high-order filter, it accesses the best removal noise but it decreases the amplitude of R peaks unnoticeably not affect valuable medical information. For example, based on records mitdb/115 from MIT-BIH Arrhythmia Dataset, a high pass filter for the noisy records before and after processing was presented as shown in Figure 4.3.

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(a) (b)

Figure 4.3 (a) Original ECG signal with simple noise (MIT--- BIH Database record mitdb/100), (b) denoised ECG signal by high pass filter.

The major difference between high pass and low pass filter is the range of frequency which they pass. If we talk about high pass filter, so it is a filter that allows the high frequency to pass through it while it will block low frequencies. On the contrary, a low pass filter is a filter that allows the low frequency to pass through it and blocks the high-frequency signal. There is a term defined for filters, i.e. cut-off frequency, it assumes a threshold value. The high pass filter offers low reactance to signals with the frequency above this cut-off frequency and provides high reactance to frequencies below this cut-off frequencies. The low pass filter offers low reactance to the signals with frequencies lower than the cut-off frequency so that low frequencies can pass but it provides high reactance to the high-frequency signal and thus blocks them.

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4.6.2 Haar Wavelet Filter

Discussion of wavelets begins with Haar wavelet, the first and simplest. Haar wavelet shown in Figure 4.4, is discontinuous and resembles a step function. It represents the same wavelet as Daubechies db1. The first DWT was invented by the Hungarian mathematician Alfred Haar. For an input represented by a list of numbers, Haar wavelet transform may be considered to simply pair up the input values, storing the difference and passing the sum. This process is repeated recursively, pairing up the sums to provide the next scale, finally resulting in differences and one final sum. The simplest form of compression is Haar wavelet transform, which involves averaging and differencing terms, storing detail coefficients, eliminating data, and reconstructing the matrix such that the resulting matrix is similar to the initial matrix.

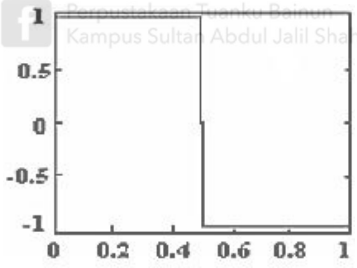


Figure 4.4 Haar Filter

4.7 Developing An Algorithm for ECG Signal COMDEC Based on DWT and PCA

4.7.1 Preprocessing

In this method, a 2-D wavelet-based ECG compression method is proposed. Firstly, the 1-D ECG signal is segmented and aligned to form a 2-D data array. Then 2-D wavelet transform is applied to the constructed 2-D data array.

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In the pre-processing stage, denoising of the ECG signal is performed. There are different types of noises that are present in an ECG signal during acquisition. The major ones are high-frequency noise; power line interference and baseline wander noise. High-frequency noise caused due to muscle activity and outer environment. Power line interference occurred due to improper grounding of the power line. Baseline wander is a low-frequency noise caused due to offset voltages in the electrodes, respiration and body movement. Thus noise removal becomes an essential part of proper analysis. The outcome of the ECG compression process is influenced by the noise level present in the signal. Accordingly, if the noise present in the signal is more, then the compression ratio will decrease. Here, probability-based ECG denoising technique is used for noise removal. In this process, at first, the acquired ECG signal is decomposed using wavelet transform. Then, the probability of wavelet coefficients is determined at different levels. The noisy coefficients are thresholded based on different probability based thresholds for different levels. Finally, the pre-processed ECG signal is obtained by inverse wavelet transform (IWT) of the thresholded coefficients.

4.7.2 Wavelet PCA Based Compression

In this scheme, compression is achieved by applying entropy coding to the selected principal components of each 2-D coefficients array obtained from 2-D DWT of the ECG signal.

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The selection of principal components is based on the variance of the original signal and the level of the wavelet decomposition. This compression technique has five major steps. First, the signal is segmented to form a 2-D array such that each segment contains approximately one heartbeat. In the second step, 2- D DWT is applied up to 4 decomposition level to the constructed 2-D array in the first step. In the third step principal components (PCs) are extracted for each 2-D coefficients array. In the next step, PCs are selected for each 2-D coefficients matrix.

Finally, selected PCs are compressed by using entropy coding. Each of the steps is discussed in detail in the following subsections.

4.7.3 Generating Data Matrix

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The signal segment of a heartbeat is represented by the column vector as:

$$y = \begin{bmatrix} x(1) \\ x(2) \\ . \\ . \\ . \\ x(N) \end{bmatrix}$$

where N is the number of samples of the segment. If M number of heart beats are considered, then the entire ensemble is compactly represented by the NxM data matrix,

$$X = [y1 \;\; y2 \;\; \dots\dots y_M]$$

Thus X is the data matrix.

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4.7.4 Wavelet Decomposition

The 2-D data matrix X of size NxM is decomposed by applying 2-D DWT. The `L' level wavelet decomposition results in `L' th approximation 2-D coefficients array L cA_L and ` j 'th detail 2-D coefficients array in three orientations (horizontal, vertical and diagonal) as $cH_j$, $cV_j$ and $cD_j$ where j =1,2,....., L. This results in `3L+1' number of 2-D coefficients matrices and arranged as $[cA_L, (cA_{L,}cV_L), \dots \dots (cH_1, cV_1, cD_1]$.

4.7.5 Applying PCA on Coefficient Matrix

After taking 2-D DWT, the PCA of each 2-D coefficients matrix is performed. This gives a number of eigenvalues and eigenvectors and they will be in pairs. Eigenvalues and their corresponding eigenvectors are arranged in descending order.

The principal components are selected based on the eigenvectors with corresponding higher eigenvalues.

The number of eigenvalues chosen determines the reduction of dimension. Ordered eigenvalues in approximation (A) and detail coefficients matrices (H, V, D) are:

$$\lambda_{A1}, \lambda_{A2}, \lambda_{A3}, \dots\dots \lambda_{An}$$

$$\lambda_{Hj1}, \lambda_{Hj2}, \lambda_{Hj3}, \dots\dots \lambda_{Hjn}$$

$$\lambda_{Vj1}, \lambda_{Vj2}, \lambda_{Vj3}, \dots\dots \lambda_{Vjn}$$

$$\lambda_{Dj1}, \lambda_{Dj2}, \lambda_{Dj3}, \dots\dots \lambda_{Djn}$$

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where ` j ' is the wavelet scale and `n' is the total number of eigenvalues for that particular 2-D coefficients array.

4.7.6 Principal Components Selection Method

Here, a new principal components selection scheme based on the variance of the original ECG signal is proposed. The principal components selection process is performed by deriving different thresholds for different coefficients matrices. These thresholds depend on the variance (σ) of the original ECG signal. Because, if vthe ariance is less, then the value of these thresholds will be more and less number of principal components will be selected, that resulting inmore compression.

Conversely, if the variance is more, then the value of these thresholds will be less and number of principal components will be selected, that resulting in less compression. These principal components selection thresholds can be defined as:

$$T_{Hj} = \frac{\sum_{i=1}^{n} \lambda_{Hj1}}{\sigma L} \quad (4.1)$$

$$T_{Vj} = \frac{\sum_{i=1}^{n} \lambda_{Vj1}}{\sigma L} \quad (4.2)$$

$$T_{Dj} = \frac{\sum_{i=1}^{n} \lambda_{Dj1}}{\sigma L} \quad (4.3)$$

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where A T is the threshold for Approximation coefficients matrix. T_{Hj} , $T_{Vj,}$ and T_{Dj} are thresholds for horizontal, vertical and diagonal detail matrices at ` j 'th decomposition level. Those eigenvalues which are greater than the threshold are selected from each coefficient matrix (A, H_j, V_j, D_j), which decide the number of principal components.

Selection of principal components, they are quantized and Huffman encoded. Here different quantization levels, such as 4-bits to 8-bits are used for different principal components. The compressed data are obtained after Huffman coding the quantized principal components. The original ECG signal is segmented to form a 2-D data matrix where each segment contains approximately one heartbeat. Then 2-D DWT is applied to this 2-D data matrix. For COMDEC method evaluation, the database is taken from MIT-BIH. Each file in the MIT-BIH database consists of 2-lead recordings sampled at 360 Hz with 11 bits per sample resolution. The process of finding the parameters are based on the nature of the ECG data (period time, presence or absence of noise in the data extracted, etc.). As a result, 10 coefficients matrices are found and PCA has then applied on each of these coefficients matrices. The below table 4.5 shows the extracted coefficients of principal components:

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Table 4.5

Principle Components Selection for each Coefficients Matrix of Rec. 101 Arrhythmia Database.

2-D Coefficients Matrix	Principle Components Total Extracted	Principle components Selected
cA4	16	4
cH1	14	9
cH 2	15	7
cH3	16	5
cH 4	16	4
cV1	14	8
cV2	15	7
cV3	16	6
cV4	16	5
cD1	14	8

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4.8 ECG Signal COMDEC Efficiency

The efficiency of the proposed compression technique can be measured based on three parameters. The compression ratio (CR) is the first measurement that reflects the ratio between the original to the compressed ECG file size. The second one is PRD, used for distortion measurement between the original ECG signal and the reconstructed ECG signal. And finally, QS (Quality Score), is the ratio of CR and PRD which measures the overall performance of the compression technique. The high value of quality score indicates high compression performance technique with less error.

A new 2-D DWT and PCA based ECG compression technique are proposed with minimum loss of clinical information in the reconstructed signal. This section

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presents the experimental results obtained from the proposed compression algorithm. The database is taken from MIT-BIH for the evaluation of the proposed compression method. Each file in the database consists of two lead recordings sampled at 360 Hz with 11 bits per sample resolution.

The use of technology has some relevant side effects, being the increase in the amount of produced information one of the most important. Currently, there is a large volume of medical devices able to collect vital signs from patients. There are many types of cardiac signals and they are of different frequencies. This diversity generated by different equipment manufacturers originates from a variety of file formats. This factor complicates the sharing of data between research centers. In this context, this study identified the main file formats existing for the storage of time-series resulting from biomedical signals. The distinct file formats were assessed by using a benchmark, which was biomedical data publicly available. It was found that the file format EDF is the one which requires less memory storage capacity and the possibility of accounting for embedding structured information relevant for the description of the data (e.g., annotation of events, patient and device information). And, It was found that each record taken from MIT-BIH for the evaluation purpose which consists of two lead recordings sampled at 360 Hz with 11 bits per sample resolution is also requires less memory storage capacity and the easy possibility of transmission.

Wavelet decomposition using Daubechies 7/9 wavelet filters is used and the same has been applied for reconstruction filters also. Here, the original ECG signal is segmented to form a 2-D data matrix where each segment contains approximately one

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heartbeat. Then 2-D DWT is applied to this 2-D data matrix. In this work, wavelet decomposition up to 3 levels was used.

Figure 4.5 (a) illustrates the original ECG signal of record 117 from the MIT-BIH Arrhythmia database while (b) illustrates the reconstructed signal.



Figure 4.5 (a) Original Signal

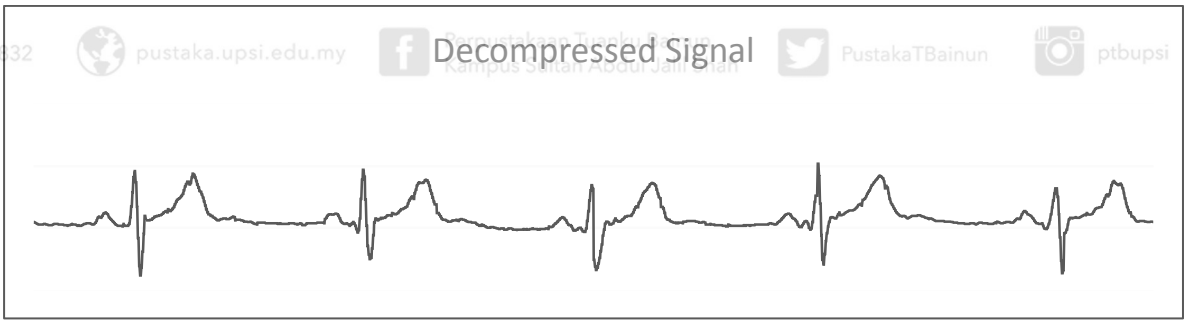


Figure 4.5 (b) Reconstructed Signal

Figure 4.5 (a),(b) Visual evaluation of the ECG signal that had undergone reconstruction by the recommended technique

Figure 4.6 (a) shows the original ECG signal of record 118e00 from MIT-BIH Noise Stress Test Database and (b) shows the reconstructed signal.

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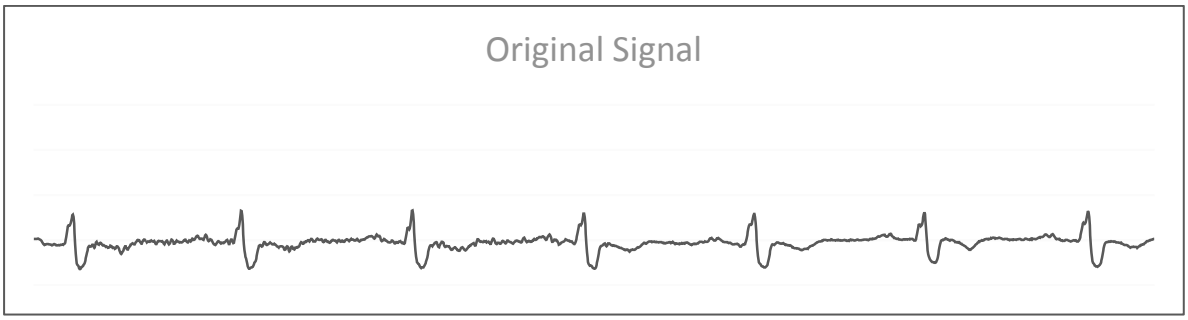


Figure 4.6 (a) Original Signal

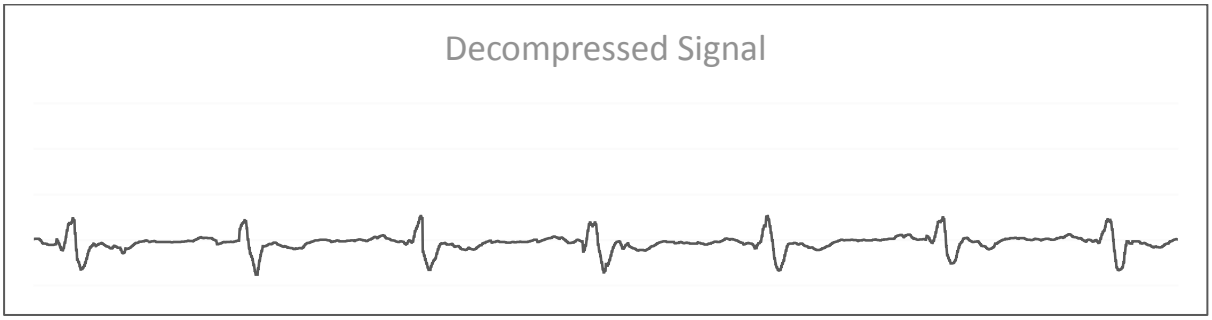


Figure 4.6 (b) Reconstructed Signal

Figure 4.6 (a),(b) Visual Evaluation of ECG signal that had undergone reconstruction by the recommended technique

Figure 4.7 (a) shows the original ECG signal of record ecgca102 from the Non-Invasive Fetal ECG Database and (b) shows the reconstructed signal.

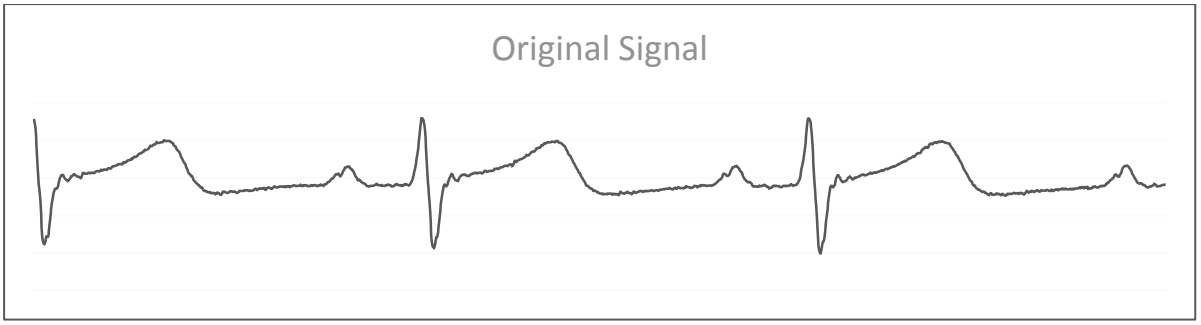


Figure 4.7 (a) Original Signal

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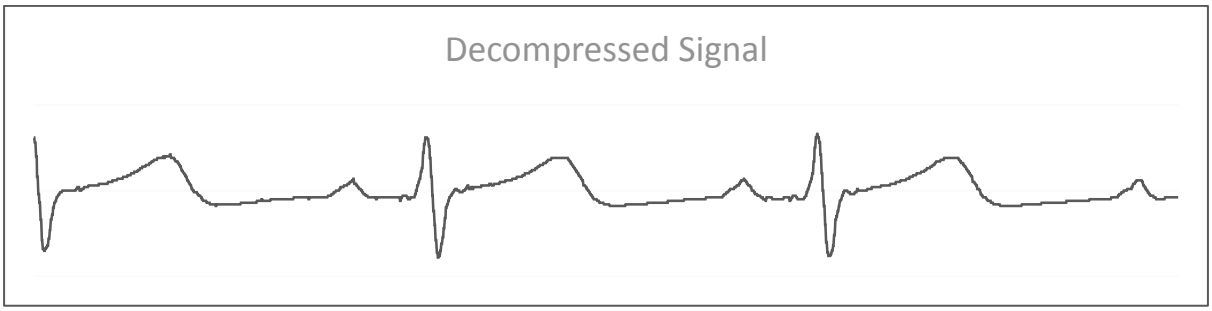


Figure 4.7 (b) Reconstructed Signal

Figure 4.7 Visual Evaluation of ECG signal that had undergone reconstruction by the recommended technique

Figure 4.8 (a) shows the original ECG signal of record patient 001/s0010_re from PTB diagnostic ECG Database and (b) shows the reconstructed signal.



Figure 4.8 (a) Original Signal

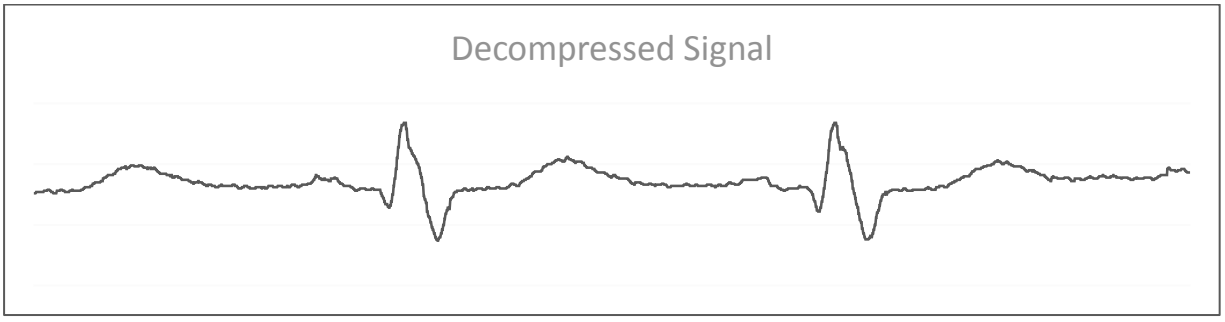


Figure 4.8 (b) Reconstructed Signal

Figure 4.8 (a),(b) Visual Evaluation of ECG signal that had undergone reconstruction by the recommended technique.

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Figure 4.9 (a) shows the original ECG signal of record 30 from the Sudden Cardiac Death Holter Database and (b) shows the reconstructed signal.

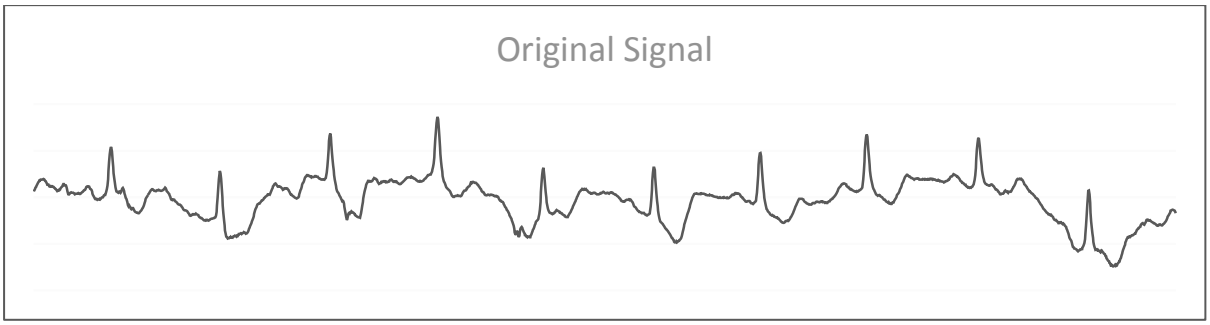


Figure 4.9 (a) Original Signal

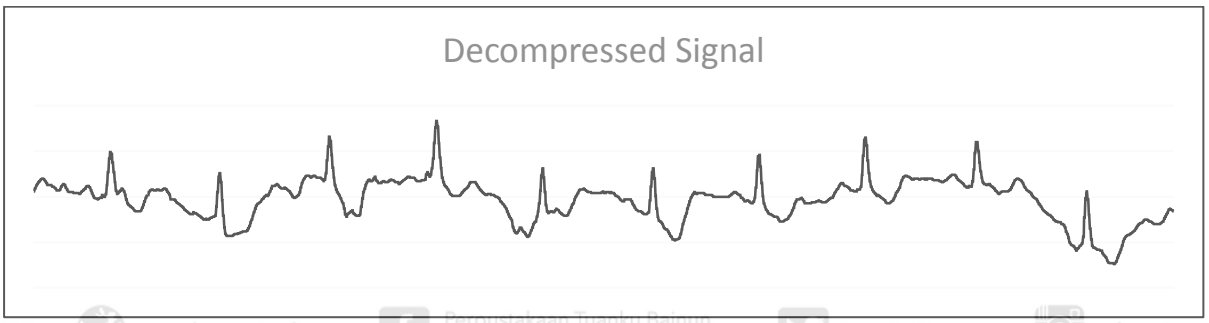


Figure 4.9 (b) Reconstructed Signal

Figure 4.9 (a),(b) Visual Evaluation of ECG signal that had undergone reconstruction by the recommended technique

The provisions of the outcomes attained by the recommended technique when executed onto MIT-BIH Arrhythmia databases can be found in Table 4.6 column number one in the table illustrates the varying records from (Physio Bank ATM) which are utilized for evaluation objectives. The additional columns in the table offer outcomes attained by the recommended ECG compression method.

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Table 4.6

MIT-BIH Arrhythmia Results for the Proposed Compression Method

Record no.	CR	PRD	PRDN	QS	RMS
100	9.802	1.280	2.723	7.653	0.0461
101	9.643	0.869	1.685	11.086	0.032
117	10.994	0.513	1.874	21.391	0.0445
119	9.707	0.704	1.485	13.770	0.069
200	9.182	1.267	1.329	7.244	0.055
Average	**9.8656**	**0.9266**	**1.8192**	**12.2288**	**0.04932**

Table 4.7 illustrates the outcomes attained by the recommended technique when executed onto the MIT-BIH Noise Stress assessment. The first column in the table shows different records from (Physio Bank ATM) that are used for testing purpose. The next columns in the table provide results obtained by the proposed ECG compression technique.

Table 4.7

MIT-BIH Noise Stress Test Results for the Proposed Compression Method.

Record no.	CR	PRD	PRDN	QS	RMS
nstdb/118e00	13.875	0.145	2.466	95.386	0.089
nstdb/118e12	12.014	0.145	2.466	82.597	0.089
nstdb/118e24	12.014	0.145	2.466	82.597	0.089
nstdb/119e00	12.014	0.197	2.539	60.878	0.118
nstdb/119e24	12.014	0.197	2.539	60.878	0.118
Average	**12.3862**	**0.1658**	**2.4952**	**76.4672**	**0.1006**

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Table 4.8, illustrates the outcomes attained by the recommended technique when executed onto Non-Invasive Fetal ECG databases.

Table 4.8

Non-Invasive Fetal ECG Results for the Proposed Compression Method.

Record no.	CR	PRD	PRDN	QS	RMS
nifecgdb/ecgca102	13.907	0.779	0.779	17.850	0.007
nifecgdb/ecgca154	12.729	0.935	0.939	13.603	0.009
nifecgdb/ecgca244	12.089	0.562	0.562	21.473	0.040
nifecgdb/ecgca300	12.405	0.785	0.785	15.784	0.009
nifecgdb/ecgca410	12.157	0.656	0.657	18.507	0.024
Average	**12.6574**	**0.7434**	**0.7444**	**17.4434**	**0.0178**

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Table 4.9, illustrates the outcomes attained by the recommended technique when executed onto PTB Diagnostic ECG databases. The first column in the table shows different records from (Physio Bank ATM) which are utilized for assessment objectives. The provision of the attained outcomes through the recommended compression method can be seen in the other columns in the table.

Table 4.9

PTB Diagnostic ECG Results for the Proposed Compression Method.

Record no.	CR	PRD	PRDN	QS	RMS
ptbdb/patient001/s0010lre	15.124	0.647	0.995	23.347	0.012
ptbdb/patient001/s0016lre	11.275	1.168	1.651	9.648	0.028

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ptbdb/patient005/s0021lre	13.046	0.551	0.984	23.657	0.007
ptbdb/patient006/s0027lre	11.063	0.252	1.332	43.880	0.015
ptbdb/patient008/s0028lre	13.814	0.206	1.079	66.796	0.006
Average	**12.8644**	**0.5648**	**1.2082**	**33.4656**	**0.0136**

Table 4.10, illustrates the outcomes attained by the recommended technique when executed onto Sudden Cardiac Death Holter databases.

Table 4.10

Sudden Cardiac Death Holter Results for the Proposed Compression Method.

Record no.	CR	PRD	PRDN	QS	RMS
sddb/30	8.099	0.609	0.615	13.277	0.014
sddb/36	7.396	0.856	0.932	8.630	0.010
sddb/40	6.801	1.218	1.224	5.582	0.039
sddb/45	6.893	1.350	1.353	5.103	0.027
sddb/50	7.064	0.586	0.643	12.034	0.021
Average	**7.2506**	**0.9238**	**0.9534**	**8.9252**	**0.0222**

The recommended technique was tested by a set of five different records onto Sudden Cardiac Death Holter databases are (sddb/30, sddb/36, sddb/40, sddb/45, and sddb/50). The experimental outcomes explained by examining records that the record (sddb/30) the highest quality score showed through QS, as well as the highest compression ratio, showed through CR, while the lowest PRD we obtained by recording (sddb/50).

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The average results obtained by the proposed method are given in Table 4.11. Column one in the table depicts the varying database kind from (Physio Bank ATM) which are utilized for assessment objectives. The other columns in the table illustrate the average results attained through the recommended ECG compression method.

Table 4.11

Average Results for the Proposed Compression Method

Database Type	QS	PRD	CR	PRDN	RMS
MIT-BIH Arrhythmia database	12.2288	0.9266	9.8656	1.8192	0.0493
MIT-BIH Noise Stress Test Database	76.4672	0.1658	12.3862	2.4952	0.1006
Non-Invasive Fetal ECG Database	17.4434	0.7434	12.6574	0.7444	0.0178
PTB Diagnostic ECG Database	33.4656	0.5648	12.8644	1.2082	0.0136
Sudden Cardiac Death Holter Database	8.9252	0.9238	7.2506	0.9534	0.0222
Average	**29.70604**	**0.66488**	**11.0048**	**1.44408**	**0.0407**

The recommended technique was tested by one record onto a set of five types of MIT-BIH dataset. The experimental outcomes explained by examining record that the highest quality score showed through QS is obtained by Non-Invasive Fetal ECG Database, as well as the highest compression ratio showed through CR is obtained by PTB Diagnostic ECG Database, while the lowest PRD is obtained by record MIT-BIH Noise Stress Test Database

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The comparison of the recommended compression technique is implemented with the currently present data compression techniques in Table 4.12. The outcomes from the experiments illustrate that the recommended techniques offer an average PRD of 0.66488, CR of 11.0048, in addition to QS 29.70604.

Notification information from Table 4.12 shows that (Pandey, Singh, Saini, & Sood, 2016) and (Pandhe & Patil, 2014) offer additional CR. However, PRD values are enhanced too. Consequently, the recommended technique depicts positive CR possessing inferior PRD value.

Additionally, we noted the preservation of clinical data to the substantial level in signals that had undergone reconstruction. Hence, the goals of this study have been attained in its entirety.

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Table 4.12

CR, PRD, and QS Comparison with Existing Methods

Method	Database used	QS	PRD	CR
Proposed method	MIT-BIH Arrhythmia, MIT-BIH Noise Stress Test, Non-Invasive Fetal ECG, PTB Diagnostic ECG, Sudden Cardiac Death Holter	**29.70604**	**0.66488**	**11.0048**
L. N. Sharma, et al. (Sharma, Dandapat, & Mahanta, 2012)	CSE Multi lead Measurement library	2.861244	2.090	5.980
Gupta, R. (Pandey, Singh, Saini, & Sood, 2016)	MIT-BIH Arrhythmia, Anterior Myocardial Infarction (AMI) and Inferior Myocardial Infarction (IMI)	3.128237	16.22	50.74
Pandhe, D. C.& Patil, H. T. (Sharma et al., 2012)	MIT-BIH Arrhythmia	3.786765	1.36	5.15
Pandey, A., et al. (Pandhe & Patil, 2014)	MIT-BIH Arrhythmia	17.53774	1.06	18.59

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In case of PRD, Figure 4.10 shows that the results of the proposed method are much lighter compared with the rest of the previous methods, indicating that the proposed method is the best in terms of the quality of ECG signals, as it maintained the quality of ECG signals after compression.

For CR, Figure 4.11 shows that the results of the proposed method are lighter than (Sharma, Dandapat, & Mahanta, 2012) (Sharma et al., 2012) (Pandey, Singh, Saini, & Sood, 2016) and (Pandhe & Patil, 2014). It exceeded the compression ratio, but that superiority in the compression ratio was at the expense of PRD as it has a

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high PRD compared to the proposed method. So, the QS results in figure 4.12 show that the results of the proposed method are the best compared with the rest of the previous methods.

Here, we conclude is that the proposed method has a good compression ratio with the lowest PRD value as it is much better than the rest of all methods.

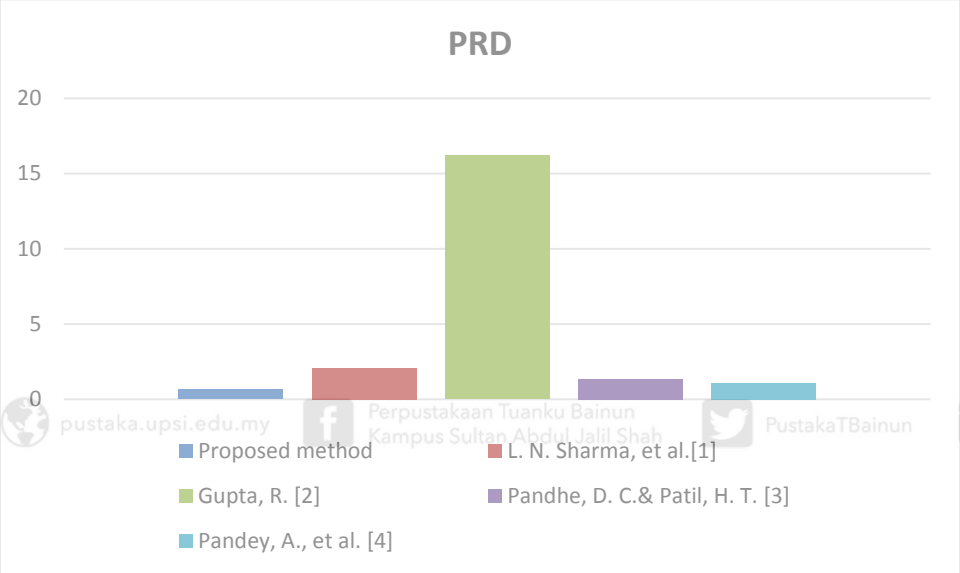


Figure 4.10 PRD Comparison

According to the Figure 4.10, the reference [1], refer to author L. N. Sharma, et al. (Sharma, Dandapat, & Mahanta, 2012). The reference [2], refers to the author Gupta, R. (Pandey, Singh, Saini, & Sood, 2016). The reference [3], refer to author Pandhe, D. C.& Patil, H. T. (Sharma et al., 2012). The reference [4], refer to author Pandey, A., et al. (Pandhe & Patil, 2014).

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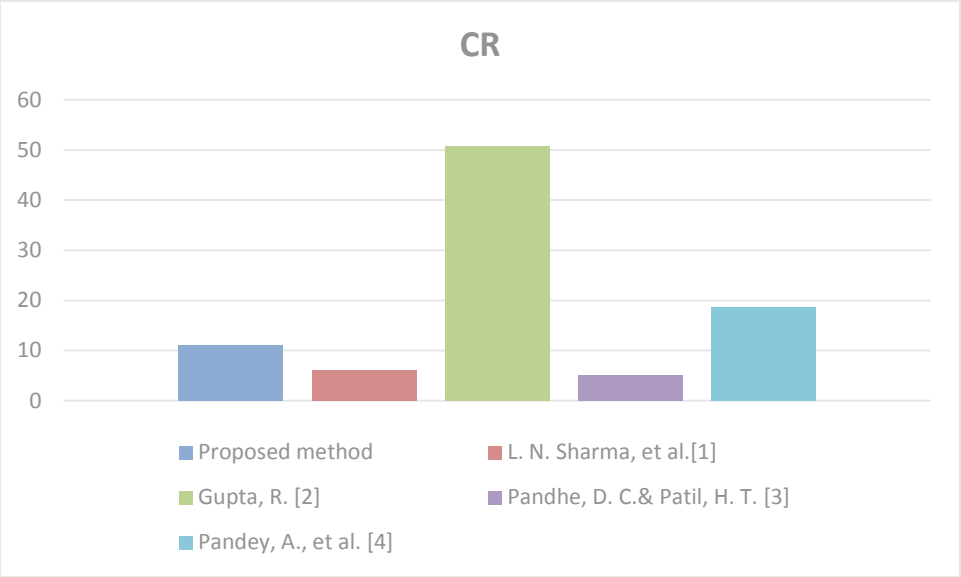


Figure 4.11 CR Comparison

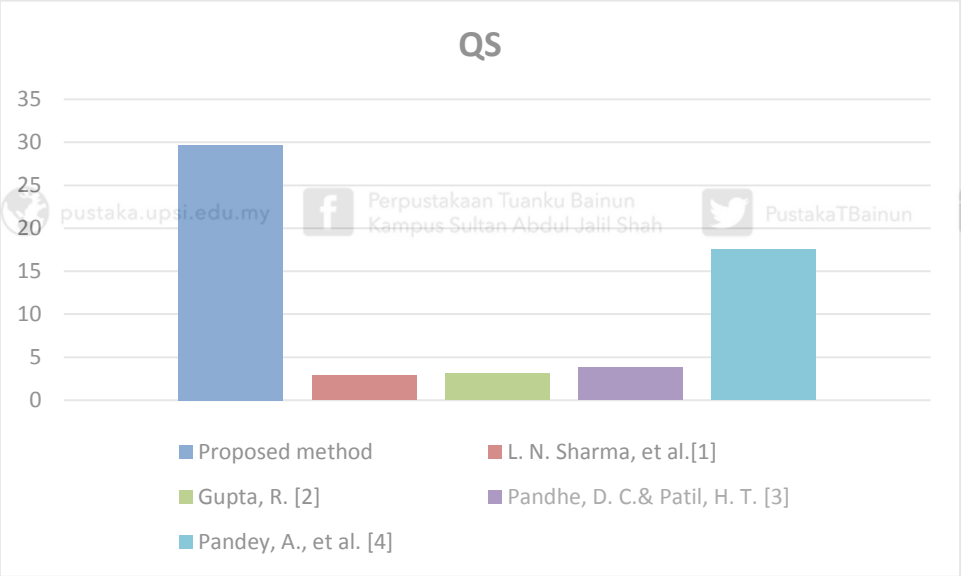


Figure 4.12 QS Comparison

Based on Figure 4.11 and Figure 4.12, the reference [1], refer to author L. N. Sharma, et al. (Sharma, Dandapat, & Mahanta, 2012). The reference [2], refers to the author Gupta, R. (Pandey, Singh, Saini, & Sood, 2016). The reference [3], refer to author Pandhe, D. C.& Patil, H. T. (Sharma et al., 2012). The reference [4], refer to author Pandey, A., et al. (Pandhe & Patil, 2014).

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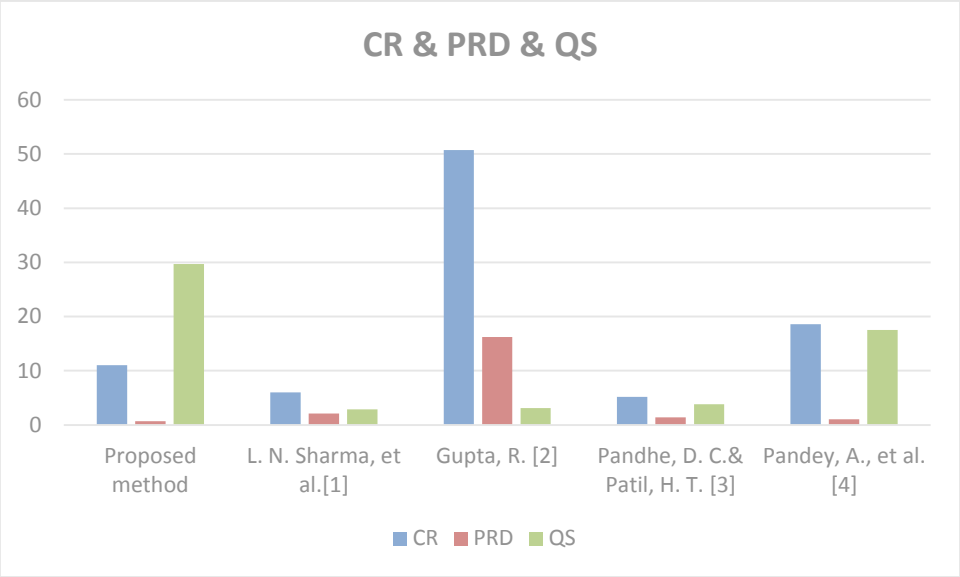


Figure 4.13 Over all Comparison

The reference [1] in Figure 4.13, refer to author L. N. Sharma, et al. (Sharma, Dandapat, & Mahanta, 2012). The reference [2], refers to the author Gupta, R. (Pandey, Singh, Saini, & Sood, 2016). The reference [3], refer to author Pandhe, D. C.& Patil, H. T. (Sharma et al., 2012). The reference [4], refer to author Pandey, A., et al. (Pandhe & Patil, 2014).

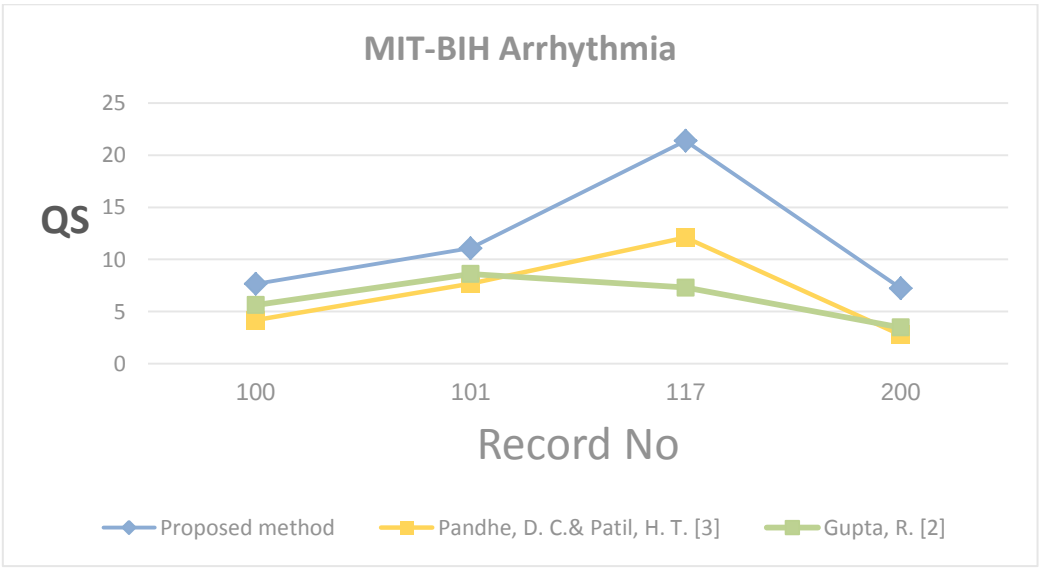


Figure 4.14 Comparison of QS based on the proposed method and Other Methods

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The reference [2] in the Figure 4.14 refers to the author Gupta, R. (Pandey, Singh, Saini, & Sood, 2016). The reference [3], refer to author Pandhe, D. C.& Patil, H. T. (Sharma et al., 2012).

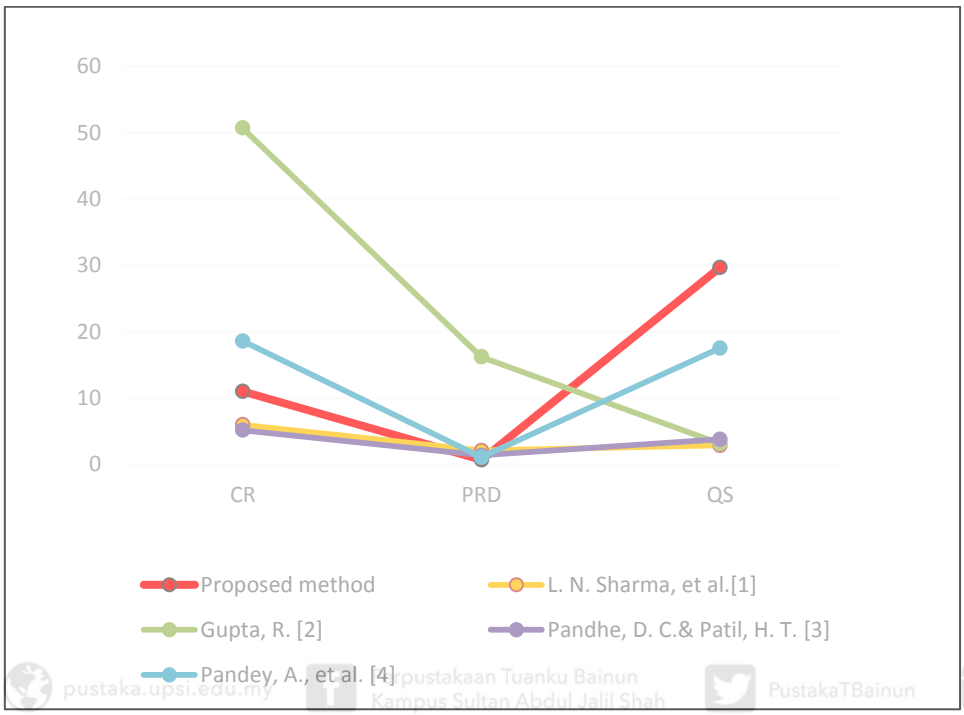


Figure 4.15 Comparison of CR, PRD, and QS based on the proposed method and other methods

Based on Figure 4.15, the reference [1], refer to author L. N. Sharma, et al. (Sharma, Dandapat, & Mahanta, 2012). The reference [2], refers to the author Gupta, R. (Pandey, Singh, Saini, & Sood, 2016). The reference [3], refer to author Pandhe, D. C.& Patil, H. T. (Sharma et al., 2012). The reference [4], refer to author Pandey, A., et al. (Pandhe & Patil, 2014).

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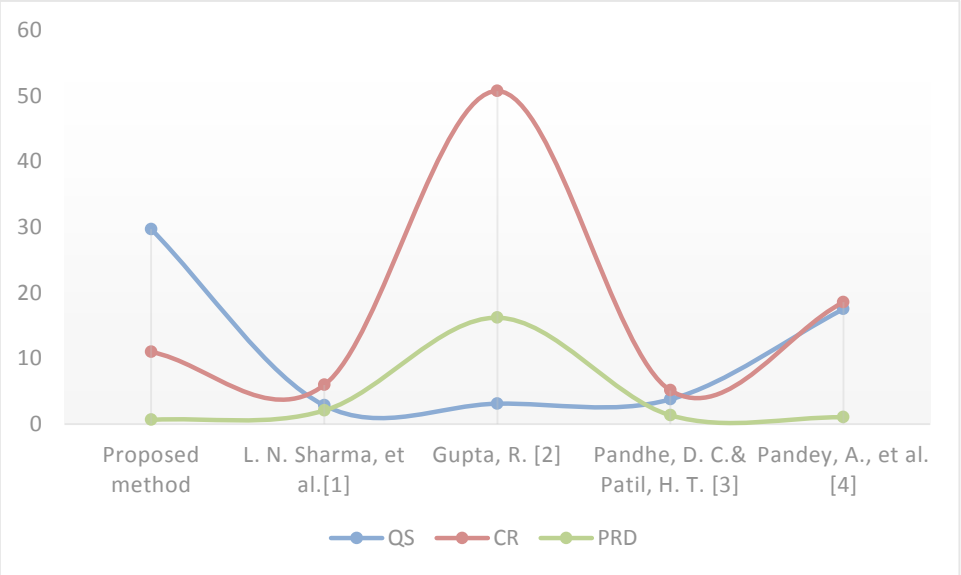


Figure 4.16 Comparison of CR, PRD, and QS based on the proposed method and Other Methods

Based on Figure 4.16, the reference [1], refer to author L. N. Sharma, et al. (Sharma, Dandapat, & Mahanta, 2012). The reference [2], refers to the author Gupta, R. (Pandey, Singh, Saini, & Sood, 2016). The reference [3], refer to author Pandhe, D. C.& Patil, H. T. (Sharma et al., 2012). The reference [4], refer to author Pandey, A., et al. (Pandhe & Patil, 2014)

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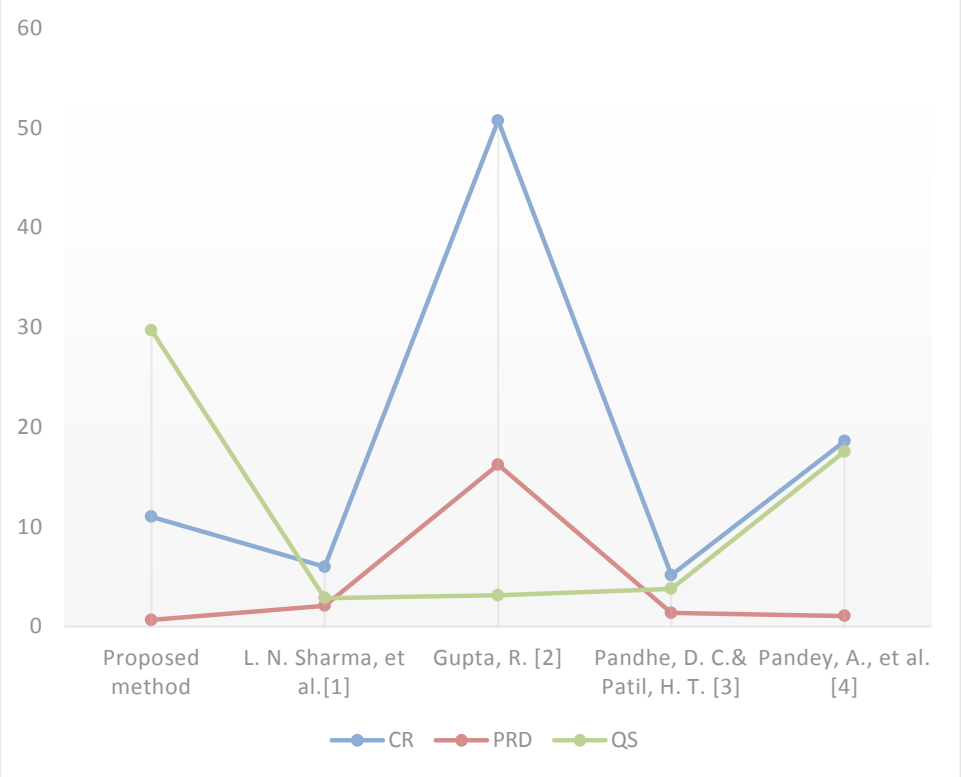


Figure 4.17 Comparison of CR, PRD, and QS based on the proposed method and Other Methods

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Based on Figure 4.17, the reference [1], refer to author L. N. Sharma, et al. (Sharma, Dandapat, & Mahanta, 2012). The reference [2], refers to the author Gupta, R. (Pandey, Singh, Saini, & Sood, 2016). The reference [3], refer to author Pandhe, D. C.& Patil, H. T. (Sharma et al., 2012). The reference [4], refer to author Pandey, A., et al. (Pandhe & Patil, 2014).

The blue color in the Figure above indicates that the highest value of the CR is obtained by the author Gupta, R. (Pandey, Singh, Saini, & Sood, 2016). As for the highest QS value obtained (Brown color), and the lowest value of the PRD was obtained (Green color) by our recommended method.

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4.9 Conclusion

Medical signal processing possesses significant functionality in conventional wellbeing care provision; as an instrument in the basic diagnosis, as well as guidance for remedial and restorative proceedings. The tendency is for the enhanced utilization of digital technological applications, which is principally driven by the benefits of digital repositories and transmission technology.

The expeditious evolvement in research and clinical procedures of signal archiving, in addition to communication schemes and digitalized telemedicine usages, alongside currently present norms for digitalized data interchanges added motivation for digitalized medical signal processing (Ramachandran & Bashyam, 2017).

The soft computing tools such as DWT and PCA are used for ECG signal compression. In DWT and PCA, a target bit rate is set, as this is compression schemes. The performance of DWT and PCA on the basis of the bit rate was compared. The performance of DWT and PCA with AES are good algorithms compared to existing algorithms, due to DWT is faster and maps quickly to the sub-band coding of signals, and basically, it gives multiple resolution decomposition of a signal. This tool is a powerful and influential method in the compression process, and methods based on DWT or PCA have been shown to perform well.

By this tool can compress ECG signal to several levels, due to wavelet-based methods offer good performance in terms of compression.

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In both the techniques, an interesting property of signal compression is verified, i.e. when the compression or decompression is verified during preprocessing, there are no artifacts (noise) are observed.

This phenomenon is very useful when the data loss occurs during transmission or because of storage media failure, where the reconstruction from a possible retained data.

The extremely high compression ratio and a very low bit rate can be achieved with these techniques, while objectionable artifacts occurring in the ECG signal can be avoided.

This tool used as a method to reduce the data dimensions for the purpose of achieving compression, while retaining as much of the information as possible in the original data. And used to remove redundant information.

In the first part, the DWT and PCA based method for ECG signal compression were compared. The DWT performs better without signal distortion. Hence DWT is focused and both QRS Regions and non-QRS Regions for ECG compression are presented. On the other hand, PCA takes the effective properties of the signal coming out of the DWT and applied it to MECG for the purpose of maintaining the important cardiac features of the diagnostic area.

In the second part of the research work, the emphasis was placed on coding and transmitting the biomedical signal for diagnostic purposes and giving the correct

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medical decision. Practically, the performance of DWT and PCA with AES is good algorithms compared to existing algorithms, due to DWT are faster and maps quickly for the sub-band coding of signals, and basically, it gives multiple resolution decomposition of a signal.

The performance of the algorithm is tested by five different records in MIT-BIH ECG arrhythmia datasets (MIT-BIH Arrhythmia Dataset (mitdb), Sudden Cardiac Death Holter Dataset (sddb), MIT-BIH Noise (Artifacts) Stress Test Dataset (nstdb), Non-Invasive Fetal ECG Dataset (nifecgdb), PTB Diagnostic ECG Dataset (ptbdb)).

A decompressed ECG signal for visual inspection of the quality of the reconstructed signal was presented. These reconstructed signals show excellent preservation of all important clinical information. The important characteristic of both algorithms is the dynamic nature through which reconstructed quality of the signal and the bitstream can be controlled by removing the spectral redundancy.

Experimental results obtained show that the proposed method offers average CR up to 11.0048 with PRD less than 0.66488 %, and QS equal 29.70604, which would be suitable for most ECG signal monitoring and diagnostic applications.

Both techniques DWT and PCA proved effective in cardiac signal compression with an acceptable distortion rate that does not affect the cardiac signal while maintaining important information in the diagnosis process.

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The limits of the proposed application compared to other technologies are summarized as follows:

1-Weakness of the bandwidth can lead to the system not working with all its efficiency and thus it becomes very slow or the response between sending and receiving is very slow too.

2- The application depends on the type of mobile device as the application works with its full efficiency on modern mobile devices with high RAM that is able to send large amounts of ECG signals with high transmission speed.

3- Lack of response to the patient, especially if the specialist's mobile device was closed.

4- The high momentum on the server used leads to slow in Sending/ Receiving ECG signals.

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CHAPTER 5

CONCLUSION AND FORTHCOMING ENDEAVOURS

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5.1 Introduction

This chapter introduces a summary of contributions, restrictions, and future work, of this research.

In Section 5.1, presents the introduction of this chapter. The conclusions review was introduced in Section 5.2. The research goals attained was described in section 5.3, while Section 5.4 reports the contribution of the research. Additionally, Section 5.5 displays research limitations. Finally, in Section 5.6, the Scope for Future Work is elaborated.

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5.2 Conclusions Review

The processing of biomedical signals is an important research field due to its wide variety of signals and obstacles encountered in medicine and biology. These signals are ranging from the traditional physiological signals like an electrocardiogram (ECG), to the very modern imaging modalities including MRI, PET and CT scan video data.

ECG is a form of a biomedical waveform that provides a lot of necessary information to physicians. It reflects many aspects of physical conditions that help to record patients' biomedical data for a long period of time.

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The main goal of the suggested research work is to implement modern hybrid algorithms for medical signal compression, like ECG signals by preserving its features and with better reconstruction quality.

Cardiology is monitored by a cardiologist, where the specialist can read the reconstructed ECG signals to identifying the imbalance, patient assessment, and then guiding the patient through the correct instructions.

The recorded data is abundant in size, therefore ECG compression is necessary. For clinical purposes, it is important to maintain the diagnostic features of the ECG signal during compression.

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The current study involves the selection of more ECG records for assessment purposes. The whole of the ECG samples uses original samplings at 360 Hz and digitized in 11 bits, whereby forthcoming study is able to evaluate ECG records using varying original sampling rate, in addition to the differing degree of resolution.

The simulation outcomes that tested over various records from the MIT-BIH database, shows that the performance of the suggested algorithm leads to high compression ratio (CR), associated with low distortion (low percentage root mean difference level PRD) if compared with algorithms of ECG signal compression that previously mentioned and referred to in the literature.

According to the outcomes which were tested and simulated in the records of the MIT-BIH database, the suggested hybrid method led to a significantly higher CR, with reduced distortion (low PRD) in the reconstructed signal based on the algorithms previously mentioned in the literature. The reconstructed signals show excellent preservation of all important clinical information. Experimental results obtained show that the suggested hybrid technique gives average CR up to 11.0048 % with PRD less than 0.66488 %, and QS equal 29.70604 %, which would be proper for most ECG signal surveillance and diagnostic applications.

Based on the proposed system, no relevant information loss is allowed, however, an efficient compression scheme has been proposed satisfying behavior in preserving features that are critical in medical diagnosis and interpretation.

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Based on the interesting area (IA), there are cases where the diagnosis depends on only one of these areas, such as (QRS-complex), and others are dependent on more than one area of IA such as (P-T-and U-waves). In such cases, there are more bits can be specified by IA to keep the signal fidelity while the rest of the signal (non-interest area (NIA)) can be subjected to higher compression. This can be reducing the size of ECG signal storage and transmission, without compromising critical medical information.

Data encryption has been used as a desirable feature in medical compression due to it protects the patient's privacy and it allows the data transmission to the physicians safely.

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5.3 Research Goals Attained

The links between the research objectives, the research methodology and the research contributions are defined to demonstrate and explain the achievement of the research objectives and to provide research advice. The research problem is how to retain the important diagnostic information within the reconstructed signal, preserve the reconstructed signal quality, reduce data capacity storage in order to ECG signal transmission rapidly.

To solve research problems, this research defines four main goals. For each objective, certain goals must be achieved. The goal of the first objective is to investigate the ECG signal compression quality for telemedicine purposes, while,

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propose an algorithm to integrate DWT and PCA to increase the efficiency in COMDEC process is the central goal of the second objective. The goal of the third objective is to propose a method to increase the efficiency in COMDEC process. Finally, the goal of the fourth objective to evaluate the ECG signal mobile device application for heart rate monitoring remotely (24/7) via telemedicine.

To attain the research objectives, the research methodology consists of main three phases. The mathematical morphological based on the preprocessing phase, the wavelet morphological based on the QRS processing phase, and finally, applying DWT and PCA based on the compression and reconstruction phase.

There is a corresponding phase for each goal that describes the main conclusion of the research contributions, these phases are, the adequate denoising performance phase, high detection accuracy phase, and the balance between the high CR and low PRD. All these phases lead to a high ECG signal fidelity that preserving a clinical information quality of the reconstructed signal. The links between the objectives of the research, the phases of the research methodology and the objectives of the research in each phase are presented in Table 5.1.

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Table 5.1

The Links Between Research Objectives, Research Goals, and Research Methodology

Research Objectives		Phases	Research Methodology Research Goals
1	To Investigate	Phase: 1 Preliminary Study	• Literature analysis and critical review for ECG signal compression, methods, and techniques. • Figure out the gabs and the main challenge.
2	To Propose	Phase: 2 Identify	• Propose an algorithm to integrate DWT and PCA to increase the efficiency in COMDEC process.
3	To develop	Phase: 3 Development	• Implement and develop a new methodology for ECG signal compression based on DWT and PCA.
4	To Evaluate	Phase: 4 Evaluation	• Evaluate the ECG signal mobile device application for heart rate monitoring remotely (24/7) via telemedicine.

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5.4 Research Contributions

The research contributions have mainly developed a methodology to:

1- Building an efficient and reliable application for ECG signal COMDEC, 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.

2- Develop an algorithm for integrating DWT and PCA, so that it gives a high efficiency in the COMDEC process with preserving important medical information in the reconstructed signal.

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3- Sending an ECG signal (24/7) from the patient to the physician and vice versa rapidly and with minimal losses with preserving the medical significant information in the target ECG signal.

5.5 Limitations of the Research

There are some restrictions in most researches that require its solution in future research. This research includes some restrictions due to the scope of the study. The encountered problems during the compression process were limited by increasing the CR of the transmitted signal, which increased the distortion rate. Therefore, The ECG signal receiving by the physician are unclear and not understandable, due to, the important medical information for medical diagnosis is completely distorted. Therefore, a threshold has been established to create a balance between CR and PRD to enable the creation of an efficient application capable of compressing the ECG signal significantly while maintaining the signal accuracy transmitted through high QS as well as reducing the difference between the original signal and the restored signal by obtaining a low PRD value in order to receive a clear and readable ECG signal by the physician.

5.6 Scope for Future Work

The research contributions have mainly developed a methodology for compression and decompression for ECG signals for telemedicine purposes. This methodology can

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also be adopted by compression and decompression of the EEG signal (electroencephalogram) to evaluate the brain functions and brain disease diagnosis. In addition, it demonstrates the value of using CR, PRD, QS that on the basis of which the patient is medically evaluated. This methodology proved to be effective by discussing and evaluating the outcomes. The work presented in the thesis can be extended to:

1. To construct a more superior EEG signal coding in order to enhance the EEG signal compression for the purpose of diagnosing ailments associated with the brain.
2. To construct a more superior EEG signal coding in order to boost the EEG signal compression through the utilization of alternative hybrid algorithms (comparison between two algorithms or more).
3. To explore a better quantization techniques for improvement in CR for ECG signal.

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Journal Article Publication 1

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AN EFFICIENT METHOD OF EEG SIGNAL COMPRESSION AND TRANSMISSION BASED TELEMEDICINE

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ABSTRACT

In this article, an efficient algorithm for EEG signals compressing and transmission based on RLE and DWT was introduced. The compression ratio (CR) provided by this algorithm is relatively high with low percent root-mean-square difference (PRDN) values. 50 records of EEG patients were monitored from the life database. Each record of EEG signals is commonly reported at the sampling rates in clinical and research settings between 250 and 2000 Hz. On the other hand, the new EEG data collection systems are able to record at sampling rates more than 20,000 Hz. The signals can be analyzed in both the time domain (TD) and frequency domain (FD) under using DWT where it preserves the necessary and main features of the EEG signals. Next step to implement this proposed algorithm is using the thresholding and the quantization over EEG signals coefficients and then encoded the signals by using RLE that enhancement significantly the compression ratio (CR). This article presents a robust method of EEG signal compression and transmission consists of DWT (discrete wavelet transform) and RLE (run length encoding) in order to improve and enhanced the compression. The suggested model presents an average values of CR (compression ratio), PRD (percentage root mean square difference), PRDN (normalized percentage root mean square difference), QS (quality score), and SNR (signal to noise ratio) of 44.0, 0.36, 5.87, 143, 3.53 and 59.52 alternately over 50 records of EEG data.

Keywords: *Encephalopathy, Run-Length-Encoding(RLE)-Discrete Wavelet Transform(DWT); Compression Ratio(CR);Telemedicine, Savitzky–Golay filter(SG filter).*

1. INTRODUCTION

Since a long time, developing countries have been the biggest medical challenge in the world. Healthy rural areas provided the best opportunities for attracting professionals and diverse medical facilities. A telemedicine proved a strong base for rural regions in this regard. The term of telemedicine is a technological application for communication for medical data transmission and receiving and consulting between patients and specialists for healthcare in remote rural areas.

Through telemedicine, medical data can be sent remotely from remote areas to the appropriate doctor's premises and vice versa. After analyzing a medical data received from patients, sensitive medical consultations can be sent from caregivers to the remote areas in order to obtain appropriate healthcare for patients. By using the telemedicine, the people in the rural regions can be can benefited by caregivers (doctors and specialists). Recently, chronic diseases, (such as encephalopathy), are the first cause of death in the world and rising exponentially. This is a caused by a great concern to caregivers as brain experts are unavailability in those remote rural areas. This trouble can be solved by using a telemedicine app. Using telemedicine, the data of EEG can be sent /received from rural areas to encephalopathy caregivers centers.

For better health monitoring of encephalopathy patients, caregivers can send and received a medical consultation to the remote regions after received and analyzed an EEG data. The EEG can be defined by electrophysiological signals caused by the human brain. One of the essential obstacles of better transmission via telemedicine is a huge continuous EEG data. To reduce the size of EEG data, A compression techniques can be employed. EEG data compression causes data to be transmission efficiently via telemedicine.

Fig. (1) below, show the various electrodes locations of EEG signals acquisition.

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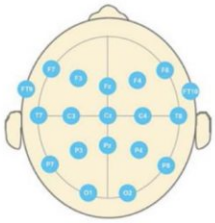


Figure 1: Electrodes locations of EEG signals acquisition

2. THE QUALITY ON-DEMAND COMPRESSION ASSESSMENT

A higher compression can be performed by decreasing the quality of the reconstructed signal and vice versa.

A clear trade-off can be made for the good quality of the decoded signal with an important amount of compression. With the applications of telemedicine, specialists in the receiving side must adjust certain parameters interactively associated with compression algorithm according to specialist's quality interests.

There are two factors, namely, bits per sample (BPS) and percent of root-mean-square-difference (PRD) define the quality on-demand terms, rarely, bandwidth constants and reconstructed signal quality, sequentially. This article describes the quality of on-demand compression plan for EEG signal using hybrid proposed technique consists of DWT and RLE respectively.

The fidelity of the EEG reconstructed signals are measured quantitatively by four parameters, namely, SNR, PRD, PRDN, QS, and CR. For EEG signal compression, there is two-step of lossless compression plans including anticipator in the first step with an entropy encoder in the second step have been used successfully. Here, the main purpose of the predictor is to calculate the existing value of a sample using its past samples and then transmit only the error (signals residues), which are generally smaller and the size of the original samples. Both of the encoding and decoding simulate a symmetrical prediction process.

The prediction method begins with the transmission of initial header information and the selected number of input sample values. On the receiver side, the prediction method is returned and the original input is restored by adding structural units sent to the expected values. If the error signals are sends based-on specific threshold values followed by quantification, there is a probability of best compression, and it may medically accepted as long as the reconstructed signal maintains the expected diagnostic features. The efficiency of the compression can be more enhancement by using an arithmetic entropy encoder in the second step. We can be performed a higher compression by decreasing the reconstructed signal quality and vice versa.

The main purpose of the proposed compression technique is to gain the reconstructed EEG signal suitable for clinical diagnosis at CR and PRD. The threshold and quantification effect determines the quality standards on-demand, and a better balance is achieved between CR and PRD for clinical examination. For the transmission and receiving in the telemedicine, there is one can be guaranteed the quality of diagnostic of the reconstructed EEGs based-on relevant election of the fidelity criteria with the utilization of effective low-bandwidth.

Based on outcomes shown in Table 3, that the proposed scheme was found achieves acceptable results if comparing with other methods

3. RELATED WORKS

To satisfy the article requirements, a survey of authors working in the field of EEG signal compression is conducted to carry out good and advanced applications with optimal operation. The survey includes a comparison between the various methods proposed and the transition between these methods for the purpose of achieving the best pressure for brain signals.

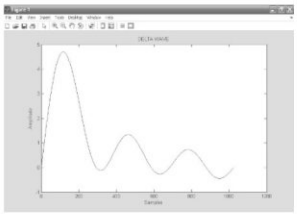
Sangjoo Lee, Jungkuk Kim, Myoungho Lee [1] presented the different methodologies for biosignal compression. This article concentrated on real time methods for a periodic biosignal, which supports to services of the e-health. A main author includes a real-time compression and transmission algorithms. The proposed algorithm of this article points significantly best performance if compared with the performance levels of other algorithms. N.Sriraam, C.Eswaran [2] introduced a compression presentation of linear and artificial neural network performance for the near-loss pressure of the EEG signal. The intended near lossless metod produced a real-time transmission with offline EEG signals over remote place economically and having less bandwidth exploitation compared other lossless and near-lossless schemes. N. Sriraam [3] has taken a

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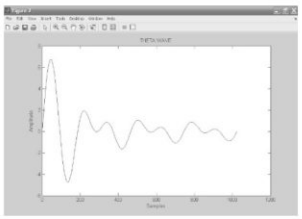
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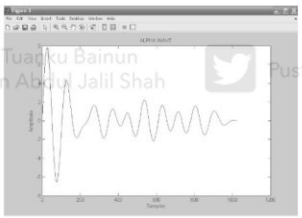
problem method to perform the best compression outcome by using artificial neural network predictor. The EEG signal reconstructed is evaluated and estimated by using PRD, SNR, cross-correlation, and power spectral density parameters. With low-value PRD and single layer perception, the reconstructed signal can be retained for important information. It provides the best compression outcome if compared with lossless methods. Yu-Ting Pai,Fan-Chieh Cheng,Shu-Ping Lu, and Shanq-Jang Ruan [4] has displayed a low bit rate transmission method. The new contribution in the proposed method is the stuffing bit can be decreased conspicuously while retaining a high compression ratio. Tao Ma, Pradhumna Lalshrestha, Michael, Hempel, Dongming Peng, Hamind Sharif &Hsiao-Hwa Chen [5] have been mentioned on developments in energy saving communications, high-quality transmission, and security. With a proposed scheme to decrease the transmission bits under the same CR (compression ratio) and the proposed scheme can be utilized for multimedia data transfer. M. Somasundaram and R.Shivakumar, have reported a survey on the cases related to the security and possible outcomes utilized to address them in the study and the forthcoming IEEE standard. The survey displayed that the popularly proposed outcomes in the security are still having restrictions needing more research and then, the survey also mentioned more areas of research being proposed in the literature [6]. N. S. [7], present presents a novel and efficient high-performance lossless EEG compression using WT and ANN predictors. Z. Z. et al. [8], present a proposed study to use the structure of block sparse Bayesian learning, which has superior efficiency to another existing compressed sensing algorithms in retrieve non-sparse signals to overcome the problem of EEG is not sparse signals in the time-domain not sparse in transformed-domains. D.D. et al.[9], present an efficient method for single or multichannel EEG compression using EZW method as this method gives gradually encoding which can be stopped anywhere or depending upon required bit rate. S.U et al. [10], present a new and easy preprocessing method of arranging EEG in matrix form before compression. R.M.[11], present a high-performance hybrid multichannel EEG compression algorithm based-on frequency transformation and parameter extraction methods. S. C. et al.[12], improve an effective algorithm EEG lossless compression by using the WT followed by AC(arithmetic coding) on the residual. K. et al.[13], developed a lossless hybrid EEG compression method based on the characteristic of DCT frequency spectrum and the Huffman coding. Below fig.(2), show the different kinds of EEG waves. The following fig. (1 to 5) and table 1, illustrates the different types of EEG waves.



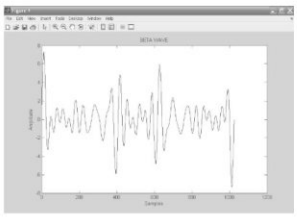
(a)



(b)



(c)

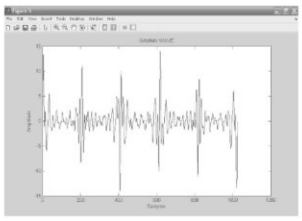


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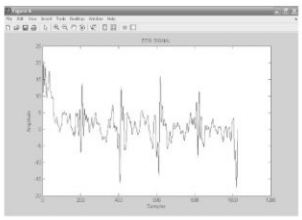
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(d)



(e)



(f)

Figure 2, Types of EEG waves, a. Delta Wave b. Theta Wave c. Alpha Wave d. Beta Wave e. Gamma Wave f. Input EEG Signal

Table 1, Different types of brain waves in normal EEG

Ryhthm	Frequency (Hz)	Amplitude (uV)	Recording & Location
Alpha (α)	8-13	50-100	Adults, rest, eyes closed, Occipital region
Beta(β)	14-30	20	Adult, mental activity, Frontal region
Theta(θ)	5-7	Above 50	Children, drowsy adult, emotional distress
Delta (δ)	2-4	Above 50	Children in sleep

4. RESEARCH OBJECTIVE :

The aim of this system is offering a reliable Hardware/Software solution for EEG diagnosis. Moreover, the system is targeted for telemedicine, thus the needs of compression and transmission are therefore at the very core of this system.

In order to solve this problem, proposed a new system-level architecture consists of DWT and RLE to transmit a compressed ECG signal during the acquisition.

This system is based on an acquisition device that is based on compression. When the EEG signal acquisition is done, the data are compressed and transferred to a remote server until the interpretation is performed by an expert. When the EEG signal acquisition is done, the data are compressed and transferred to a remote server until the interpretation is performed by an expert. Here, compression of the EEG signal is important, due to reducing the data size and minimizing the transmission time.

The main goal of the EEG signal compression is

1. Signal compression with adequate size.
2. Preserve the most valuable clinical information.
3. Provide a minimal loss in signal fidelity while maximizing CR

5. LOSSY COMPRESSION

Lossy data compression reduces bits by analyzing unnecessary information and removing this unwanted information.

From all available data lossy compression techniques, DWT is most efficient compression technique needs to be chosen due to[30]:

1. DWT is a powerful and influential method in the compression process, and methods based on DWT have been shown to perform well.
2. Have a little impact on the EEG signal data
3. Can compress EEG signal to several levels, due to wavelet-based methods offer good performance in terms of compression.
4. DWT is perfect for non- stationary signals compression.
5. Basically it gives multiple resolution decomposition of a signal
6. DWT is faster and maps quickly to the sub-band coding of signals.

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6. THE SCENARIO OF EEG SIGNALS COMPRESSION

6.1 Compression Phase

1. Preprocessing of EEG signals

The example of the EEG signal contains a noise in the power line. Therefore, it is necessary to extract the precise EEG characteristic to eliminate this noise. To create the proper pre-filter for the elimination of signal noise, each EEG signal is decomposed with the frequency response. The selected signals have a sampling frequency of 360 samples / second. Therefore, using the Nikyst standards, the frequency response range was selected from 0 Hz to 180 Hz. The signals are displayed in the frequency range from 0 Hz to 50 Hz in the lower range and from 130 Hz to 180 Hz. Hz. On a larger scale. Therefore, a notch filter of comparable ranges can be used for the pretreatment of EEG signals. When the original signals have a high resolution, these signals may be inactive. The sampling frequency of these real (original) signals is 360, then the original signal is sampled by a factor of 2. The fig.(3) described below show the normal EEG signal sample

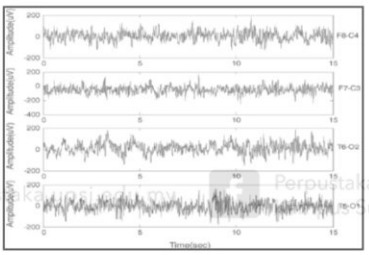


Figure 3: Normal EEG Signal Sample

The example of the EEG signal contains a noise in the power line. Therefore, it is necessary to extract the precise EEG characteristic to eliminate this noise. To create the proper pre-filter for the elimination of signal noise, each EEG signal is decomposed with the frequency response. The selected signals have a sampling frequency of 360 samples / second. Therefore, using the Nikyst standards, the frequency response range was selected from 0 Hz to 180 Hz. The signals are displayed in the frequency range from 0 Hz to 50 Hz in the lower range and from 130 Hz to 180 Hz. Hz. On a larger scale. Therefore, a notch filter of comparable ranges can be used for the pretreatment of EEG signals. When the original signals have a high resolution, these signals may be inactive. The sampling frequency of these real (original) signals is 360, then the original signal is sampled by a factor of 2 [13][28].

2. Peak detection:

The highest signal peaks are detected during the peak detection method. The proposed peak detection technique depends on the characteristics of the EEG signal. One of the characteristics of the EEG is the amplitude of the maximum threshold. the amplitude of the threshold is the value of the minimum possibility of the peak. Values below this threshold are not maximum. The second EEG attribute is the minimum distance between the vertices of the bottom part). The advanced detection method that is suggested here is described. First, specify the maximum value in some samples. If the maximum value is greater than the threshold, the peak is taken into account. Samples adjacent to the previously discovered peak may be larger than the maximum threshold amplitude. Therefore, to detect the next peak, all neighboring samples are removed from the current detected peaks. This will prevent the detection of pseudo-peak samples adjacent to the recently detected peak [14].

3. Linear transformation:

The EEG signal is evaluated in several shifts. Each round consists of a sample between two sequential peaks. Each EEG shift, a separate FFT is calculated. The FFT values are measured for the storage objective. Different quantification factors ranging from 0: 1 to 4 are chosen to analyze the impact of the quantification.

4. Entropic coding (Hoffman coding):

The Huffman coding is chosen for entropy coding. Because the repeated EEG signal, FFT can be predicted. Some of the FFT values occur with high probability. After calculating an FFT, a histogram is considered for each FFT value. The frequency graph shows the occurrence of each of the FFT values. Therefore, the probability of each FFT sample value can be calculated. Most of the FFT sample values were found to range from -20 to +20. Other values are unpredictable [15].

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6.2 Eeg Signals Reconstruction Phase:

The reconstruction phase of the EEG signals or the decompression procedure is the reverse compression procedure. This decoding phase comprises the encoded entropy signal, the inverse linear transformation and the post-processing. The constructed EEG signal is created to regenerate. The EEG signal is given as input to the decompression process [16].

6.2.1 Decoding of the entropic encoded signal:

There are two types of bits encoded in a compressed signal. First, a transmission containing Huffman coding codes is transmitted to the Huffman decoder. The Huffman Decoder decodes the bits using the Huffman Dictionary. Then, the second bitstream decoder, which does not have Huffman coding codes. The values of the second bit sequence contain the DWT values and their indices in the original vector. The values of these indices are assigned to the Huffman block previously decoded with the aforementioned DWT values in the second bit stream [17].

6.2.2 Reverse linear transformation:

DWT was used for the linear transformation in the compression stage. Therefore, the discrete transformation of discrete wavelets (IDWT) is used in the reverse process. An IDWT is calculated for each cycle. Each turn depends on a sample between two consecutive peaks. The result of the reverse entropy coding is divided into several cycles based on peak indicators. Then it is fed to the EFT block. The output of the EEG signal will be reconstructed with a certain tolerance due to the quantization used in the compression phase[18].

In postprocessing phase, the IFFT signal is fed to the samples. Then, the sample output is fed to the post-stop band filter. A generated signal reconstructs the EEG signal. This is compared to the original reference to estimate the performance of the suggested technique [19].

7. MATERIALS AND METHODS

7.1 Overview

EEG (Electroencephalography) involved a recording of the electrical potential stimulated by the scalp.

The proposed method consists of two phases : compression phase and decompression phase as shown in figures(4). Compression phase show both the EEG signals compression that is used at transmitter side (the patients) via telemedicine, and decompression phase is the EEG signals decompression at the receiver side(the specialists) via telemedicine[20].

To achieve the compression process, there are 50 EEG signals records related have been preprocessing before backward signal difference (BSD) is applied. The preprocessing begin with filtering the EEG signals to reduces the power line interference of 50 Hz, and then applied backward signal difference for EEG signals which lossless compresses by 50%. After that, applied DWT for EEG signals after applying and implement threshold and quantization grades of these signals[21,22].

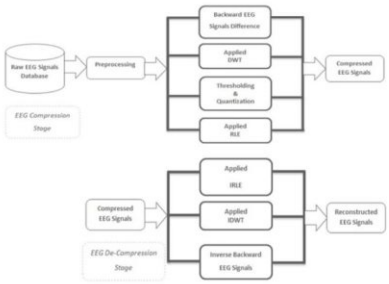


Figure 4: Two Stages of EEG Signals processing – Compression and Decompression (Reconstruction)

7.2 Savitzky–Golay filter (SGF):

A digital filter (also called DSP filters (digital smoothing polynomial filters)), used for signals data smoothing to set of digital data points in order to improve SNR (signal-to-noise ratio) without signals data deforming. SG filter smoothing filters present a better standard averaging FIR filters, which results in the filtering of a large portion of the high-frequency digital signal content along with the noise. The SG filter is very effective conserve a high-frequency component of signals if this signals compared with finite impulse response (FIR) filters. In the figure(5) below demonstrate the original EEG signals with using Savitzky –Golay filter [23].

In order to achieved moreover signals compression at the transmitter side, RLE is

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applied. At the reconstruction side, applied inverse run length encoding (IRLE) and inverse discrete wavelet transform (IDWT), and finally applied backward difference[31].

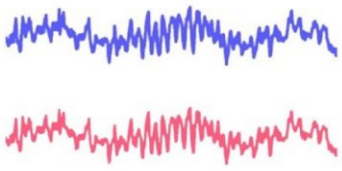


Figure 5: (a) The Noisy original EEG Signal and, (b) Enhanced EEG Signal after applied SG Filter.

7.3 Compression with Wavelet Transform

The wavelet transforms analysis (WTA) of EEG signal can be achieved in both time domain and frequency domain, and it also retains very well of the local features of the signal. Then, it is fitted well for use in the biomedical signal compression, where it preserves the features of the EEG signal safety[24].

In the time domain, a function of mother wavelet is ψ (t) with zero average, according the below equation (1):

$$\int_{-\infty}^{+\infty} \psi(t)dt = 0 \qquad (1)$$

The function of daughter wavelet with parameter p (scale parameter) and parameter q (translation parameter) can be represented by the following equation (2):

$$\psi^{p,q}(t) = \frac{1}{\sqrt{p}}\psi\left(\frac{t-q}{p}\right) \qquad (2)$$

Wavelet transform can be calculated for a function x(t) by using the cross-correlation of x(t) function of daughter wavelet ψp,q (t) according the below equation (3):

$$Xw\ (p,q)=\frac{1}{\sqrt{a}}\int_{-\infty}^{+\infty} x(t)\psi * \left(\frac{t-q}{p}\right) dt \qquad (3)$$

According to the equation (3), the digital implementation for this equation is DWT.

7.4 Compression with RLE

Run length encoding (RLE) has been utilized to encode transform coefficients of EEG signal which is repeated in nature. DWT coefficients include a long run of data and can be collected as a single data value. RLE uses redundancy of data and it provides an improvement of compression ratio (CR) of EEG signal[25].

7.5 Performance Parameters

The effectiveness of an EEG compression method can be sentenced by both parameters, a compression efficiency, and the error criterion. These parameters include the ability of compression method to reconstruct the EEG signal and to conserve the relevant information.

To test the quality of reconstruction signal, the following performance parameters are used:

7.5.1 Compression Ratio (CR)

(CR) can be defined as the ratio of the original signal size and compressed signal size. The CR provides information about the degree by which the compression algorithm eliminates the unnecessary data. Higher the CR, less the number of bits needed to store or transmits the data which can be defined as a below equation (4):

$$\text{Compression Ratio (CR)} = \frac{\text{The size of original signal in byte}}{\text{The size of reconstructed signal in byte}} \qquad (4)$$

If the (CR) is a high value, it means a high compression performance.

7.5.2 The Percentage Root Mean Square Difference(PRD%)

The Percentage Root Mean Square Difference (PRD%) used to measures the error between the original signal and the reconstructed signals and can be described as a following equation(5)[26]:

$$PRDN = \sqrt{\frac{\sum_0^{N-1}(X(n)-Y(n))^2}{\sum_0^{N-1}(X(n)-\text{mean }(Xn)))^2}} \times 100\% \qquad (5)$$

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7.5.3 The Quality Score (QS)

The Quality Score (QS) can be described as a following equation(6):

$$\text{Quality Score (QS)} = \frac{\text{CR}}{\text{PRD}} \quad (6)$$

A high value of QS refer to a high quality of compression[27].

7.5.4 The Root Mean Square Error (RMS)

The Root Mean Square Error (RMS) provides a measure of the error in reconstructed signal with respect to the original signal , and can be described as a following equation (7):

$$\text{RMS} = \sqrt{\frac{\sum_0^{N-1}(X(n)-Y(n))^2}{N-1}} \quad (7)$$

7.5.5 The signal to noise ratio (SNR)

The signal to noise ratio (SNR) can be described as the following equation (8):

$$\text{SNR} = 10 \times \log\left(\frac{\sum_0^{N-1}(X(n) - \text{mean}(X(n)))^2}{\sum_0^{N-1}(X(n) - Y(n))^2}\right) \quad (8)$$

The dataset of the EEG signals from the Florida university[28].

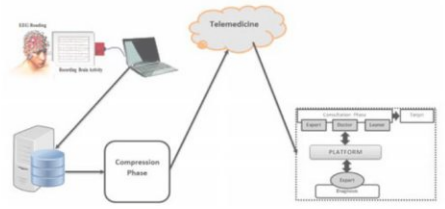


Figure 6: Overall System Structure

8. RESULTS AND DISCUSSION

This section explains the performance evaluation of the proposed method for 20 patients records of EEG data taken from Florida university database. The results of the compression are shown in Table 1.

Table2 , Compression outcomes of the proposed method

Patient Rec. No.	PRD	PRDN	RMS	SNR	QS	CR
Rec.10	0.23	7.34	2.16	53.8	167	39.9
Rec.11	0.18	4.48	1.73	59.4	267	48.7
Rec.12	0.5	15.5	5.32	69.5	55.5	27.9
Rec.13	0.33	5.59	3.19	58.9	100	33.9
Rec.14	0.34	7.02	3.71	55.2	217	75
Rec.15	0.34	5.62	3.4	55.8	169	59
Rec.16	0.36	5.73	3.34	58	180	65.2
Rec.17	0.66	4.71	7.63	59.5	59.6	39.6
Rec.18	0.30	10.00	3.47	61.2	249	75.2
Rec.19	0.38	5.06	4.17	60.8	99.7	38.6
Rec.20	0.18	2.73	1.54	72	248	45
Rec.21	0.24	6.10	2.54	61.4	188	46.1
Rec.22	0.22	5.12	1.9	60.7	244	53.9
Rec.23	0.32	4.06	3.18	62.6	149	48.3
Rec.24	0.21	9.51	2.04	64.3	201	42.9
Rec.25	0.28	4.30	2.59	61.8	164	46.8
Rec.26	0.50	3.75	4.15	62.7	76.9	38.7
Rec.27	0.31	6.40	2.78	61.4	148	47
Rec.28	0.67	7.1	5.71	51.2	63.6	42.6
Rec.29	0.47	3.42	3.95	63.4	81.8	38.5

The original EEG signal and the reconstructed EEG signal, and the error signal for the record no. 10 are shown in Fig. 6 and it is clear that the reconstructed EEG signal retains the characteristic features of the original EEG signal very well.

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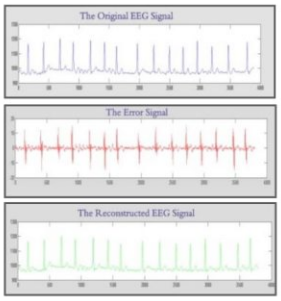


Figure 7: Three samples implementation of the record 10

Based on the outcomes shown in table 2, it's clear that the performance of the proposed method provides a better compression than the other algorithms as shown in the records no. 10, 27 and 29 has been shown in Table 3.

Table 3, Comparison between the Compression Results

Method	CR	PRD
Darius Birvinskas et	2.66	10.33
Hakan G¨urkan et al (2009)	14.4	8.01
S.Chitra et al.(2015)	1.8347	0.0802
Seema .A.Taywade et al.	21.30	1.75
The proposed method	39.9	0.23

Fig. 7, refer to the CR and PRD values plots for 10 - 21 records of EEG signal. From these plots, it can be seen that there are not important variation in CR and PRD values. It means that the proposed algorithm is proper for compression and transmission of various morphologies of EEG data.

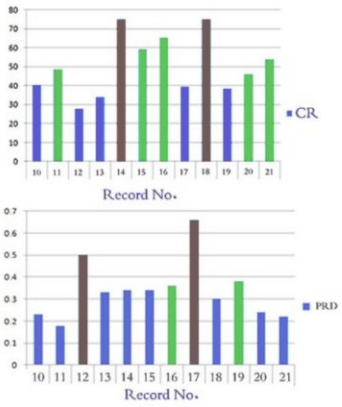


Fig. 7, Parameters of CR and PRD plotted from 10 – 21

The below fig.(8), show the input EEG signals and extracted the EEG output signals with different types of EEG signals:

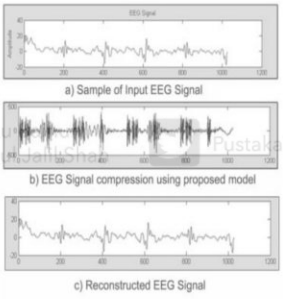


Figure 8: Samples of input, Compressed, and Reconstructed EEG signal

9. CONCLUSION

The EEG data compression still a significant issue, despite the vast improvement in the storage capacity and the transmission speed in the pathways of the communication. This is because their diagnostic features, which set a common attempt to all compression aspects i.e., efficient

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EEG data compression and transmission yet unaffected diagnostic features.

The attempts continued to improve detection algorithms but their performance is still not perfect. There is still room to enhance the parameters such as compression ratio, bandwidth, signal-to-noise ratio (SNR), quality score (QS), interconnection, data reliability and quality of service, the security and the privacy to meet the real-time challenge of compression and transmission of EEG data.

This article presented an efficient compression and transmission hybrid proposed technique using DWT (discrete wavelet transform) and RLE (run length encoding).

Compression outcomes of the proposed technique have been compared with other techniques and it is found that it gives the best performance. The proposed hybrid technique gives a high compression ratio and very less PRD (%), hence the features of the original EEG signal are preserved very well through the reconstructed signal.

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Journal Article Publication 2

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Recruitment Internet Of Things For Medical Condition Assessment: Electrocardiogram Signal Surveillance

Reclutamiento Internet De Cosas Para La Evaluación De La Condición Médica: Vigilancia De La Señal De Electrocardiograma

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ABSTRACT/ Recently, the world has witnessed a significant increase in attention to healthcare sensing and surveillance. For surveillance purpose of cardiac patient, the physiological information acquisition is very significant as many chronic patients can interest from continuous surveillance as a part of a diagnostic procedure. The internet of things is becoming a promising future for various applications. One of its operations is to monitor the physiological signals of patients with cardiac diseases, which can be measured by wearable wireless sensor networks. In this paper, a complete real-time surveillance Electrocardiogram system that monitors patients in various environments is presented. This system is consists of Arduino LIKE system with wireless sensor networks connect directly on the patient body by many electrodes which connect directly with PC to implement a complete connection to the internet. To guarantee a stored Electrocardiogram signal safely and quickly without any distortion through transmission, and to guarantee the compatibility of these signals through the processing, the authenticated Blynk server was used with its software app. Keywords: Internet of Things; Electrocardiogram; Wireless Body Sensor Network; Arduino LIKE.

RESUMEN / Recientemente, el mundo ha sido testigo de un aumento significativo en la atención a la detección y vigilancia de la atención médica. Para fines de vigilancia del paciente cardíaco, la adquisición de información fisiológica es muy significativa ya que muchos pacientes crónicos pueden interesarse por la vigilancia continua como parte de un procedimiento de diagnóstico. El internet de las cosas se está convirtiendo en un futuro prometedor para diversas aplicaciones. Una de sus operaciones es monitorear las señales fisiológicas de los pacientes con enfermedades cardíacas, que pueden medirse mediante redes inalámbricas de sensores portátiles. En este documento, se presenta un sistema completo de electrocardiograma de vigilancia en tiempo real que monitorea a los pacientes en diversos entornos. Este sistema consiste en un sistema Arduino LIKE con redes de sensores inalámbricos que se conectan directamente en el cuerpo del paciente mediante muchos electrodos que se conectan directamente con la PC para implementar una conexión completa a Internet. Para garantizar una señal de electrocardiograma almacenada de forma segura y rápida sin ninguna distorsión a través de la transmisión, y para garantizar la compatibilidad de estas señales a través del procesamiento, se utilizó el servidor Blynk autenticado con su aplicación de software.
Palabras clave: Internet de las cosas; Electrocardiograma; Red inalámbrica de sensores corporales; Arduino como.

I. INTRODUCTION

According to the institution of the World Health Organization, recently, cardiac disease has become a serious and fatal disease that causes death to people. Therefore, the disease cannot be seen as a minor disease. Consequently, most health surveillance systems are designed to track the disease [1].

With the development of technology and electronic industry, medical data collection has become much easier. Electrocardiogram devices are smaller, have lower weights and also have lower power consumption, making them one of the most basic medical diagnostic systems in any health care center or hospital. The heart attack is the most common cardiac disease that causes sudden death, which is the

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public cardiac disease. For purposes of monitoring and constantly monitoring the state of the heart, Electrocardiogram is the most common and direct method. The heart patient needs periodic and continuous surveillance and is maintained sometimes in an insensitive care unit (ICU) that needs more facilities and manpower that ultimately increases the cost and demand for qualified medical staff such as caregiver [2].

Recently, medical information systems have become inexpensive and affordable, especially as there are ongoing attempts to develop them to make them accessible to everyone. These systems have become very widespread, especially with the development of Internet of Things-based technology as well as bandwidth and PC. These factors have provided connecting data in the environment information through large medical equipment, such as an Electrocardiogram device.

A wireless network called wireless biomedical sensor networks is wirelessly connected to the PC in order to provide essential information about the physical phenomenon to be studied. It is a collection of sensors used for specific physical phenomenon transmission (such as temperature, humidity, Electrocardiogram signal, etc.) and then transmits phenomenon information wirelessly to the data processing center (server) to benefit without the need the patient's presence. These networks represent a potential solution to the problem of transmitting vital signals from the patient to specialists in remote areas for medical diagnosis purposes which represents a solution for monitoring long-term(24/7) and ongoing healthcare [3].

The designing of this surveillance scheme is for homecare conditions and is usually classified into three elements, which is the data acquisition part, the data terminal part and the data processing part that will be demonstrated in the next parts. This article will additionally explain the HW and SW improvement and integral.

The proposed surveillance system for a cardiac disease patient-care environment in various settings are usually divided into three basic parts as shown embedded in Figure 1, as follows:

1. Data acquisition part (patient side, Wireless Body Sensor Network),
2. Data Processing Part (Arduino LIKE Part), and
3. Diagnosis or Decision part (Physician Part)

This work is organized as follow: Related work Electrocardiogram signal surveillance is discussed in Section3. The system method and materials presented in Section 4. Section 5, presented a proposed system architecture. The proposed procedure, introduced in section 6. Experiments results & discussion are shown in section 7. And in section 8, show the concludes the work [4].

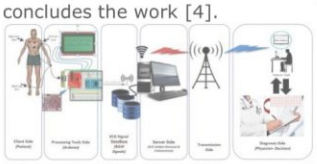


Figure 1. The Overall Proposed System

II. SYSTEM OBJECTIVE

Whatever portable devices were embedded with the patient's body (by clothing or a portable device or others), the optimum objective of wearable technology is easy to patient information access directly and rapidly.

III. RELATED WORKS

There are many heart rate monitoring systems used by health professionals in most hospitals. Most of these systems are manual methods to measure the Electrocardiogram signal.

For the purposes of the examination, the Electrocardiogram chart is read on a device installed beside the bed or through special screens for this purpose. The long distances here are not supported by these wired and optical devices.

There are many problems in these systems related to the high cost of hospital stay, which is financially burdensome for the patient if it is a long time and is one of the requirements for treatment completion for patients and needs to be fixed in addition to the monitoring of experts [5][6].

There are novel methods have been designed in order to measure the heart rate and surveillance the patient's case, including the heart rate's automation and measurements of Electrocardiogram utilizing modern approaches. Many authors have made an assessment of the available systems available for the purpose of controlling various vital body features such as temperature, Electrocardiogram, heart rate, pulse rate, etc. [8][7].

Many researchers utilized many techniques for different heart signals data gathering in order to detect a heart attack or emergency related to cardiac disease[12]. The authors proposed

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a detection system for heart attack by using a ZigBee heart rate surveillance system and an alarm. Researchers conducted an extensive study on healthcare and medical practices based on mobile phones. This method highlights the use of inbuilt applications such as services on site for smartphones such as the Global Positioning System which is used to monitor the location of older cardiac patients with instability [9][10].

There are many researchers who have suggested their different methods using smartphones and are able to detect, store and analyze collected medical records in order to monitor the health of heart patients[11]. Based on a healthcare surveillance system in different settings (hospitals, homes, etc.) that use a wireless sensor network, cardiac patients can be closely monitored to give a proper diagnosis and save their lives[13]. Hence, these systems have made great progress as they became more accurate, reliable and cost-effective and facilitated wear using biological sensors. These systems have achieved different goals such as low cost and reduced long hospital stay as well as continuous and long-term monitoring of heart patients without expert attendance[14] [15].

IV. METHOD AND MATERIALS

Each heartbeat can be captured through an Electrocardiogram sensor with electrodes that can be directly attached to the patient's chest. These heartbeats turn into an electrical signal by the Electrocardiogram electrodes connected directly to the chest of the patient through the medical test. Electrocardiogram sensors are very light and lightweight sensors, which measure the accuracy of the continuous heartbeat and give heart rate data. The doctor and medical assistant using this device continuously.

There are three pins in the Electrocardiogram sensor electrodes connected by a 30-inch cable. The Electrocardiogram sensor is easily connected to the control unit, can be carried easily, and placed on the patient's waist or in the pocket. The Electrocardiogram sensor is placed on the arm and leg of the patient to easily pick up the pulse as all sensor poles have ways to assemble into the body. So, the patient can select the kind of electrode to measure heartbeat. The following figure 2, shows the overall methodology of the proposed system.

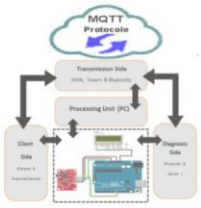


Figure 2. The Methodology of Electrocardiogram Signal System

The proposed surveillance system is consists of three main parts, firstly, the patient tier (the client, as an input to the system as Electrocardiogram signals); secondly, is the system tier (based on Arduino LIKE as a processing unit); and finally is the specialist's tier (Diagnosis or Decision level). The proposed system halts any part of these three parts mentioned above causes the system stops completely. Every part of these parts is the system is directly connected wirelessly with Wireless Body Sensor Network that used for patient healthcare monitoring.

V. PROPOSED SYSTEM ARCHITECTURE

The architecture of the proposed system can be described as the following:

A. H/W and S/W System Requirements:

All healthcare tracking devices for cardiac diseases consist of two basic parts: hardware and software. A patient's heart health monitor consists of both hardware and software requirements. Hardware requirements consists of, Arduino LIKE -Microcontroller Type (model WEMOS D1-ESP 8266), Operating Voltage 3.3 V, Digital I/O Pins 11, Analogue Input Pins 1(Max Input:3.2 V), Clock Speed 80MHz/160MHz, Flash 4 MByte, Module of Electrocardiogram Sensor (Electrocardiogram AD8232), Pieces of Electrocardiogram Electrodes Connector (RA, LA, and RL: RA-Input, LA - Input, and RL- Input with size 3.5 mm, and finally Power Supply. On the other hand, software requirements include, IDE Arduino LIKE with C language built-in, Processing IDE, Blynk Cloud Server, Cloud Server App, to implement the proposed model.

1) Message Queuing Telemetry Transport (MQTT) Protocol

The MQTT protocol is one of the most widespread and dependable Internet protocols. The simplified design and lightness of these protocols make it an appropriate solution for embedded devices with limited

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and unlimited resources in processing and storage capacity. The protocol offers benefits that reduce power consumption and bandwidth, and these are two very important factors in Internet objects. MQTT is a message-transfer protocol between a server and a client/publisher/publish/subscribe client. Is a light, open, and easily designed. protocol. This is according to the official definition and is designed specifically for the context of Internet applications[18][19][20]

B. Electrocardiogram Data Acquisition

The acquisition of data is a part of the surveillance system concerns with the Electrocardiogram sensor panel development consisting of amplified signal circuits and Electrocardiogram electrodes. The function is to collect data (heart signal) of the human body and amplify and filter the signal before sending it to its destination. Another part of the enterprise is a data terminal consisting of microcontroller circuits to process the acquired data and then send it to the data processing part[21][22][23]. It receives a heart signal in analog format and then transforms it to an 8-bit resolution of the digital signal and 500Hz sampling rate before sending these signals to the PC. For the purpose of enabling multi-hop connections, a simple routing mechanism is implemented, thus ensuring that the data reaches its destination via intermediate sensor points regardless of the patient's distance from the base station. The Electrocardiogram sensor node is designed in Figure 3 for continuous transmission to signal wirelessly to the base station. The sensor collects helpful Electrocardiogram data for the patient. These collected cardiac signals are filtered and amplified in order to prepare them for transmission purposes, that can be obtained directly from the patient's body through continuous observation. These signals range in value from 0.5 mV to 5.0 mV.

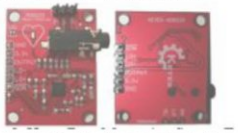


Figure 3. Heart Rate Measuring Sensor Type (Electrocardiogram AD8232)

A. The Core Terminal

Vital Electrocardiogram data is transferred from the patient to the server as well as the PC using the AODV multi-hop routing system. The function of the PC is a data processor, where it is utilized for Electrocardiogram signals reconstruction from the digitized signals.

As a serial interface, the receiver module can be connected directly as shown in Figure 3, is connected as a serial communication interface to the PC via RS22. It receives data sent by a wireless controller and sends these data sequentially to a PC that will be processed and displayed in the form of analog Electrocardiogram signals that were built using the built-in graphical user interface built-in.

Graphical user interfaces is easy to use, it has been programmed by applying Visual Studio version 6.0 programming and able to get an information packet in real time. Then decoded the stream raw data package, and plot it upon the screen[16].

Showing the heartbeat visually and on the computer screens helped to detect the abnormalities and abnormalities in the heart, for example, bradycardia sinus or tachycardia sinus. Figure 4, explains the core terminal of the suggested system:



Figure 4. WEMOS D1 Arduino Like

A. Wearable Wireless Sensor Network

Signals measurement will be transmitted directly to the local PC located in the patient to be able to constantly sense Electrocardiogram signals of any patient, a wearable wireless network sensor that is built on the patient's body is utilized. wireless sensor networks has main electrodes, sensor chest, communication, transmitter, and a signal processing circuit. The electrodes connected to the patient's chest capture heart signals from the heart. Captured Electrocardiogram signals will be filtered and amplified utilizing the interfacing and signal processing circuit home, and then transfer these signals to the internet and to the mobile device that supports the software sending measured data to the Internet.

In case a patient outside the boundaries of the hospital, Electrocardiogram data will be captured and transferred to the internet directly, and then to the hospital control room for any emergency procedures should be

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taken. The physician will communicate with the hospital server directly for any action[17].

B. Environment Local Server (ELS)

ELS has all indispensable databases for all patients and doctors that connected to these databases. It contains all necessary patients information since they have been connected to this server. This server is the general signals used by physicians for the proper diagnosis of their patients and the therapy speed.

C. Alarm System (AS)

In case of an emergency, the AS will be activated. Therefore, a warning and light warning procedure will be taken. A small, high-volume warning device is connected to the Arduino LIKE system. In the future, the warning system will be integrated into the mobile phone, as well as the local server, and the PC in the patient's environment.

VI. THE PROPOSED PROCEDURE

In this article, a broad real-time monitoring Electrocardiogram system that monitors the patient through various environments (home, office, hospital, and others) was introduced. In this scheme, a wireless sensor networks Network on the body of a patient with a cluster head sensor which connects with the deployed Wireless Home Network, Wireless Office Network or Wireless Hospital Network is connected. All data recorded utilizing the wireless sensor networks network are transmitted via Wireless Hospital Network. For any urgent emergency action, the hospital sends the data to the doctor immediately.

For Electrocardiogram signal surveillance, the Arduino LIKE board to perform the functions of communications and data processing were utilized. The patient assessment suggested procedure is described below:

1) Connect Arduino LIKE Circuit with PC directly.
2) An Electrocardiogram signal acquisition from the patient body by using 3 main electrodes (LA, RA, and RL)
3) Send the Electrocardiogram signal through the amplification circuit.
4) Using the amplification circuit for Electrocardiogram signal amplification.
5) Using the board of Arduino LIKE for signal amplification reading.
6) Measuring the voltage and time interval for all Electrocardiogram signal.
7) Utilizing a home wireless network or Bluetooth for Electrocardiogram data transmission.
8) Comparing an Electrocardiogram data with an Electrocardiogram Value rated on PC.
9) If found an Electrocardiogram irregular signal, the alarm message is sending.

The following part describes the practical side of the proposed system applied on the real patient through the testing phase.



Figure 5. Overall System Connections

The above figure shows the method of components connections of the proposed system and the method of connecting to the patient's body.

WEMOS D1 Arduino Like is connected directly to the Electrocardiogram sensor type EC82 AD8232, which is connected to the three electrodes that directly connect to the patient's body. The first electrode (V1) placed on the right rib of the chest, the second electrode (V2) placed on the left rib of the chest, the last electrode (V3) is located in the half distance between V1 & V2. All these components are directly connected to the WiFi ESP 8255 embedded in the WEMOS D1 Arduino Like, and directly to the access point (internet). These data sent to the cloud server (based-on MQTT protocol) to transmit directly to the physician for diagnosis purpose.

VII. RESULTS AND DISCUSSION

A prototype was developed to monitor and test an Electrocardiogram signal by the physician. System validation includes determining the correct samples for a human study indicated to evaluate the performance of the system in various real-world environments. Heart rates can be divided into three basic stages: sinus arrhythmia, sinus rhythm, and irregular heartbeat sinus. The heart rate is measured within the number of beats per minute (BPM) or the number of contractions of the heart in one minute. The following Figures 5 (a, b, and c), shows the different Electrocardiogram signal readings from various patients gained from a private clinic that has been monitored by the proposed model. These three forms were taken from three patients with myocardial infarction: Electrocardiogram arrhythmia (Electrocardiogram Irregular

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heartbeat), Sinus arrhythmia, Sinus arrest, and Sinus bradycardia. These signals were captured through the proposed system.

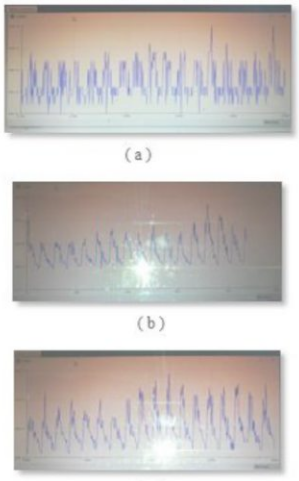


Figure 6. a,b, and c, A different Electrocardiogram signal readings for different patients

The QRS detection flag recognizes the steep slopes and high amplitudes of the QRS complex adequately to be utilized as an Electrocardiogram device for patient surveillance.

Based on the above readings, the cardiac disorders kind determined with the assist of the proposed model.

VIII. CONCLUSION

The mortality of cardiovascular disease is a surprise, and that patients with this disease need to continuously monitor the interest of their lives. Therefore, the patient must be medically monitored by observing the body's vital parameters which accurately illustrates the patient's current condition, such as heart rate, pulse rate, electrical heart (Electrocardiogram). In this paper, present the system architecture of the healthcare surveillance based on WSN and Arduino LIKE that is developed to surveillance the parameters of a certain body of the cardiac patient continuously. The Electrocardiogram signal captured by biometric sensors connected to the Arduino LIKE plate is sent to measure the heart rate and signals to the server using the wireless node. Data is provided on remote servers for doctors and caregiver based on Internet of Things. Electrocardiogram data are acquired by readings from heart rate sensor using an Arduino LIKE, and send it over Wi-Fi to the internet to transmit to the specialists for diagnosis purposes. Data is provided on remote servers for doctors and caregivers. The initial tests mention to the system accuracy is better results, this is referred to the system efficiency to provide necessary medical assistance to the cardiac patients. To ensure that cardiac signals stored safely and rapidly transmission without distortions during transmission, and to ensure the compatibility during the processing, a reliable Blynk cloud server was used with its application.

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APPENDIX (A)

Sample of Pseudocode of the Main Activities in the Physician's Side

```
using Android.App;
using Android.OS;
using Android.Support.V7.App;
using Android.Runtime;
using Android.Widget;
using SocketLibrary;
using Parse;
using OxyPlot.Xamarin.Android;
using System;
using System.IO;
using Accord.Statistics.Analysis;
using Accord.Math.Wavelets;
using Android.Net;
namespace ServerName_S
{
   [Activity(Label =  @string/app_name , Theme =  @style/AppTheme , MainLauncher =
true)]
   public class MainActivity : AppCompatActivity
   {
      Button receive;
      TextView state;
      PlotView view;
      EditText diagnosis;
      IWavelet haar = new Haar(3);
      string c_pid;
      protected override void OnCreate(Bundle savedInstanceState)
      {
         base.OnCreate(savedInstanceState);
         // Set our view from the  main  layout resource
         SetContentView(Resource.Layout.activity_main);
         //----------------------------------     app configeration   ------------------------------
         pid = FindViewById<TextView>(Resource.Id.PID);
         receive.Click += Receive_ClickAsync;
               state.Text =  write the diagnosis ;
               string compressed_sig = StringCipher.Decrypt(data.Get<string>( data ),  12345 );
//
               double[] signals = Decompress(compressed_sig); //
               view.Model = CreatePlotModel(signals);
               Toast.MakeText(this,  Done , ToastLength.Short).Show(); }}
         else
            Toast.MakeText(this,  No Internet Connection , ToastLength.Long).Show();
      }
```

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APPENDIX (B)

Sample of Pseudocode of the Main Activity Socket Listener

```
namespace SocketLibrary
{
   using System;
   using System.Diagnostics.CodeAnalysis;
   using System.Net;
   using System.Net.Sockets;

   /// <summary>
   /// An IPv4 TCP socket listener.
      private readonly Socket _socket;

      /// Constructs and listens in the given port.
      /// </summary>
      /// <param name= endpoint >Endpoint to listen (defaults to 127.0.0.1)</param>
      /// <param name= backlog >Number of incoming connections that can be queued for
acceptance</param>
      public SocketListener(EndPoint endpoint, int backlog = 10)
      {
         _socket = new Socket(AddressFamily.InterNetwork, SocketType.Stream,
ProtocolType.Tcp);
         _socket.Bind(endpoint);
         _socket.Listen(backlog);
      }


      /// <param name= port >Port to listen</param>
      /// <param name= ip >IP to listen (defaults to 127.0.0.1)</param>
      /// <param name= backlog >Number of incoming connections that can be queued for
acceptance</param>
      public SocketListener(int port, string ip =  127.0.0.1 , int backlog = 10)
      {
         var _ip = IPAddress.Parse(ip);
         var endpoint = new IPEndPoint(_ip, port);
         _socket = new Socket(AddressFamily.InterNetwork, SocketType.Stream,
ProtocolType.Tcp);
         _socket.Bind(endpoint);
        _socket.Dispose();
      }
   }
}
```

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APPENDIX (C)

Sample of Pseudocode of the De Ciphering Activity in the Physician's Side

```
using System;
using System.Text;
using System.Security.Cryptography;
using System.IO;
using System.Linq;

using Android.App;
using Android.Content;
using Android.OS;
using Android.Runtime;
using Android.Views;
using Android.Widget;

namespace Azmi_S
{
   public static class StringCipher
   {
      private const int DerivationIterations = 1000;

      public static string Encrypt(string plainText, string passPhrase)
      {
         // Salt and IV is randomly generated each time, but is preprended to encrypted cipher
text
         // so that the same Salt and IV values can be used when decrypting.
         var saltStringBytes = Generate256BitsOfRandomEntropy();
         var plainTextBytes = Encoding.UTF8.GetBytes(plainText);
         using (var password = new Rfc2898DeriveBytes(passPhrase, saltStringBytes,
DerivationIterations))
         {
            var keyBytes = password.GetBytes(Keysize / 8);
            using (var symmetricKey = new RijndaelManaged())
            {
               symmetricKey.BlockSize = 256;
               symmetricKey.Mode = CipherMode.CBC;
               symmetricKey.Padding = PaddingMode.PKCS7;
               using (var encryptor = symmetricKey.CreateEncryptor(keyBytes, ivStringBytes))
               {
                  using (var memoryStream = new MemoryStream())
                  {
                     using (var cryptoStream = new CryptoStream(memoryStream, encryptor,
CryptoStreamMode.Write))
                     {
                        cryptoStream.Write(plainTextBytes, 0, plainTextBytes.Length);
                        cryptoStream.FlushFinalBlock();
```

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```
                        // Create the final bytes as a concatenation of the random salt bytes, the
random iv bytes and the cipher bytes.
                        var cipherTextBytes = saltStringBytes;
                        cipherTextBytes = cipherTextBytes.Concat(ivStringBytes).ToArray();
                        cipherTextBytes =
cipherTextBytes.Concat(memoryStream.ToArray()).ToArray();
                        memoryStream.Close();
                        cryptoStream.Close();
                        return Convert.ToBase64String(cipherTextBytes);
                    }
                }
            }
        }
    }

    using (var password = new Rfc2898DeriveBytes(passPhrase, saltStringBytes,
DerivationIterations))
        {
            var keyBytes = password.GetBytes(Keysize / 8);
            using (var symmetricKey = new RijndaelManaged())
            {
                symmetricKey.BlockSize = 256;
                symmetricKey.Mode = CipherMode.CBC;
                    {
                        var plainTextBytes = new                    }
                }
            }
        }
    }

    private static byte[] Generate256BitsOfRandomEntropy()
    {
        var randomBytes = new byte[32]; // 32 Bytes will give us 256 bits.
        using (var rngCsp = new RNGCryptoServiceProvider())
        {
            // Fill the array with cryptographically secure random bytes.
            rngCsp.GetBytes(randomBytes);
        }
        return randomBytes;
    }
  }
}
```

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APPENDIX (D)

Sample of Pseudocode of the Main Activities of in Patient Side

```
namespace SocketLibrary
{
   using System;
   using System.Net;
   using System.Net.Sockets;
   using System.Text;

   /// <summary>
   /// An IPv4 TCP connected socket.
   /// </summary>
   public sealed class ConnectedSocket : IDisposable
   {
      private readonly Encoding _encoding;

      private readonly Socket _socket;

      /// <summary>
      /// Constructs and connects the socket.
      /// </summary>
      /// <param name= endpoint >Endpoint to connect to</param>
      public ConnectedSocket(EndPoint endpoint) : this(endpoint, Encoding.UTF8) { }

      /// <summary>
      /// Constructs and connects the socket.
      /// </summary>
      /// <param name= endpoint >Endpoint to connect to</param>
      /// <param name= encoding >Encoding of the content sended and received by the
socket</param>
      public ConnectedSocket(EndPoint endpoint, Encoding encoding)
      {
         _encoding = encoding;
         _socket = new Socket(AddressFamily.InterNetwork, SocketType.Stream,
ProtocolType.Tcp);
         _socket.Connect(endpoint);
      }

         _socket.Shutdown(SocketShutdown.Both);
         _socket.Dispose();
      }

      /// <summary>
      /// Sends the given data.
      /// </summary>
      /// <param name= data >Data to send</param>
```

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APPENDIX (E)

Sample of Pseudocode of the Ciphering Activity in the Patient's Side

```
using System;
using System.Text;
using System.Security.Cryptography;
using System.IO;
using System.Linq;
using Android.App;
using Android.Content;
using Android.OS;
using Android.Runtime;
using Android.Views;
using Android.Widget;
namespace Ciphern
{
   public static class StringCipher
   {
      // This constant is used to determine the keysize of the encryption algorithm in bits.
      // We divide this by 8 within the code below to get the equivalent number of bytes.
      private const int Keysize = 256;
      // This constant determines the number of iterations for the password bytes generation
function.
      {
         // [32 bytes of Salt] + [32 bytes of IV] + [n bytes of CipherText]
         var cipherTextBytesWithSaltAndIv = Convert.FromBase64String(cipherText);
         // Get the saltbytes by extracting the first 32 bytes from the supplied cipherText bytes.
         var saltStringBytes = cipherTextBytesWithSaltAndIv.Take(Keysize / 8).ToArray();
         // Get the IV bytes by extracting the next 32 bytes from the supplied cipherText bytes.
         var ivStringBytes = cipherTextBytesWithSaltAndIv.Skip(Keysize / 8).Take(Keysize /
8).ToArray();
         // Get the actual cipher text bytes by removing the first 64 bytes from the cipherText
string.
                symmetricKey.BlockSize = 256;
                symmetricKey.Mode = CipherMode.CBC;
                symmetricKey.Padding = PaddingMode.PKCS7;
                using (var decryptor =                {
                 using (var memoryStream = new MemoryStream(cipherTextBytes))
                   {
                      using (var cryptoStream = new CryptoStream(memoryStream, decryptor,
CryptoStreamMode.Read))
                  using (var memoryStream = new MemoryStream())
```

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APPENDIX (F)

Sample of Pseudo Code of DWT algorithm
Initial Step: /* Pseudo-code for the Computation of the DWT*/ Load Signal File();/*input signal file */ Initialize Input matrix (); /* Input matrix */ Convolution with scaling vector ();/* FDWT */ Down sample by_2 (); /*Thresholding */ Initialize threshold value (); Calculate dead value (); Perform thresholding on the transform matrix();

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APPENDIX (G)

Sample of Pseudo Code of PCA algorithm

/* Pseudo-code for the Computation of the PCA*/
sig_data = ReadFile();
sig_data = Math.Round(sig_data, 2);
haar.Forward(sig_data);
for I = 0 to sig_data.length / 2
dwt_data[I] = sig_data[I];
end for
convert dwt_sig to 2D array
pca = new PrincipalComponentAnalysis(2D_dwt_sig);
pca.Compute();
components = pca.Transform(2D_dwt_sig, Threshold);
/*IPCA*/

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APPENDIX (H)

Sample of Pseudo Code of Server Preparing for Sending and Receiving

```
ParseClient.Initialize(new ParseClient.Configuration
            {
               WindowsKey = GetString(Resource.String.back4app_dotnet_key),
               Server =  https://parseapi.back4app.com
            if (diagnosis.Text != null)
            {
               ParseQuery<ParseObject> query0 = ParseObject.GetQuery( chat );
               ParseObject data0 = await query0.GetAsync( CyT7r5O5lj );
               data0[ pid ] = c_pid;
               await data0.SaveAsync();
               ParseObject data2 = await query.GetAsync( HRwWZCp0El );
               data2[ data ] = StringCipher.Encrypt(diagnosis.Text +    , 12345 );
               await data2.SaveAsync();

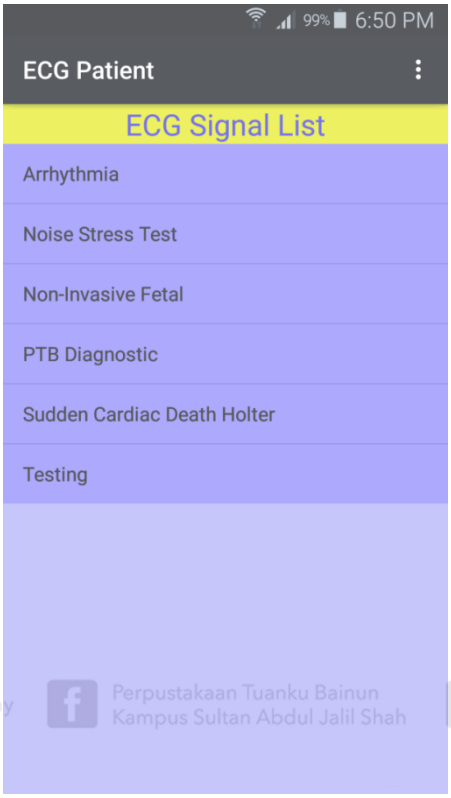
               diagnosis.Text =   ;
               Toast.MakeText(this,  Done , ToastLength.Short).Show();
            }
            else
            {
             Toast.MakeText(this.ApplicationContext,  write the diagnosis ,
ToastLength.Short).Show();
            }
         }
         else
            Toast.MakeText(this,  No Internet Connection , ToastLength.Long).Show();
      }
```

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APPENDIX (I)

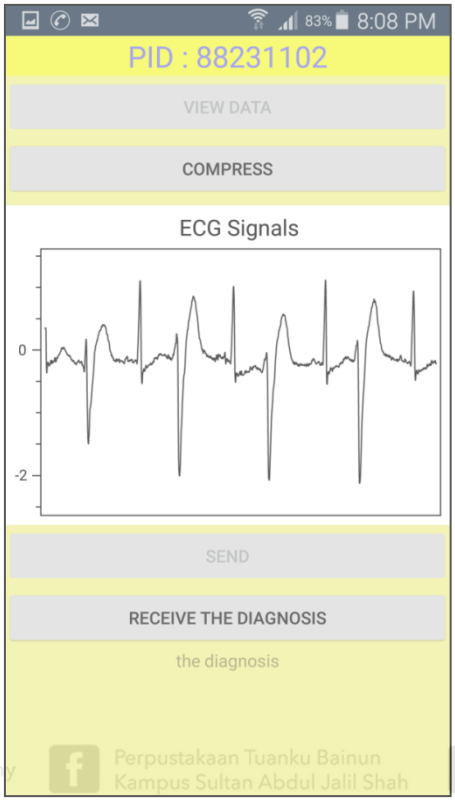
Mobile App (***Sending*** and ***Receiving*** ECG Signals between **Patient** and **Specialist**)

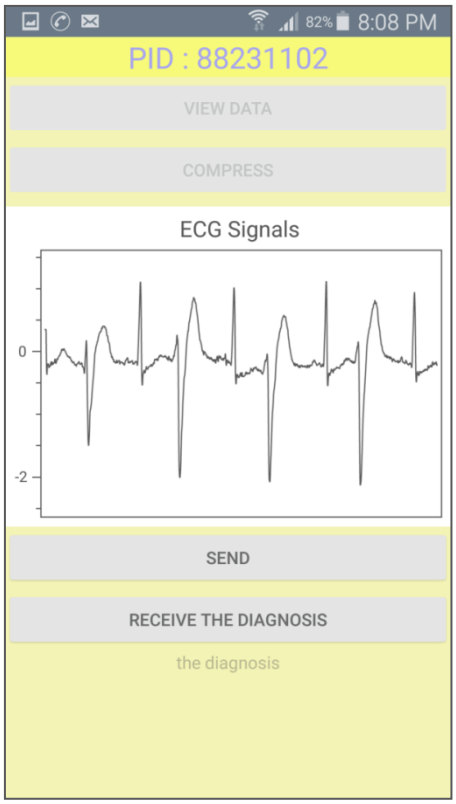




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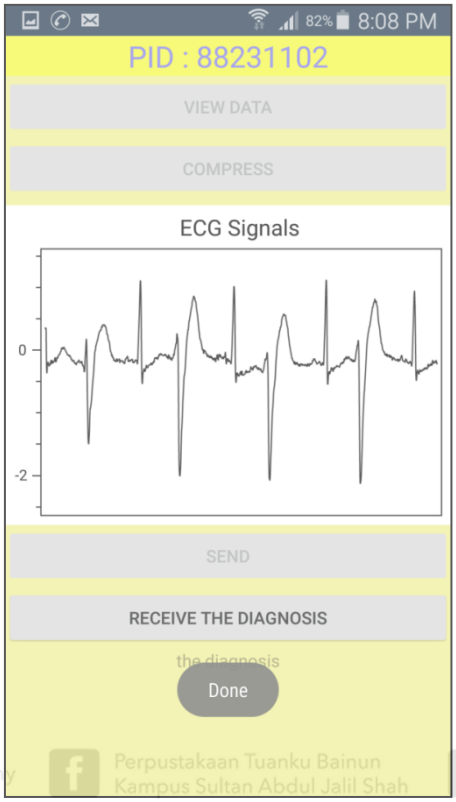
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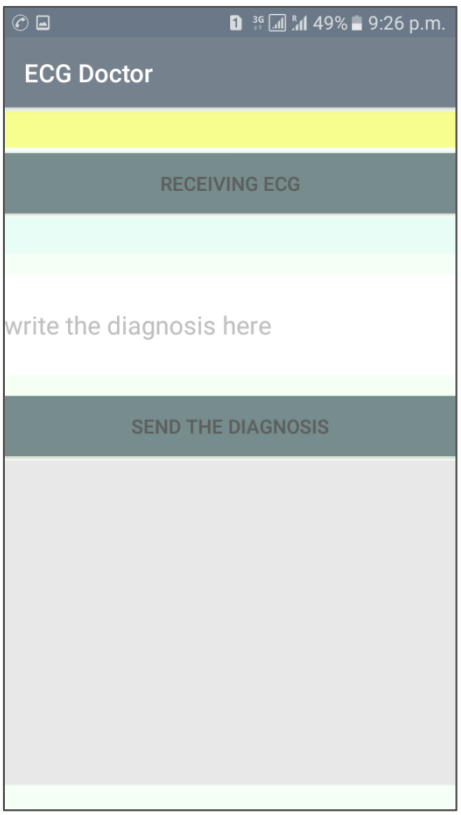




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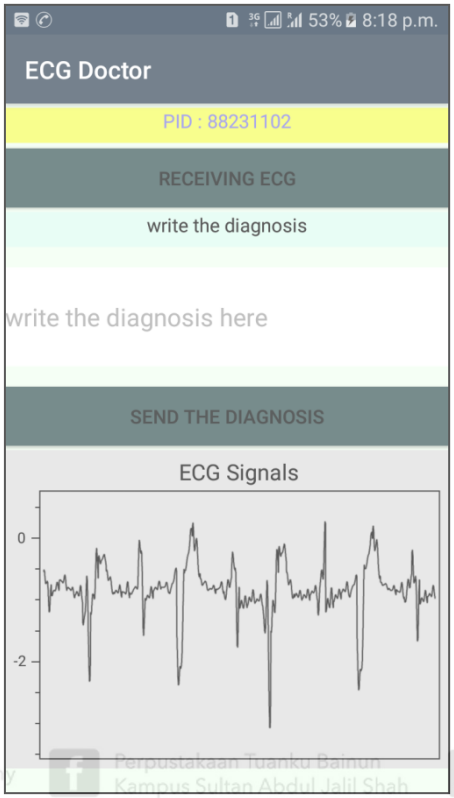
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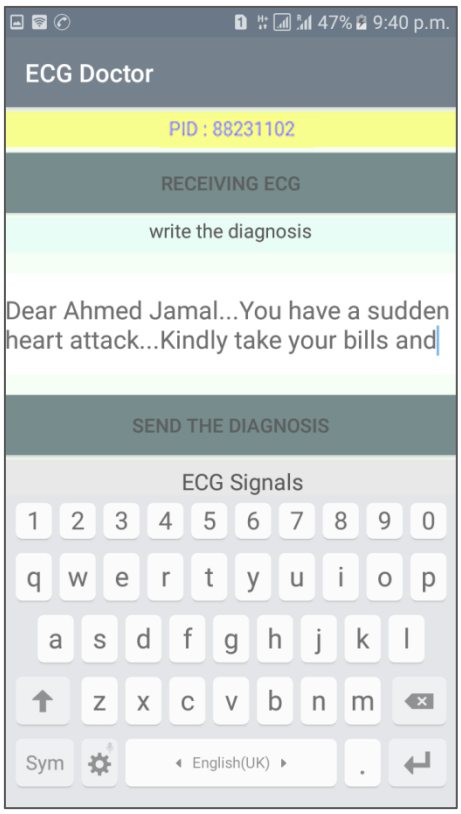




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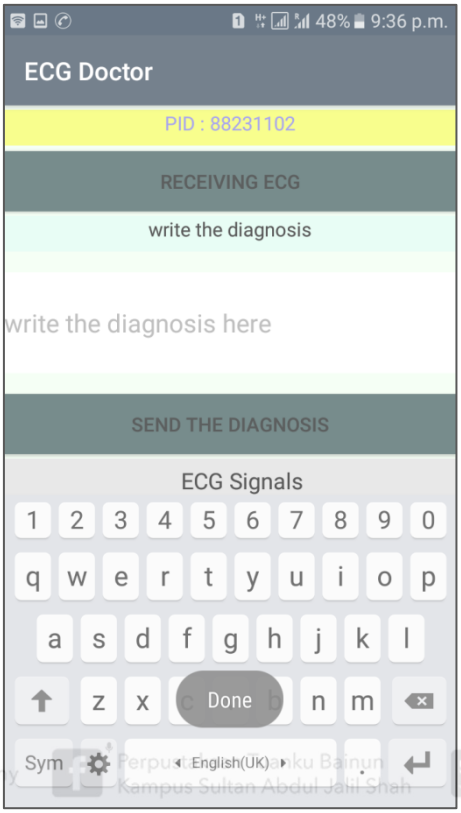
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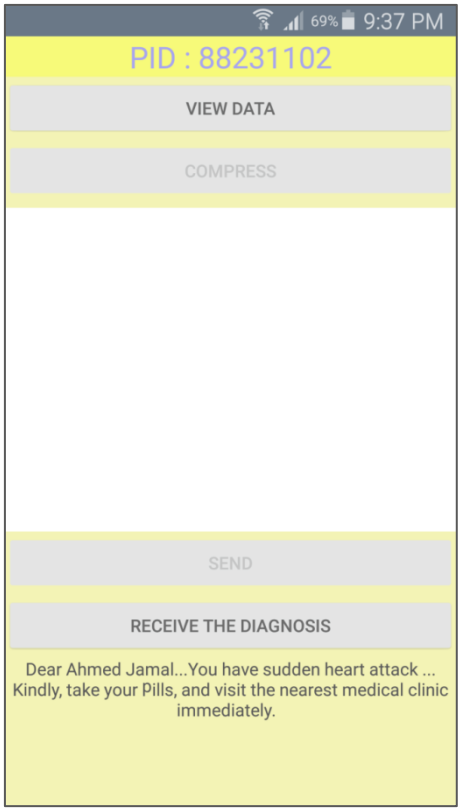




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APPENDIX (J)

The Hashemit Kingdom of Jordan
Specialty Hospital

المملكة الاردنية الهاشمية
المستشفى التخصصي

Tel. : +962 6 200 1111

(P00063631)

وإذا مرضت فهو يشفين

DR. Tayseer Muhammad Qahwaji
Cardiologist - Consultant of Cardiac and Coronary

Department: **Cardiovascular**

Mr. Azmi Shawkat Abdulbaqi attended the Jordanian Hospital accompanied by his scientific project in transferring cardiac signals from the patient to the doctor.

Mr. Azmi Shawkat Abdulbaqi was referred to cardiologist **Dr. Tayseer Muhammad Qahwaji**, Consultant of Cardiac and Coronary.

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Dr. Tayseer Muhammad Qahwaji gave his opinion after he tests the system:

" The system is successful and effective in the rapid transfer of cardiac signals from the patient to doctor". But the doctor did not give his clear opinion in the cardiac signals compression system due to it is a scientific subject and outside of his medical specialization. **Dr. Tayseer Muhammad Qahwaji** gave his opinion about system development: " in the future, the system could be developed to transfer brain signals if a company adopts system development."

Finally, **Dr. Tayseer Muhammad Qahwaji** wished good luck to Azmi.

المستشفى التخصصي
المملكة الاردنية الهاشمية
Specialist Hospital

Dr. Tayseer Mohammad Qahwaji

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