CHAPTER 1

INTRODUCTION

Telemedicine is the integration of telecommunication technology with the advancements of information technology. It is aimed at enhancing health care delivery to a wider population. This technology supports the transfer of pathological and imaging reports of patients across the telemedicine networks, in order to provide consultation by specialists located in geographically different locations. The integration of mobile communication and biomedical instrumentation technology plays an important role in telemedicine, as doctors away from the system could also get the health status of their critical patients (Hernandez et al 2001). Advances made in the field of biomedical engineering, has led to the development of more accurate biomedical instrumentation to measure vital physiological parameters and the development of interdisciplinary areas to fight the effects of body malfunctions and disease.

The chapter is organized as follows. Subsections under 1 describe the application of telecommunication technology to health care and the necessity of telemedicine in India. The challenges pertaining to telemedicine have also been identified and addressed accordingly. Concepts of effective medical image compression and the effectiveness of Huffman Compression in telemedicine are also discussed. The general framework of Content based Image Retrieval System CBIR and their application in telemedicine has been presented.
1.1 APPLYING TELECOMMUNICATIONS TO HEALTH CARE

The term telecommunications generally means electronic transmission of information over a distance. Modern telecommunication and information technologies could be used for the provision of clinical care to individuals at a distance. This application is very efficient since patient records, stored electronically, could be made available through the Internet, resulting in the elimination of the need for physical storage and transfer of records. Furthermore, images and video could be included and transmitted as part of a computerized file. Hence, the patient’s history could include previous examinations, lab test results, X-rays, etc., in addition to textual descriptions of the results from previous health care. Records on remote sites could also be accessed. This would greatly enhance the chances of correct diagnosis of a particular illness and possibly suggest courses of treatment. Health information of the patient, collected in digitized form, could be easily transmitted without requiring the patient’s physical presence for the examination. The support of video conferencing through the Internet allows a health care professional to observe and interact with the patient who is not in the same physical location.

E-mail or Video Recording could be used for asynchronous discussions. Patient records, lab results and images from detailed examinations could be stored in computer file format, making them easier to search and transfer to distant locations when needed. E-mail and Internet access for regional and rural medical centers and hospitals could be extremely useful. The benefits from connecting as many hospitals and medical centers as possible to the medical information system is to deliver:

- Improved standard of medical practice
- Improved epidemiological and other reporting
• Educational benefits for doctors and medical staff in distant medical centers and Continuous Medical Education (CME).

Therefore, the telecommunication partners of these telemedicine projects would be a key factor for the future extension of telemedicine services. Successful introduction of telemedicine services require more than just the delivery of the right equipment to the users (Uwe Engelmann et al 2001).

The Internet is already changing the way in which telemedicine is deployed and the extent to which it becomes widely available. The focus should be on low-cost, low-bandwidth Internet applications that facilitate discussion and the transmission of text, data and images (Hernandez et al 2001). Telemedicine could help to develop new ways to deliver medical and health education to professionals and to the community and improve the CME (Mockzo et al 2001).

1.2 TECHNOLOGY BEHIND TELEMEDICINE

Most of the telemedical applications use one of the two widely available technologies. The store and forward technology transfers digital images from one location to another. The other popular technology is the two-way interactive television (IATV). This is used when a 'face-to-face' consultation between the health expert and the patients become mandatory. It is usually between the patients and their provider in one location and a specialist in another location. Videoconferencing equipment at both locations allows a 'real-time' consultation to take place (Hung and Zhang 2003). The technology has decreased in price and complexity over the past five years, and many programs now use desktop videoconferencing systems. This includes transfer of basic patient information over computer communication
networks, exchange of images such as radiographs or pathologies among geographically separated specialists, remote patient interviews and examination through activities. A telemedicine system enables ‘virtual consultation’ wherein the local doctor plays the role of a remote medical expert and implements effective decision making and treatment. Telemedicine bridges the gap between specialist doctors and patients, thereby overcoming the barriers of distance and time. Health care in isolated areas are improved by enhancing continuing care.

Advantages of telemedicine technology include

- Reduction in time and cost incurred in travel
- Easy and quick access to specialist
- Cost effective post treatment consultation
- Efficient use of medical resources.

The major areas of telemedicine technology are

- Tele-consultation
- Tele-diagnosis
- Tele-treatment
- Tele-education
- Tele-training
- Tele-monitoring
- Tele-support

Figure 1.1 and Figure 1.2 depict the scenario in a telemedicine setup in real time (Anunay Nayak et al 1998)
1.3 **NECESSITY OF TELEMEDICINE IN INDIA**

The geographical set up of India provides an ideal setup for telemedicine to be implemented in the sub-continent. India’s huge population makes it difficult for health care facilities to be made available for everybody and at any place. India is characterized by low penetration of healthcare services. 80% of secondary & tertiary healthcare facilities lie in cities and towns, distant from rural India where 70% of the population resides. Primary health care facilities for rural population are highly inadequate (Amrita Pal et al 2005).

![Diagram of Day 1 of a Telemedicine consultation](image)

*Figure 1.1 Day 1 of a Telemedicine consultation*
Figure 1.2 Day 2 of a Telemedicine consultation

Studies reveal that the rural population, though with the same disease than their urban counterparts face twice the risk of death, due to inexperienced and poor medical facilities in the rural areas. Despite several initiatives by the Government and private sectors, the rural and remote areas continue to suffer from absence of quality healthcare. Telemedicine attempts to narrow the gap underlying urban and rural counterparts, in terms of quality health care.

India has begun to make remarkable progress in the fields of telemedicine and e-health. Indian Space Research Organization (ISRO) and the Department Of Information Technology (DOIT) provide the infrastructure to support tele applications. One of ISRO’s first successful ventures to implement telemedicine in the country was in the year 2001, linking Apollo Hospital in Chennai to a rural hospital in Aragonda village in Andhra Pradesh. Later in March 2002, Karnataka telemedicine project linked a super specialty hospital in Bangalore to a small district hospital. The successful implementation of these pilot projects was ISRO’s initial steps contributing to the growth of telemedicine in India. The Telemedicine link provided by the Indian Space Research Organisation is depicted in Figure 1.3.
In India, Telemedicine projects are implemented through the State Governments (Mishra). There is active participation from the Government and private sectors to bridge the gap in the quality of health care facilities between the urban and rural Indians, through setting up of telemedicine networks. ISRO has established a telemedicine network for 300 hospitals. A total of 257 remote/rural district hospitals and health centres have been connected to 43- super specialty hospitals located in major states. Ten mobile tele-ophtamology units are also present. A majority of the State Governments has collaborated with the Department of Information Technology, in setting up telemedicine networks with the state specialty hospitals and smaller district centers (Saroj Mishra et al 2008)
The growing need of telemedicine in India could be traced back to the works of Amrita Pal et al (2005), where a telemedicine setup in India is absolutely essential. There has been a number of situations in which telemedicine has been successfully implemented. The Online Telemedicine Research Institute (OTRI) provided telemedicine links for tele consultation in Bhuj during the earthquake at Gujarat during 2001. Asia Heart Foundation (AHF) has been successfully practicing tele-cardiology between Bangalore and cities in Eastern India. The last decade witnessed many more success stories Sood (2002).

1.4 CHALLENGES ADDRESSED IN THE PRESENT STUDY

The major goal of this thesis is to address Compressed Image Retrieval for Telemedicine with challenges mentioned below.

- Compressed medical images take a fraction of time for transmission compared to a regular medical image. The challenge is to identify compression techniques which is near lossless, but does not lose any of its important characteristics.

- In order to help the medical professional make an automated diagnosis, wherein the health professional is able to study similar medical cases based on the query input image on which he prefers to obtain a second opinion. The challenge lies in Image Retrieval techniques where features are extracted from compressed images.

1.4.1 Significance of medical image compression in telemedicine

Most medical images occupy large space and due to their large size and hence require high bandwidth for transmission. This becomes a major
issue for rural medical centres which may not have sufficient telecommunication infrastructure. Lossless compression becomes a viable solution with advantage of bandwidth saving. However, work needs to be done to improve the compression ratio such that it does not lose its visual characteristics and at the same time can be effectively used for automated image retrieval applications.

1.4.1.1 Compression for medical images

Medical imaging has impacted disease diagnosis and surgical planning. But imaging devices continue generation of more data per patient, often 1000 images or ~500 MB. These require long-term storage and efficient transmission. Current compression schemes have high compression rates if quality loss is affordable. But medicine cannot afford deficiency in important regions diagnostically. Thus, an approach that allows high compression rate with good quality in the ROI is necessary. A hybrid-coding scheme is the only answer to this twofold problem. The general aim is to preserve quality in diagnostically critical regions, while at the same time allowing lossy encoding in other regions. The reason for region preservation other than ROI is to enable viewers to locate the position of critical regions in the original image easily and also to evaluate possible interactions with other organs. After evolution of digital imaging techniques, researchers attempted application of compression methods to medical data, with initial emphasis being on information preserving methods.

Medical images are compressed due to their large size and repeated usage for the purpose of diagnosis. Certified radiologists and doctors assess the degree of image degradation resulting from various types and amounts of compression associated with several different digital image file formats. A qualitative, rather than a quantitative approach is normally chosen because radiologists typically evaluate images qualitatively in their day-to-day
practice and, also, because common metrics used for comparing images pre- and post-compression, e.g., mean pixel error, root mean square error, maximum error, etc., may not correlate well with visual assessment of image quality.

1.4.1.2 Effective medical image compression

Medical images should be subjected to loss-less compression, a technique that stems from mathematical theory of communication (Shannon 1948). Loss-less compression techniques use variable length codes, proposed by Huffman (1952). Compression ratio achieved is not very satisfactory in Huffman. Hence modifying Huffman’s technique and optimizing it, yields a more effective compression algorithm that increases the compression ratio on medical images. Compression ratio and storage space are inversely proportional. Hence effective compression technique results in a reduction in storage space, thereby improving the bandwidth and speed of transmission of medical images with no added complexity and resources.

Although, new techniques that provide better compression ratio are developed now, a careful study into the Huffman Compression technique reveals the scope for improvement in terms of compression ratio and computationally simpler code. Such an algorithm is developed which optimises the existing Huffman’s variable length codes and produces an effective compression technique for medical images.

There are many loss-less compression techniques such as Arithmetic coding, Run Length Encoding (RLE), Huffman Coding and some famous Dictionary based algorithms like Lempel-Ziv-Welch (LZW) coding. But, Huffman Coding forms the basis of many compression algorithms. JPEG, MPEG which are lossy compression methods use Huffman coding.
Algorithms like JPEG-2000, Burrows-Wheeler Transformations (BWT) use Huffman coding in the final stages.

1.4.2 Transform based image compression

The focus on image compression algorithms lie on the fact that image should be represented with a minimum number of bits while maintaining a desirable quality. A number of methods are available in literature. Transform coding is a widely used method of compressing medical images. 2-D images from the spatial domain are mapped to the frequency domain and concentrates vital information into few transform coefficients. The generalized transform-based image compression method as shown in Figure 1.4 works as follows:

- Image Transform: This operation aims to decorrelate pixels of the image. This operation is reversible and does not cause any loss of information in the image. Examples of such a transform operation are Discrete Cosine Transform (DCT), Wavelet Transform (WT) and Contourlet Transform (CT).
- Quantisation: This operation is irreversible and represents the lossy stage in the compression process. It maps a large set of input image values to a smaller set of quantized values.
- Encoding: This process removes redundancy of the output of the quantiser. The most common entropy coding techniques are Run-Length Encoding (RLE), Huffman coding, arithmetic coding and Lempel-Ziv-Welsh methods.
1.4.3 Segmentation of medical images

Segmentation of medical images is one of the interesting applications of image processing techniques and has attracted a significant amount of attention in the past few years (Lei Ma et al 2005). It is a technique for partitioning the image into meaningful sub regions or objects with same attributes and usually is image and application dependent. Several segmentation methods have been proposed in medical images and especially in ultrasound images (Ma and Manjunath 2000). A number of algorithms based upon approaches such as histogram analysis, region growing, edge detection, and pixel classification have been proposed in the past. These methods make use of local information (i.e., the gray-level values of the neighboring pixels) and/or the global information (i.e., overall gray-level distribution of the image) for image segmentation. Some algorithms using neural network approach have also been investigated in image segmentation problems Kuo Sheng Cheng et al (1996).

A large number of different approaches are employed recently on segmenting images. The methods for medical image segmentation rely on five main approaches, namely, thresh holding technique, boundary-based method,
region based methods, and hybrid techniques that combine boundary and region criteria and active contour based approach.

1.4.4 Content Based Image Retrieval Application in Telemedicine

Content based Image Retrieval (CBIR) is the retrieval of images based on visual features such as colour, texture and shape. Researchers relied heavily on text-based retrieval before the wide spread use of CBIR in order to retrieve images. In CBIR, the user is required to input the query image. The retrieval process is carried out by extracting features from the query image and matching the features with the index kept in the database.

1.4.4.1 CBIR framework

Remco and Mirela (2000) conducted a survey on recent CBIR systems. They surveyed how user queried the system, whether relevance feedback was available, what features were used and how features from query images and database were matched. It was concluded from their work that most CBIR system would follow a similar design to the framework depicted in Figure 1.5. The figure shows that a graphical user interface is used to handle users query. The Query formulation could be done in three ways, which is by direct query, Query by example, or by simply browsing the database. An integral part of any CBIR system is the feature extraction module. This module uses specific algorithms to extract visual features from images. Another important module is the Index construction module which creates indexes in the database. Careful implementation of this module could save much time when retrieving images from large scale databases.
Figure 1.5 Content-based image retrieval framework

Different implementations of CBIR make use of different types of user queries. Query By Example (QBE) for example, requires the user to provide a query image to the system. The system would then extract low level features from the query image, and find for similar images from the database.

In Query By Sketch (QBS), users draw a rough approximation of the image they are looking for. This task could be accomplished by creating blobs of flat-colour or drawing a rough sketch of an object in the image and colouring it. The system would then locate images whose layout matches the sketch drawn. Other methods include specifying the proportions of colours desired. For example, users could enter values for each red, green and blue
intensity values or by using percentage values (red 20%, green 10%, blue 70%).

1.4.4.2 CBIR for Telemedicine

Telemedicine involves the presence of an expert on one side and the patient / health professional on the other end for her consultation. However, experts may not be available for consultancy all the time. This problem can be partially overcome by implementing a CBIR system which can retrieve similar images based on the query medical image. This would help health professionals to take a second opinion and if doubt, they could opt for a live conversation with an expert.

1.5 OBJECTIVES OF THE THESIS

In the present thesis, various challenges pertaining telemedicine technology have been addressed. This study addresses medical image compression which is near lossless and Image Retrieval (IR) techniques for effective use of telemedicine even without the presence of an expert. The major contributions made in the present study are listed here under:

- To investigate existing compression technique using Haar Wavelet and Huffman Coding.
- To propose an improved Huffman Coding Technique to increase the Compression Ratio (CR) without compromising the Peak Signal to Noise Ratio (PSNR).
- To investigate feature extraction techniques for Image Retrieval using Fast Fourier Transform (FFT).
- To propose an improved FFT based feature extraction technique, Image Retrieval Specific FFT (IRS FFT).
To investigate existing classification algorithms for IR.

To propose a Novel Neural Network based classifier.

To optimize the Learning rate and Momentum of the proposed Neural Network using Genetic Algorithm.

To investigate the proposed algorithm for classification of Stroke images from MRI imaging.

1.6 ORGANISATION OF THE THESIS

Literature review of the key aspects of telemedicine technology, medical image segmentation, image compression and various soft computing techniques for effective medical image retrieval are presented in chapter 2.

Chapter 3 explains the role of image compression on medical images. A novel 3 pattern Huffman encoder, an improvement over the existing Huffman algorithm is proposed in this chapter.

Chapter 4 explains the algorithm of the proposed IRS FFT transform. Chapter 5 explains the design and implementation of the Hybrid compression technique. The significance of medical image segmentation is presented. An improved approach to image retrieval using a Back Propagation network (BPN) was also introduced.

An optimisation technique by genetic parameters and the effect of the genetic optimised classifier on the retrieval efficiency is presented in Chapter 6.

Chapter 7 discusses the results obtained and concludes the work.