LOSSLESS COMPRESSION OF X-RAY CARDIAC IMAGES

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ABSTRACT

Digital medical imaging systems like Picture Archiving and Communication System (PACS) has become a crucial tool supporting both decision making and treatment procedures in medical environments. Advantages come from reduced storage and management costs associated with image data and increased intra and inter-institutional portability of data in communication networks. One of the most important benefits of the digital medical image is that it allows the widespread sharing and remote access to medical data by outside institutions. Mass storage and digital communication systems costs are continuously decreasing, but, as individual digital medical studies become significantly larger, requirements for transmission bandwidth and data storage capacity still exceed available technologies. Image compression algorithms offer the means to minimize storage cost and to increase transmission speed. This paper provides a comparison about the application of Digital Imaging and Communication in Medicine (DICOM) lossless compression standards on Angiography cine acquisition images. Moreover, some other state-of-the-art compression schemes are evaluated when applied on angiographic images. We also propose new directions for the lossless compression of this type of images, based on exploring a third dimension of the data. Preliminary results are presented using some lossless video compression methods.

1. INTRODUCTION

To minimize storage space and increase transfer rate, the medical images go through a compression process which is of vital importance in PACS and teleradiology applications, due to the typical huge volume of patients data [1]. Some grayscale image modalities used in radiology applications have very large sets of images (e.g. a single 240 frames angiographic cine acquisition represents approximately 60 MB of storage and a multislice Cardiac Computerized Tomography study of 2500 images per patient, may reach approximately 1.3 GB). Medical images digital storage can be challenging since it is essential to preserve the image quality and also because the images can be very large in size and number [2, 3]. Several reasons can be pointed to stress the importance of compression [3]: Digital medical images databases are normally very large repositories; Patients data must be stored for long periods resulting in a continuous growth of medical imaging databases; High resolution and many bits per pixel results in large volumes; Image transmission time is volume driven. The usefulness of a PACS depends greatly on appropriate transfer waiting times.

Various methods, both for lossy and lossless image compression, are proposed in the literature. Lossy compression techniques can achieve high compression ratios but they do not allow one to reconstruct exactly the original version of the input data. The use of lossy compression in medical imaging is still controverse for particular applications since it can result on decreased diagnostic accuracy and confidence. Completely reversible compression schemes are only possible using lossless compression methods but, in this case, the achievable compression ratios are modest, in the order 2:1 up to 4:1 [3, 4]. The lossless mode of the JPEG standard [5, 6, 7], the lossless mode of JPEG2000 [8, 9] and the JPEG-LS [10, 9] are nowadays the lossless image compression algorithms allowed by the DICOM standard.

Coronary Angiography (XA) is currently a prominent modality for coronary heart disease diagnostic and interventional procedures. A set of 40 DICOM 8 bits digital cine angiograms were used in this experiment. The sequences length vary from 44 to 238 images.

2. STANDARD IMAGE COMPRESSION METHODS

PNG[11], JBIG [12], JPEG-LS [10, 9] and JPEG2000 [8, 9] are state-of-the-art standards for coding digital images. They have been developed with different goals in mind, being PNG designed for compression simple and color-quantized images, JBIG more focused on bi-level imagery, JPEG-LS dedicated to the lossless compression of continuous-tone images and JPEG2000 designed with the aim of providing a wide range of functionalities. These four standard image encoders cover a great variety of coding approaches. In fact, whereas JPEG2000 is transform based, JPEG-LS relies on predictive coding, JBIG relies on context-based arithmetic coding and PNG is a dictionary based compression method. This diversity in coding engines might be helpful when drawing conclusions regarding the appropriateness of each of these technologies for the case of compression of Angiography cine acquisition images.

3. EXPERIMENTAL RESULTS AND DISCUSSION

In order to perform the experiments reported in this paper, we used a set of 40 DICOM digital cine angiograms, acquired at 15 fps with 8 bits grayscale (256 gray levels) and a matrix size of 512×512 pixels. The length of the sequences varies from 44 to 238 images, corresponding to about 3 to 16 seconds.

Table 1. Compression results, in bits per pixel (bpp), using lossless JPEG2000, JBIG, PNG and JPEG-LS standards. For reference, results are also given for the popular compression tool GZIP and, as a benchmark, we also present results regarding CALIC [13].

Gzip	CALIC	JLS	J2k	JBG	PNG
3.910	2.272	2.324	2.415	2.712	3.212

From the experimental results obtained (Table 1, and regarding the standard image coding techniques allowed by DICOM standard, we conclude that JPEG-LS gives the best lossless compression performance and accomplish, in some cases, better compression results than CALIC.

In our experiments, we observed noticeable differences in the compression ratios for different cine angiograms. When compressed with JPEG-LS, for example, differences of 1 bpp can be observed between the best and the worst compression ratio, revealing that angiographic studies are relatively heterogeneous although they were acquired with the same equipment.

By observing some XA frames (Figure 1) it is possible to recognize that consecutive images are very similar and the exploitation of this inter-frame redundancy, together with image spacial redundancy, would possibly lead to a better compression approach. On the other hand, the majority of data volume produced in an angiographic study is relative to dynamic captures (i.e. videos).

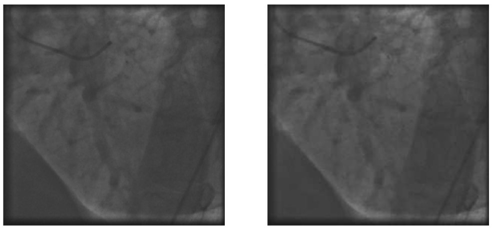

Fig. 1. An example of two successive XA frames.

Since angiographic cine acquisition has intrinsic dynamic behavior, lossless video compression algorithms are logical alternatives to still frame image coding.

To perform the video experiments, three freely available lossless video codecs were chosen. These codecs are considered the best lossless video compressors available in terms of compression ratio. The results obtained with these video codecs are presented in Table 2.

Table 2. Average compression results, in bits per pixel (bpp), using three freely available lossless video codecs.

Encoder	bpp
Alparysoft lossless	2.685
Lagarith lossless	2.395
MSU lossless	2.381

The MSU lossless codec has a slightly better average compression ratio but the compression time is very high, disabling the usage of this codec (with maximum compression configuration) in a real environment. This codec can be tuned so that the time will be similar to the others codecs but the compression ratio falls between the Lagarith and the Alparysoft codecs.

Comparing the results of Table 1 and Table 2 it can be seen that video lossless codec compression ratios are worse than the ones obtained with CALIC and JPEG-LS (JPEG2000 is slightly better than Alparysoft codec). Available lossless video codecs do not improve compression ratio of XA since they do not take into account the fact that XA files are 8 bits grayscale and it is not necessary to save three color components but only one. Even if two of the three color components are set to zero (or some other constant), the codec still need some data to represent them. Moreover, these codecs are developed for lossless compression of natural content color video and don't explore the particular characteristics of these type of images.

The results obtained in this study points that the development of a grayscale video codec is of great importance and could lead to better compression ratios. Since X-ray imaging is necessarily grayscale, the future codec could be extended to almost every X-ray medical imaging modalities. However, it must be taken into account that some modalities have higher bit depths than angiography, like Computerized Tomography that could have 12 or 16 bits resolution. Nevertheless, better compression ratios can be achieved if a video codec is specially developed for medical X-ray imaging.

4. REFERENCES

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