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Research article

RUN LENGTH ENCODING BASED LOSSLESS MRI IMAGE COMPRESSION USING LZW AND ADAPTIVE VARIABLE LENGTH CODING

使用LZW和自适应可变长度编码的基于运行长度编码的无损MRI图像压缩

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Abstract

Medical image compression is considered one of the most important research fields nowadays in biomedical applications. The majority of medical images must be compressed without loss because each pixel information is of great value. With the widespread use of applications concerning medical imaging in the health-care context and the increased significance in telemedicine technologies, it has become crucial to minimize both the storage and bandwidth requirements needed for archiving and transmission of medical imaging data, rather by employing means of lossless image compression algorithms. Furthermore, providing high resolution and image quality preservation of the processed image data has become of great benefit. The proposed system introduces a lossless image compression technique based on Run Length Encoding (RLE) that encodes the original magnetic resonance imaging (MRI) image into actual values and their numbers of occurrence. The actual image data values are separated from their runs and they are stored in a vector array. Lempel–Ziv–Welch (LZW) is used to provide further compression that is applied to values array only. Finally the Variable Length Coding (VLC) will be applied to code the values and runs arrays for the precise amount of bits adaptively into a binary file. These bit streams are reconstructed using inverse LZW of the values array and inverse RLE to reconstruct the input image. The obtained compression gain is enhanced by 25% after applying LZW to the values array.

Keywords: Lossless Compression, LZW, RLE, VLC, MRI.

摘要

医学图像压缩被认为是当今生物医学应用中最重要的研究领域之一。大多数医学图像必须无损压缩,因为**每**个像素信息都很有价值。随着医疗保健领域中有关医学成像的应用的广泛使用以及远程医疗技术的重要性日益提高,至关重要的是最大限度地减少归档和传输医学成像数据所需的存储和带宽需求,而不是采用以下方法:无损图像压缩算法。此外,提供高分辨率和图像质量的处理图像数据的保存已变得非常有益。拟议的系统引入了一种基于游程长度编码(RLE)的无损图像压缩技术,该技术将原始磁共振成像(MRI)图像编码为实际值及其出现次数。实际图像数据值与其运行分**开**,并将它们存储在向量数组中。朗佩尔 - 谢夫 - 韦尔奇(LZW)用于提供仅应用于值数组的进一步压缩。最终,将应用可变长度编码(VLC)对值进行编码,并针

对精确数量的位将数组自适应地运行到二进制文件中。使用值数组的反LZW和反RLE重构这些位流,以重构输入图像。将LZW应用于值数组后,获得的压缩增益提高了25%。

关键词:无损压缩,LZW,RLE,VLC,MRI。

I. Introduction

Digital imaging technologies have become of great importance due to their widespread use in most fields, especially medical imaging. These technologies have made possible the transformation of real-world medical images to computerrecognizable formats known as digital images. Medical images are used for medical diagnosis and surgery preparation in the health recovery process. Several medical imaging types, such as MRI, computed tomography (CT), ultrasound (US), Xray, Gamma-rays, electrocardiography (ECG), etc., are being used for medical imaging [1]. Compression refers to storage size, data cost reduction, and accelerating the transmission speed of medical information from one source to the destination networks. Therefore, lossless medical image compression is an important research field. Due to the large size of medical images, it requires a lot of storage space and bandwidth compared to normal images [2]. Medical images are preferred to be compressed in lossless way to preserve image quality because all of the image details are crucial. Badashah, Liew, Zain, and Ali [1] introduced a lossless image compression technique that focuses on watermarking of US medical images applying LZW lossless-compression to watermarked images. The technique reduces watermark payload without losing data. Where, watermarking is the combining of a defined region of interest ROI and a watermarking secret key. Another compression technique for medical images was proposed by Singh and Pandey [2] by extracting the region of interest ROI and then compressing the medical images using LZW in preparation for transmission. Manlmekalai and Vasanthi [3] proposed a medical image compression technique where the MRI images are pre-processed by applying median filter. Then the smoothed image is split in to ROI and non-ROI of deep fully convolutional networks based on Jaccard distance. Following the ROI segmentation, the edge of ROI is encrypted by Freeman chain coding. The ROI segment is then compressed by hybrid LZW and clipped histogram equalization (CHE). In CHE, the ideal threshold value is selected using a particle swarm optimization technique for the purpose of enhancing with brightness preservation. The non-ROI part is compressed by applying the embedded zero tree wavelet (EZW), where an initial threshold is selected by a firefly algorithm. Saravanan and Surender in [4] suggested a two-step fast lossless compression scheme. In the first step, Huffman coding is utilized to compress the image. In the second stage, all of the Huffman output code words are concatenated and compressed with LZW coding. Reddy, Reddy, Kumar, and Reddy [5] introduced an ROI-based lossless image compression for MRI images, where they segmented based on ROI and non-ROI. The EZW algorithm is used to compress the non-ROI segment while the HARR Wavelet is used to compress ROI. In Singh, Agrawal, Tripathi, and Vaish [6], they suggested a lossless biomedical image compression approach that applies discrete cosine transform (DCT) followed by LZW. Sanchez and Bartrina-Rapesta [7] proposed a lossless compression technique for medical images through improved High Efficiency Video Coding (HEVC) to compress the grayscale anatomical medical images that are depicted with their great volume of edges. The researchers proposed alternative angular and planar projection modes that are based on sample-wise differential pulse code modulation (DPCM) with larger range of directionalities. They also propose an implementation of the DPCM decoding process that maintains the block-wise coding structure of HEVC. Singh, Kumar and Verma [8] presented a hybrid scheme using discrete wavelet transform (DWT) and DCT for medical image compression. DCT is smeared to the DWT details, which normally have zero mean and small variance value, thus achieving higher compression ratio than would be obtained from applying either of the techniques alone.

II. THE PROPOSED COMPRESSION TECHNIQUE

The proposed lossless image compression technique is based on RLE, which is considered a very simple form of lossless data compression, where the data runs (for example, sequences where data of the same value appears in many consecutive data elements) are stored as a single data value and count rather than the original run. This is most

useful on data that contains high redundancy [9]. The output of this step is presented in two arrays: one for values and the other for the number of occurrences. The values array only is then fed to LZW. This approach is considered a dictionarybased lossless compression technique that can compress any image and text without data loss. For further compression [1], [2], the resulting dictionary and the runs array are both encoded using variable length coding on each output stream from the earlier stages, which makes the proposed system locally adaptive because it considers the algebraic attributes of the incoming residue stream. The optimum values for these two codeword lengths should suit the criteria as "they lead to the minimum total number of bits required to characterize all sequence elements values" [10].

III. IMAGE TEST MATERIALS AND **EXPERIMENTAL RESULTS**

The proposed compression approach is tested on four different MRI images (taken by 1.5T MRI scanner Siemens MAGNETOM Avanto in Rizgary Teaching Hospital, Irbil/Iraq); Table (1) shows the general characteristics for the tested images displayed in Fig. (1); the proposed algorithm was tested on a laptop computer with a processor: Intel® Core™ i7 CPU Q740 @ 1.73 GHz, RAM 8.00 GB, x64-based processor). C# programming language was used to implement the proposed compression approach.

Table 1. The general characteristics for the tested images

Image	Sample 1	Sample 2	Sample 3	Sample 4
Sample				
Bit Depth	8	8	8	8
Dimensions	1105 x	1105 x	1105 x	1105 x
	650	650	650	650
Size (KB)	47.3	47.3	46.8	47.4









Sample 1.jpg

Sample 2.jpg

Sample 3.jpg

d. Sample 4.jpg

Figure 1. Tested images samples.

The effect of applying RLE to the MRI image on fidelity criteria

Image	CR	PSNR	MSE	CG	Time (in seconds)	
image	CK				Encode	Decode
Sample 1	1.57	34.95	20.77	36%	1.108	0.803
Sample 2	1.56	35.39	18.76	36%	1.002	0.712
Sample 3	1.56	36.14	15.78	36%	1.068	0.734
Sample 4	1.55	36.04	16.18	35%	1.056	0.732

Table 3. The effect of applying RLE and LZW to the non-redundant values of an MRI image on fidelity criteria

Imaga	CR	PSNR	MSE	CG	Time (in seconds)	
Image					Encode	Decode
Sample 1	2.60	33.69	27.77	61%	1.174	0.893
Sample 2	2.58	34.95	20.76	61%	1.192	0.782

Sample 3	2.59	34.01	25.78	61%	1.482	0.776
Sample 4	2.56	33.95	26.18	61%	1.312	0.935

Tables (2) and (3) show the effects of applying RLE only and RLE combined with LZW and also show the enhancement in compression gain after applying LZW to the array of non-redundant values that are already affected by RLE application.

IV. COMPARISON WITH PREVIOUS RESEARCH

The attained results of the proposed system are compared to the universal published research regarding compression ratio, visual quality measures, and the size of the images tested; the results are shown in Table (4).

Table 4.

The proposed scheme conducted results compared to previously published researches in lossless Medical image compression

Method applied	Compression Ratio	Image Size	PSNR	Reference	Image Type
RLE + LZW	2.60	1105 x 650	34.95	The proposed scheme	MRI
LZW	0.087	100 × 100	-	[1]	Ultra Sound
LZW applied to ROI	2.27	120 x 160	-	[2]	MRI
HEVC intra	2.23	512 x 512	-	[7]	MRI
DCT + DWT	-	-	35.05	[8]	Ultra Sound

Table (4) shows that the compression ratio obtained from the proposed system is higher than the related research, considering the image size is the largest among those tested where the compression scheme is applied to all values of the MRI image, not to a specific ROI or block as in other research.

V. CONCLUSIONS

- Run length encoding is considered the best choice for MRI images that have very large amounts of redundant data as a default characteristic.
- Applying LZW to the runs array didn't show a good compression. According to the nature of the runs, results were obtained that were more like similar values that didn't show the efficiency of LZW, unlike the values arrays that have different data values, and raised the compression ratio and gain.
- Applying variable length coding is a storage-saving method that can calculate the exact

number of bits needed to code each value in both arrays into a binary file that is ready for storage or transmission over open networks.

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