Compression Algorithms for Imaging Instruments – A Mini Review

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***Abstract*—Remote consultation, surgery, and diagnosis can generate a variety of technical issues of the image compression for the patients' text and video data because of the communication channel requirements. Therefore, various image compression algorithms have been developed for portable, point-of-care, and mobile medical imaging systems. Nowadays, multimodality or portable medical instruments have been widely used and they have wireless transmission capabilities using WiFi or 5G communication channels such that image compression algorithms are very important to transfer the image data quickly and efficiently. Therefore, the image compression algorithms and measurement parameters are reviewed for medical imaging instruments.**

Keywords— image compression algorithm; medical imaging instruments; imaging system; imaging instruments; image data; measurement parameters

I. Introduction

Medical imaging instruments are X-ray, computed tomography (CT), magnetic resonance imaging (MRI), ultrasound, optical coherence tomography (OCT), optical imaging, single photon emission computed tomography (SPECT), and positron emission tomography (PET) [1-5]. They have been widely used to monitor a variety of clinical applications such as small animal imaging or surgical tools for research or human body conditions for diagnosis and treatment in the clinics and hospitals [1, 6-13]. X-ray, CT, SPECT, and PET are ionized and invasive medical imaging instruments [14-19]. However, MRI, OCT, optical imaging, and ultrasound are non-ionized, non-destructive, and non-invasive medical imaging instruments [20-27].

Advanced semiconductor, artificial intelligence, deep learning, machine learning, and communication technologies could provide medical imaging instruments more efficient and powerful diagnosis [28-35]. These kinds of advanced technology development can make patients use less hospital visit and more frequent usage for wireless medical services with portable devices [36-41]. Therefore, it could be helpful to improve the life quality because the patients could reduce medical expenses.

In the hospitals, picture archive communication system (PACS) can control the image and text data of the patients using network servers with their own special security algorithms [42]. However, remote-consultation, surgery, and diagnosis have been used between the patients and medical doctors working remotely using personnel computers or cellular phones through communication channels [43, 44]. Therefore, image compression issues have been generated for portable communication machines such as cellular phones and tablet personal computers because of bandwidth and speed limitation.

Image compression algorithms are very useful and efficient tools because the picture and video data obtained from MRI and PET are very large which is up to several gigabyte size only for one image data [45, 46]. However, several image data need to be obtained for diagnosis.

Nowadays, multimodal medical image instruments like PET-CT, PET-MRI, and MRI guided ultrasound have been widely used because only one single medical image instrument has its own advantages and disadvantages [47-51]. For example, the PET has very low image quality for structural information. However it can provide useful information to detect the cancer information [52]. The CT has very high image quality for structural and anatomical information [52]. However, it cannot provide functional information such as cancer information [53, 54]. Therefore, PET-CT are valuable to investigate the certain cancer information even though they provide very highly invasive medical image [55].

Ultrasound imaging can easily provide video data compared to MRI [9, 56, 57]. Ultrasound also can detect the sudden temperature changes during surgery operations for patients [58, 59]. However, MRI can provide very accurate temperature information for patient body because MRI can measure tissue magnetic properties, water diffusion, and blood oxygenation data simultaneously [60]. For cancer treatment using high intensity focused ultrasound which we called HIFU, temperature monitoring process is very important especially for surgery operation [61].

Therefore, MRI could support such a useful function of temperature variances.

For multimodal image instruments, the hospitals might be preferable for accurate diagnosis. However, the picture and video data size generated from multimodal medical image instruments are much larger than only one single medical image instrument [62]. Therefore, it is not possible to transmit and receive such huge data using current cellular phones and tablet personal computers without image compression.

Compared to other medical imaging instruments, ultrasound machines manufactured from several medical imaging companies such as Teratech, General Electric, Sonosite, Siemens, and MobiSante have been developed as portable, point-of-care, or mobile type ultrasound image instruments [63-65]. Therefore, these instruments can easily transfer patient data out of the hospitals or even local clinics; portable ultrasound machines have been used to diagnose broken arms and shoulders even during the sports game and emergency rooms [29, 30, 66]. For such situation, the speed to transmit the data and receive the diagnosis from the hospitals is very important for immediate diagnosis [67]. The multimodal imaging instruments or portable medical imaging instruments can possibly transfer the patient image data through communication channels such as Wi-Fi, 4G, and 5G communications very quickly [68, 69]. Therefore, it is useful to use efficient image compression algorithms for medical imaging instruments. For these various situations, the image compression algorithms for medical imaging instruments are more demanding for immediate diagnosis [67, 70].

Section II describes a variety of image compression algorithms for currently developed communication systems. In addition, these image compression algorithms for medical image instruments and evaluation parameters for image compression algorithms will be studied. Section III is the conclusion of the review paper.

II. MATERIALS AND METHODS

A. Image Compression Algorithms

To use communication channels for transmitting the image data remotely, we need to obtain the patient image data from the medical image instruments [71-73]. Fig. 1 describes how to generate compressed image files from medical image instruments through communication channels [74]. The image instruments such as ultrasound, CT, or MRI generate digital imaging and communication in medicine (DICOM) image files obtained from patients and then, transfer these files to communication servers for further encoding process [75]. The DICOM is a standard image type of transferring the patient image with secured digital signature and watermark algorithms [1]. Through communication channels such as Wi-Fi or 5G, encoded image data are transmitted via air and then, received data was decoded to fully recover the original image data [76]. This is the fundamental transmission process to transfer and receive the image data through communication channels [77, 78]. The multimodal image instruments need to generate each different image so the images need to be combined. Additionally, some image processing techniques like bandpass filter to improve the image quality could be performed before image compression process begins [45].

A variety of image compression algorithms have been developed for communication systems. The joint photographic experts group (JPEG), Lempel-Ziv-Welch (LZW), portable network graphics (PNG), tagged image file format (TIFF), and graphics interchange format (GIF) are common image compression file types which are widely used in the academic and business fields [79]. In the medical imaging instruments, independent JPEG Group (IJG), JPEG 2000, LZW, PNG, GIF, and BMP file format have been used. For mammograms and CT instruments, JPEG and JPEG 2000 are used [55]. For CT and MRI medical imaging instruments, IJG is used [80]. For EEG and MRI medical imaging instruments, LZW is used [81]. For portable medical ultrasound imaging instruments, PNG is used [79].

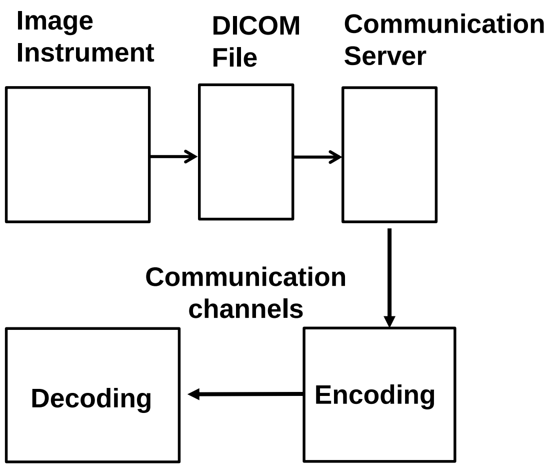

Fig. 1. *Image file transfer with communication channels*

Fig. 2 describes procedures for image compression and decompression process in detail [82]. The compressed image format is converted from DICOM file format through computer programs. Original DICOM files need to be reduced due to some redundant error data [83]. These converted file format can be obtained by reducing and mapping the image data for processing and quantizing the image data [84]. After further encoding process, compressing the image data are performed.

When receiving compressed image data through the communication systems in the personal computers, personal digital assistants, readers, or tablet computers, need to properly perform decoding process using some image processing tools such as MATLAB (MathWorks, Natik, USA) or Python (Python Software Foundation, Delware, USA) programs in the personal computers to obtain the original data [85]. However, these several processes could be mixed with other unwanted noise or distorted signals, thus reducing the image quality [86]. Therefore, additional several filtering processes could be performed using fast Fourier transforms and inverse fast Fourier transforms [87]. In the spectrum domain, we can easily improve the image quality by reducing unwanted noise or harmonic signal components [88-90].

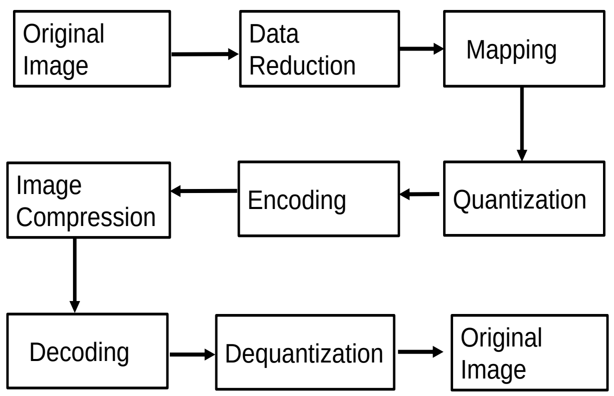

Fig. 2. *Imge comrpession algorithm with encoding and decoding prcoess*

B. Measurement parameters for Image Compression

There are several measurement parameters to estimate image compression quality. However, compression ratio, peak signal-to-noise ratio (PSNR), structural similarity index (SSIM), and mean square error (MSE) are commonly used [91]. First, the compression ratio can be obtained by dividing the original image file size by compressed image file size [79]. The image file size reduction is very useful to reduce burden of the occupied bandwidths for high-speed communication systems [92]. Therefore, compression ratio of the image data is important to evaluate the image compression algorithms in the communication systems. The DICOM files have no compressed image data so they have 100% image quality compared to compressed image data [83]. However, wireless or portable communication instruments have their own occupied bandwidth and speed limitation [93]. Therefore, compressed image data need to be used instead of DICOM files which have 100% image quality.

The PSNR parameter is the ratio of the maximum signal power of the image data to the noise power of the image data at center frequency [94]. The signal power of the image data should be higher than noise power of the image data. Otherwise, the image cannot be observed in the computer. The compressed images are supposed to have low noise signals so higher PSNR parameter is always desirable [95]. For communication systems, PSNR parameter has been used to estimate how much compressed image file is corrupted [55].

SSIM parameter is a kind of measurement parameter to show how much the compressed image data is similar to the original image data [96]. Higher SSIM parameter is also desirable for compressed image [97]. Therefore, SSIM is used to compare the original image data and compressed image data and indicate how much images are similar each other.

MSE parameter is the measurement parameter to show how much the pixel value differences between the compressed and original image data [98]. Lower MSE parameter is also desirable for compressed images. After processing compressed image data, some image data could be lost so lower MSE parameter needs to be important.

For each different image quality used in the medical imaging instruments, several measurement parameters such as compression ratio, PSNR, SSIM, and MSE need to be estimated because each different communication systems has its own occupied physical hard disk space, speed, and bandwidth limitations. However, most of image quality has reached up to maximum of 80% after image compression process performed [99]. Otherwise, the image quality for medical instruments for diagnosis and treatment is hard to be predicted. Developed algorithms have their own advantages and disadvantages for each different parameter. These measurement parameters are also related with axial and lateral image resolutions [100-106]. The image resolutions are very crucial for diagnosis and treatment. Therefore, image compression results for different image systems need to be evaluated.

III. CONCLUSION

The various medical imaging data with enhanced imaging compression algorithm is essential for current medical imaging systems. The multimodal, point-of-care, and portable medical imaging instruments possibly have a chance to transmit and receive the patient data through communication channels using high speed WiFi or 5G communication channels. Due to fast wireless internet technologies with remote diagnosis and treatment capabilities could be possibly applied to medical imaging instruments. Therefore, this review of the currently developed algorithms for medical imaging instruments could be helpful to develop the remote consultation, surgery, and diagnosis.

To evaluate the developed image compression algorithms, several measurement parameters such as compression ratio, PSNR, SSIM, and MSE need to be evaluated for wireless communication system requirements. The compression ratio is valuable to reduce the file size because of the limited bandwidth for current communication systems such that the transmission time could be reduced. The transmission time is crucial for high speed communication systems. The PSNR parameter is very important to estimate how much the original image data is distorted or corrupted after the image compression process. The SSIM is useful how much the compressed image data after transmission is similar to the original image data before transmission. The MSE is the parameter to show how much the pixel value differences between the compressed image and original image data. These measurement parameters are also related with axial and lateral image resolutions. Therefore, developed image compression techniques need to be evaluated using several measurement parameters before integrating with medical imaging instruments.

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