A Literature Review on Performance Analysis of Medical Image Compression Techniques using Wavelets on Cloud Computing

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Abstract - This paper presents state of the art literature survey on design and development of lossless and lossy compression techniques for bio-medical images in general and performance analysis in particular. Image compression is one of the successful, predominant and inevitable research areas in the field of image processing and wavelet is a cutting edge technology. A wide variety of image coders has been proposed by researchers, academics and scientists globally in the past three decades. This literature survey is classified into nine subcategories such as transform based compression and wavelet coding for biomedical applications and performance analysis of the latest coders etc. This in-depth literature treatise and review will be useful and beneficial not only for the imaging processing novices but also for the research scholars who are interested in the knowledge of performance analysis of medical image compression using wavelet techniques and methods.

Keywords – medical image compression, wavelets, structural similarity index (SSIM), PSNR, MSE, SPHIT, EZW, WDR, ASWDR, STW, subjective quality assessment, performance analysis, objective measures, cloud computing

I. INTRODUCTION

SMART e-Health Gateway or E-health services have been trying to utilize the multimedia technologies such as teleradiology, teleconsultation, telemedicine, telediagnosis and telematics for better patient care and timely services [1]-[5]. Rahmani et al. (2015) proposed and implemented an e-health services for telediagnosis on the cloud platform [1]. Biomedical images and biosignals play a major role in modern e-health services and have become an integral part of medical data communication systems [4]. The medical communication system is a technology that allows any type of medical data to be transmitted from the point of care to the desired specialist(s). The data is transmitted securely and rapidly for delivery to mobile devices or computers so that physician’s can review the data and provide opinions [6]-[7].

Nowadays a large volume of medical image data are being generated in hospitals and health care institutions through various advance medical image modalities, namely, Magnetic Resonance Imaging (MRI), Ultrasound Imaging (US), Single Photon Emission Computed Tomography (SPECT), Positron Emission Tomography (PET), Nuclear Medicine (Scintigraphy), Computed Tomography (CT) images, Digital Subtraction Angiography (DSA), Digital Fluorography (DF) and X-ray imaging (Radiography). Wearable Internet of Things (IoT) devices and Body Sensor Networks (BSN) also generate a massive collection of biosignals such as heart-rate, oxygen level, respiration, blood pressure at low cost [4]-[8]. Ravichandran et al. (2016) suggested that as medical imaging facilities move towards complete filmless imaging and also generate a large volume of image data through various advance medical modalities, the ability to store, share and transfer images on a cloud-based system is essential for maximizing efficiencies. The major issue that arises in teleradiology is the difficulty of transmitting large volume of medical data with relatively low bandwidth. Image compression techniques have increased the viability by reducing the bandwidth requirement and cost-effective delivery of medical images for primary diagnosis [7],[9]-[10].

Although lossy compression techniques yield high compression rates, the medical community has been reluctant to adopt these methods [11]-[12], largely for legal reasons, and has instead relied on lossless compression techniques that yield low compression rates Zukoski et al. (2006). Analysis and compression of medical imagery is an important area of Biomedical Engineering. Dhawan (2011) observed that medical image analysis and data compression are rapidly evolving field with growing applications in the healthcare services e.g. teleradiology, teleconsultation, e-health, telemedicine and statistical medical data analysis, image fusion, registration and watermarking [7]-[11]. Ansari et al. (2008) argued that the ultimate aim of analyzing and compressing the medical imagery is to extract important features of the image from which a description, interpretation and understanding of the image can be provided by the computer to the other end user [13].

Rohaya MOHD-NOR (2011), observed that increasing demand for radiological services over the past few years and there has been a growing trend toward introducing
medical imaging technologies across hospitals worldwide. Medical imaging technologies consist of a number of components including PACS (Picture Archiving Communication Systems), RIS (Radiology Information Systems) and HIS (Hospital Information Systems) which are typically linked and interfaced through a computer network. He concluded that the implementation of technological components of medical imaging particularly digital imaging modalities and PACS/RIS is very expensive [14].

For the past two decades, efficient compression algorithms have been proposed and used in order to reduce transmission time and storage costs. The quality evaluation of medical image compression is an essential process in order to provide the cost effective services to the common men in the healthcare sector. Motivation of investigating of the proposed study is that image quality measurement is still an unsolved problem today [13]-[16]. New studies exploiting certain aspects of the HVS report reasonable success in quantifying certain types of distortion based on subjective ranking. This issue is continuing to expand and has achieved a certain maturity level within the community of multimedia communication and multimedia computing [17]-[25].

This rest of the paper is organized as follows: In section 2, we present a review of related works involving cloud computing in medical imaging and high light image compression based on transform coding and wavelet transform are given subsequently. The medical image compression based on advanced wavelet coders are covered in section 5. The coding performance based on image statistics and image features and image quality assessment based on structural similarity index (SSIM) are presented in section 6 and 7. The state of the art picture coding evaluation for medical image compression and the review literature discussions are made in section 8 and 9. Finally, in section 10, we present the conclusions and future scope of this research study.

II. CLOUD COMPUTING IN MEDICAL IMAGING

It is well known that cloud computing is available on-demand and provides flexible and scalable computing resources from remote locations in order to store, process and share data without large capital expenditures [90]. Due to the inherent properties of cloud computing such as better scalability, quicker deployment, and more flexibility, organizations in several industries are opted for exploring their business adventures on a cloud platform in an economical manner [11]-[12]. Since teleradiology companies work with a large volume of images through various advance modalities, it is essential for them to store, share and transfer images on a cloud-based system for maximizing their benefits [6]. Nowadays a majority of the hospitals moves towards filmless imaging and goes completely digital and that will allow Picture Archiving and Communication System (PACS) to reduce the file sizes on their storage requirements while maintaining relevant diagnostic information [5]-[12]. One of the challenges and the major issues for the health care institutions and hospitals is storing and transferring a large volume of medical images through limited bandwidth network configurations on the cloud platform [26]-[27].

Kagadis et al. (2013) has observed that cloud computing has been introduced only recently but is already one of the major topics of discussion in research and clinical settings. They conclude that healthcare researchers are moving their efforts to the cloud, because they need adequate resources to process, store, exchange, and use large quantities of medical data [11]. Among the potential driving forces for the increased use of cloud computing in medical imaging are raw data management and image processing and sharing demands, all of which require high-capacity data storage and computing. Pino et al. (2013) has suggested that cloud computing represents an essential opportunity to develop applications that ensure high performance data processing and easy management of the different tools in medical environment ensuring a consistency storage capabilities, overcoming the Grid computer lack [26]. Aluja et al. (2012) has noticed that current trends aim towards accessing information anytime, anywhere, which can be achieved when moving healthcare information to the cloud. This new delivery model can make healthcare more efficient and effective, and at a lower cost to technology budgets [27].

Ravichandran et al. (2015) argued that healthcare researchers are moving towards their efforts to the cloud platform in order to process, store, exchange and use a large amount of medical image data which are generated and acquired through various advance medical modalities [60],[90]. One of the challenges that arises in hospitals and medical organizations is the difficulty of transmitting such a large volume of medical images with relatively limited bandwidth. Image compression techniques have been incorporated in order to reduce the bandwidth requirement and economically transfer of medical images for primary diagnosis [11]-[13].

III. IMAGE COMPRESSION BASED ON TRANSFORM CODING

Image coding techniques based on transform use a mathematical transform to map the image pixel values onto a set of de-correlated coefficients, thereby removing inter-pixel redundancy. These coefficients are then quantized (psycho-visual redundancy), and encoded (coding efficiency). The key factor for the success of transform-based coding schemes is their excellent energy compaction property i.e. large fraction of total energy of image is packed in few coefficients. Most of the transform coefficients for natural images have small magnitudes and can be quantized and encoded or discarded without causing significant loss of information [28]-[36].
There are many types of image transform like discrete Fourier transform (DFT), discrete sine transform (DST), discrete cosine transform (DCT), Karhunen-Loeve transform (KLT), Slant transform, Hadamard transform and discrete wavelet transform (DWT). For compression purposes, the higher the capability of energy compaction, the better the transform. Though KLT transform is best in terms of energy compaction (transform coding gain), one drawback of KLT transform is that it is data dependent and overhead of sending the transform may reduce the transform coding gain. Another popular transform is discrete cosine transform (DCT), which offers transform coding gain closer to KLT and higher than DFT. In addition, the computational complexity of DCT is less than DFT. Due to these reasons, DCT has become the most widely used transform coding technique [36]-[50].

IV. IMAGE COMPRESSION USING WAVELET TRANSFORM

Wavelet transforms have received significant attention in diverse areas of engineering and scientific applications such as signal and image processing, audio and video compression, antenna and wave propagation, pattern recognition and computer vision, detection of aircrafts and submarines and other medical image technology [38]-[45]. Discrete Wavelet Transform (DWT) is one of the transform based coding techniques which uses a reversible and linear mathematical transform in order to map the pixel values into a set of coefficients. The main feature of DWT is multiscale, invertible and orthogonal [46],[50]. An image is a two dimensional array of M rows and N columns of pixel elements. Discrete wavelet transform (DWT) is used to transform the image from its spatial domain into its frequency domain.

The Discrete Wavelet Transform (DWT) is the transform adopted by the recent image compression standard JPEG2000 [46] and is most popular transform employed in image coding nowadays. It significantly outperforms algorithms based on other transforms, such as the DCT. The success of the DWT lies in ease of computation and its decomposition of an image into spatial sub bands that facilitates the design of efficient quantization algorithms and allows exploitation of the human visual system characteristics. The main advantage of wavelet transforms is that they are capable of representing an image with multiple levels of resolution and yet maintain the useful compaction properties of the DCT, therefore the subdivision of the input image into smaller sub images is no longer necessary as is done in DCT based coding [49].

An important property of wavelet transform is the conservation of energy (sum of square of pixel values). Wavelet transform results in energy of the image divided between approximation and details images, but the total energy remains constant. In lossy compression, loss of energy occurs because of quantization [41]-[50].

Another property of wavelet transform is energy compaction. The compaction of energy describes how much energy has been compacted into the approximation image during wavelet analysis. Compaction will occur wherever the magnitudes of the detail coefficients are significantly smaller than that of the approximation coefficients. Compaction is important when compressing signals because more the more energy compaction into the approximation image, the higher compression efficiency may be obtained. Wavelet transform decomposes the signal into various sub bands, each of which has its own spatial orientation feature that can be efficiently used for image coding [33]-[37].

V. MEDICAL IMAGE COMPRESSION BASED ON ADVANCED WAVELET CODERS

Historically, the concept of "ondelettes" or "wavelets" originated from the study of time-frequency signal analysis, wave propagation, and sampling theory [53]. One of the main reasons for the discovery of wavelets and wavelet transforms is that the Fourier transform analysis does not contain the local information of signals. So the Fourier transform cannot be used for analyzing signals in a joint time and frequency domain [54]-[60]. Wavelet transform has a good locality character of time-frequency domain, overcome the limitations of Fourier transform in dealing with the smooth complex image signal decomposition and reconstruction effectively and efficiently. Due to its higher coding efficiency and superior spatial and quality scalability features over the DCT coding technique, the discrete wavelet transform (DWT) coding has been adopted by JPEG-2000 still image coding standards as the core technology.

As a matter of fact that digital images generally contain significant amounts of spatial and spectral redundancy. Spatial redundancy is due to the correlation between neighbouring pixel values, and spectral redundancy is due to the correlation between different colour planes. Image compression (coding) techniques reduce the number of bits required to represent an image by taking advantage of these redundancies [20]-[25]. An inverse process called decompression (decoding) is applied to the compressed data to get the reconstructed image. The objective of image compression is not only to save the storage area but also to keep the resolution and the visual quality of the reconstructed image as close to the original image as possible [48].

Many image coders have been designed, developed, constructed, and used for the past two decades and each algorithm has got its own merits and demerits [51]-[53]. Shapiro proposed EZW (Embedded Zero-tree Wavelet) algorithm in 1993 and the complexity of this algorithm is not high and the streaming is embedded. It is easy to control compression ratio and realize scalable coding [53]. Said and Pearlman proposed a new efficient improvement method in 1996, namely SPIHT (Set Partitioning In Hierarchical Tree), using the spatial
of the coder [86]-[93]. Peak signal-to-noise ratio (PSNR) has been used for the purpose of comparison because it is easy to calculate and is mathematically tractable [94]-[95].

VII. IMAGE QUALITY ASSESSMENT BASED ON STRUCTURAL SIMILARITY INDEX (SSIM)

Most of these techniques make use of transform coding, vector quantization, fractals, or sub band/wavelet coding for removing psycho visual and statistical image redundancies [66]. It is well known that the image quality assessment plays a major role in many multimedia computing and communication in general and biomedical applications in particular because each compression technique introduces artifact, creating blocky, blurny, patchy or smudgy images. Nowadays automated quantitative metrics are also proposed for testing and evaluating various image compression techniques or devices. However, the goal and purpose of quality metric is easy to compute and able to quantify all types of image artifacts.

Several methods have been suggested in the literature trying to overcome the drawbacks of subjective measures. The well known and classic work of quality assessment for image systems are summarized here. Wang et al. (2004) suggested that how Image quality assessment can be measured from error visibility to structural similarity [85]. Wang and A. C. Bovik (2004) elucidated in their research report that why image quality assessment is so difficult specially on multimedia domain [86]. These indicators provide quality results in concordance with human judgment which requires the integration of the major properties of the Human Visual System (HVS).

An objective assessment of the image or video quality is based on various criteria to identify an objective quality score. Eskicioglu et al. (1995) proposed the comprehensive treatment on image quality measures and their performance based on quantitative based approach [112]. Rehman et al. (2011) suggested how reduced reference image quality assessment by Structural Similarity Estimation (SSIM) can be used to still images and video applications [90]-[95]. Seshadrinathan et al. (2010 ) conducted a study on subjective and objective quality assessment of video based on structural similarity index and found that SSIM gives better results than the PSNR or MSE index [89]. Grgic et al. (2001) experimentally proved the quality assessment for the performance of image compression using wavelets techniques [113].

VIII. STATE OF THE ART PICTURE CODING EVALUATION FOR MEDICAL IMAGE COMPRESSION

One can find in the literature several variants of the original model with respect to the image fidelity and the compressed image. Most proposed quality assessment
approaches in the literature are error sensitivity-based methods. There are a number of notable reviews of image quality metrics. In particular, Kim et al. (2010) presented an in-depth survey on a number of quality metrics that primarily on mathematically oriented metrics [109]. Eckert et al. (1998) elucidated a useful discussion of a number of visual factors which could be incorporated in a perceptual metric assessment to predict image quality [110].

Sakrison, (1977) proposed a picture quality scale and gave an integrated view for image coding applications [115]. Tulu et al. (2008) intimated how an empirical investigation of objective and subjective video quality for the internet-based telemedicine [117]. Lukas et al. (1982) suggested a picture quality prediction based on a visual model for still images and video coding applications [119]. Kurt et al. (1979) comprehended a second-generation image-coding techniques and pointed out an empirical formula for quality assessment for video coding [124]. Miyahara (1988) presented quality assessments for visual service which covered only the basics of the picture evaluation [125]. Quality measurements are usually made using the pixel elements of digitized images. For more accurate assessment, a continuous image field can be generated by two-dimensional interpolation of the pixel matrix. Metrics for image quality have been defined in either spatial or frequency domain. Two-dimensional discrete wavelet transform is a common tool for frequency domain analysis [126]-[132].

IX. RESULTS AND DISCUSSIONS

From the literature survey, it is evident that lossless image compression, the encoding time and algorithm complexity is too high. To overcome these difficulties, an efficient hybrid algorithmic approach for medical image compression method based on Discrete Wavelet transform (DWT) and a suitable variable entropy encoding is proposed. Secondly, the trait features of the existing algorithms are carefully investigated and found that the trade-off between compression ratio and the picture quality is also investigated or evaluated based on different wavelet filters, number of decompositions, image contents and statistical analysis of the medical images. Thirdly, research work is also investigated, examined and found out the various state of the art image quality metrics for gray scale and their application to medical image compression system.

For the past two decades, efficient compression algorithms have been proposed and used in order to reduce transmission time and storage costs. The quality evaluation of medical image compression is an essential process in order to provide the cost effective services to the common men in the health care sector. In the above literature study, we have observed that the image quality measurement is still an unsolved problem today [67]-[69]. New studies exploiting certain aspects of the HVS report reasonable success in quantifying certain types of distortion based on subjective ranking. This issue is continuing to expand and has achieved a certain maturity level within the community of multimedia communication and multimedia computing [2]-[5].

X. CONCLUSIONS AND FUTURE SCOPE

In this proposed paper, we have investigated and examined a detailed survey on performance analysis of image compression techniques for medical applications on cloud computing. Several available image compression techniques have been analyzed and examined. We comprehend from the literature that implementation of medical image compression is risky, expensive and complicated. Its implementation success rate depends on many factors. A good understanding on the complexities and issues related to implementing the technology is very crucial in order to have a successful implementation plan for a hospital wide medical installation.

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