Inverse Diamond Search Algorithm for 3D Medical Image Sets Compression

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Abstract: The scheme of motion estimation is introduced to exploit the redundancy between continuous frames of 3D medical image sets in this paper. The proposed scheme is based on inter-frame motion estimation of inverse diamond search algorithm. The residual images are encoded by the Huffman encoder. The test images include five sets of the heart and two sets of the brain MRI images. The average compression ratio of the inverse diamond search algorithm is similar to the JPEG_LS and diamond search algorithm. The inverse diamond search leads to speed improvement around 5 % over diamond search for all the tested MRI sets.

1. Introduction

In Medical-PACS system (picture archiving and communication system), whose core is computer network, digital medical images play a more important role, with an increasing conflict with limited storage space and transportation bandwidth, so finding effective image compression methods are getting more and more attention. Although lossy compression usually provides much higher compression than lossless compression, lossless compression of medical image data has been required by doctors for accurate diagnosis and legal protection [1-3].

One of the main techniques for efficient lossless compression is prediction. In general, the compression efficiency is highly related to the accuracy of the prediction scheme. A high quality predictor gives high compression performance. The JPEG-LS uses three neighboring pixels to guess the values of the pixels, and is of very high quality predictor for one-pass sequential technique.

On the other hand, to compress a 3D medical image set with multiple slices (frames) is very important in radiology because the most commonly used digital modalities, including MRI(magnetic resonance imaging), CT(computed tomography), PET(positron emission tomography), generate multiple frames in a single examination. The inter-frame redundancies of 3D medical image set are similar to video sequence. The correlation between two adjacent frames is larger than the distances between two adjacent pixels in a frame. It can be exploited the schemes of video coding to the 3D medical image set compression. There are large amount of correlation between adjacent frames in a 3D medical image sets as the same in video sequence.

The block-matching motion estimation (BMME) has been widely adopted in various video coding to reduce the temporal redundancy. The full search (FS) algorithm test all the candidate blocks within the search window exhaustively. The FS algorithm achieves the global optimum result to the motion estimation, while the huge computational load is required. To overcome this drawback, many fast BMME algorithms was developed to locate optimal motion vectors step by step by evaluating as few points as possible to save the computational load. Among them is the well-known three-step search (TSS) [4] and recently developed diamond search (DS) [5].

The DS algorithm employs two search patterns, the first pattern, called large diamond search pattern (LDSP), comprises nine checking points from which eight points surround the center one to compose a diamond shape. The second pattern consisting of five checking points forms a smaller diamond shape, called small diamond search pattern (SDSP). In the searching procedure of the DS algorithm, LDSP is repeatedly used until the step in which the minimum block distortion (MBD) occurs at the center point. The search pattern is then switched from LDSP to SDSP as reaching to the final search stage. Among the five checking points in SDSP, the position yielding the MBD provides the motion vector of the best matching block.

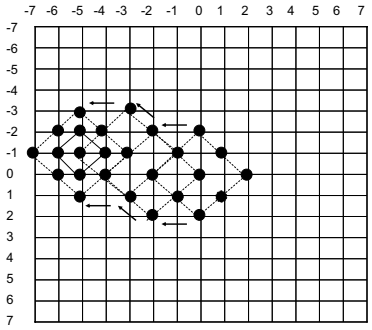


Figure 1 Search path example of diamond search

2. The proposed method

Motion estimation is introduced to exploit the redundancy between continuous frames of 3D medical image sets in this paper. The motion vectors of 3D medical image sets are smaller than the video sequence. To reduce the prediction cost in the steps of motion estimation. The proposed scheme is based on inter-frame motion compensation of inverse diamond search algorithm as shown in Fig. 2. We inverse the steps of the diamond search algorithm. The search procedure firstly uses small diamond search pattern consisting of 5 points. The coarse search continues based on a gradient scheme until the center point of the diamond has the current smallest distortion. Then the large diamond pattern consisting of 9 search points is used until the step in

which the minimum block distortion (MBD) occurs at the center point. The search pattern is then switched from SDSP to LDSP as reaching to the final search stage. The residual image is obtained by subtracting the prediction frame from the actual one. The residual images are encoded by the Huffman encoder. The Huffman coding technology is a commonly used scheme for data compression because it is very simple and effective.

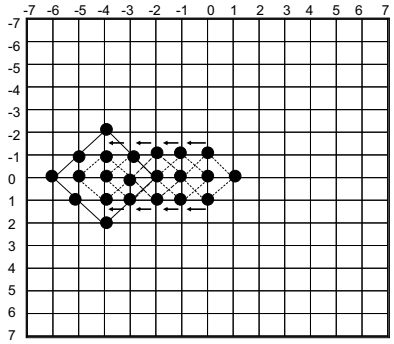
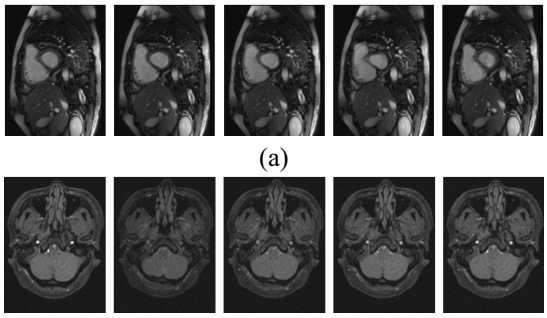


Figure 2 Search path example of inverse diamond search

3. Simulation results

The test images include five sets of the heart MRI and two sets of the brain with voxel values ranging from 0 to 255. Each heart MRI set consists of 25 frames. The frames of brain_1 and brain_2 MRI set are 50. Both five frames of the heart_1 and brain_1 are shown in Figure 3.



(a)

(b)

Figure 3 Test MRI medical images (a) Heart_1 (b) Brain_1

The criterion used to compare them is compression ratio defined as

$$Compression \quad Ratio(C.R.) = \frac{original \quad file \quad size}{compressed \quad file \quad size} \qquad (1)$$

Comparisons of compression ratio between the intra frame and inter frame coding are shown in Table 1. The residual images of the DPCM are also encoded by the Huffman encoder. The inter frame coding is superior to the intra frame coding including the DPCM and JPEG_LS for all five heart MRI image sets. The average compression ratio of the inverse diamond search algorithm is similar to the JPEG_LS and diamond search algorithm.
The compression ratio of the four inter frame coding is similar as show in Table 1. The compression ratio of heart_1 t with all 25 frames and part frames of brain_1 MRI set are shown in Figure 4 and Figure 5.

Table 1 Comparison of compression ratio between the intra frame and inter frame coding

	Intra frame		Inter frame			
	DPCM	JPEG-LS	FS	TSS	DS	Inverse-DS
Heart_1	1.39	1.68	1.87	1.84	1.85	1.85
Heart_2	1.49	1.8	1.96	1.94	1.94	1.94
Heart_3	1.46	1.76	1.91	1.89	1.9	1.9
Heart_4	1.49	1.78	1.95	1.93	1.94	1.94
Heart_5	1.55	1.87	2.02	1.99	2	2
Brain_1	1.82	1.94	1.65	1.65	1.65	1.64
Brain_2	2.21	2.34	1.86	1.86	1.86	1.84
average	**1.63**	**1.88**	**1.89**	**1.87**	**1.88**	**1.88**

To evaluate performance of the proposed reverse DS algorithm with the time complexity, we compare it against the full search, three steps search and DS algorithms in terms of number of search points. The average search points per block are listed in Table 2. The speed improvement rate (% SIR) is defined by [6]

$$SIR = \left(N_2 - N_1\right) / N_2 \times 100\% \qquad (2)$$

where N_1 and N_2 are the number of search points needed in the two search algorithms. Table 3 shows the Speed improvement rate of the inverse DS with the full search, three steps search and DS algorithms. From Table 3, we can see that the inverse diamond search leads to speed improvement around 5 % over diamond search for all the tested MRI sets.

Table 2 Average number of search points per block

Search Points	inter frame			
	FS	TSS	DS	Inverse-DS
Heart_1	225	25.75	16.42	15.71
Heart_2	225	25.69	16.71	15.88
Heart_3	225	25.66	16.79	15.99
Heart_4	225	25.67	16.68	15.79
Heart_5	225	25.66	16.87	15.85
Brain_1	225	25.39	21.94	20.1
Brain_2	225	24.98	26.19	24.2
average	**225**	**25.54**	**18.80**	**17.65**

Table 3 Speed improvement rate of the inverse DS

SIR(%)	Inverse-DS		
	Over FS	Over TSS	Over DS
Heart_1	93.02	38.99	4.32
Heart_2	92.94	38.19	4.97
Heart_3	92.89	37.69	4.76
Heart_4	92.98	38.49	5.34
Heart_5	92.96	38.23	6.05
Brain_1	91.07	20.83	8.39
Brain_2	89.24	3.12	7.60
average	**92.16**	**30.79**	**5.92**

4. Conclusions

The scheme is based on inter-frame motion estimation of inverse diamond search algorithm for 3D medical image sets has been developed and tested. Experiments show that The inter frame coding is superior to the intra frame coding including the DPCM and JPEG_LS for all five heart MRI image sets. The average compression ratio of the inverse diamond search algorithm is similar to the JPEG_LS and diamond search algorithm. The inverse diamond search improves the speed around 5 % over diamond search for all the tested MRI sets.

The choice of near lossless is another important aspect of the medical image compression. The further work can determine whether compression ratio can be improved with the use of inverse diamond search.

Acknowledgment

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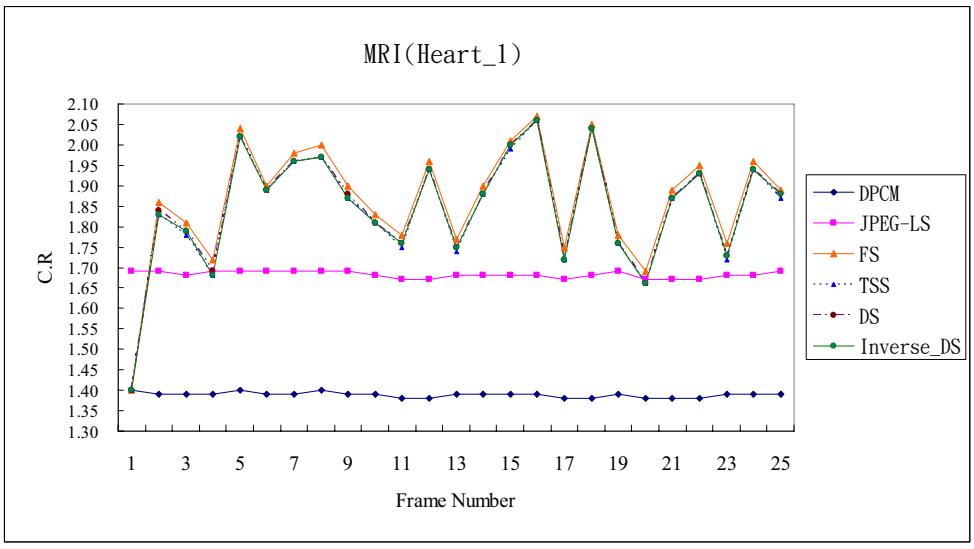

Figure 4 Comparison of compression ratio with Heart_1

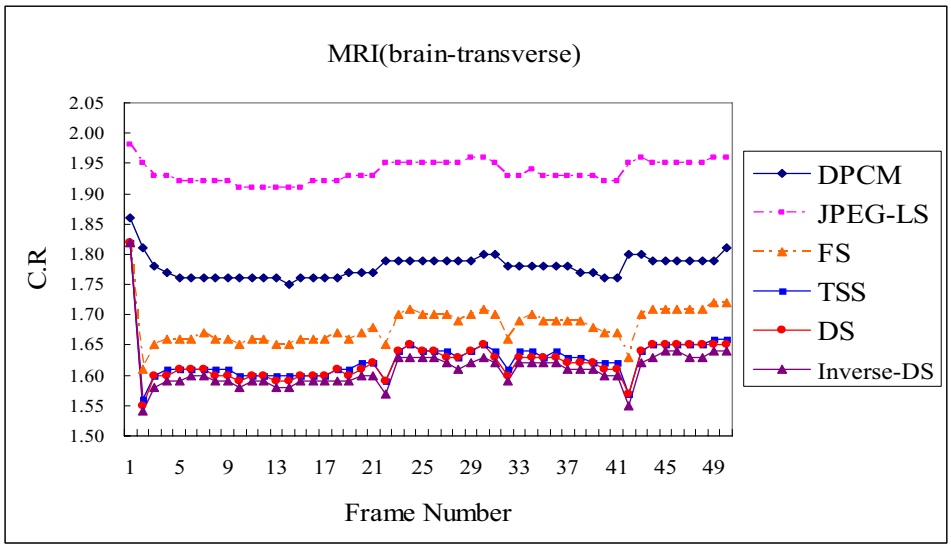

Figure 5 Comparison of compression ratio with Brain_1

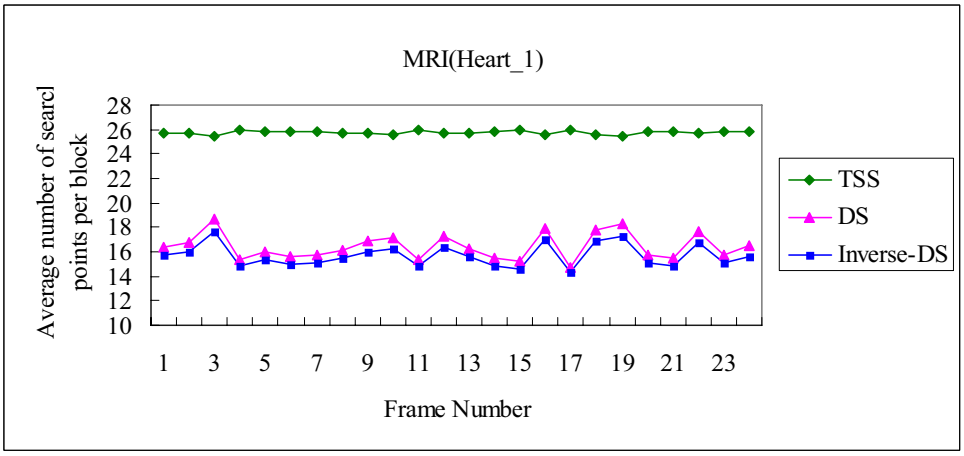

Figure 6 Comparison of average search points with Heart_1

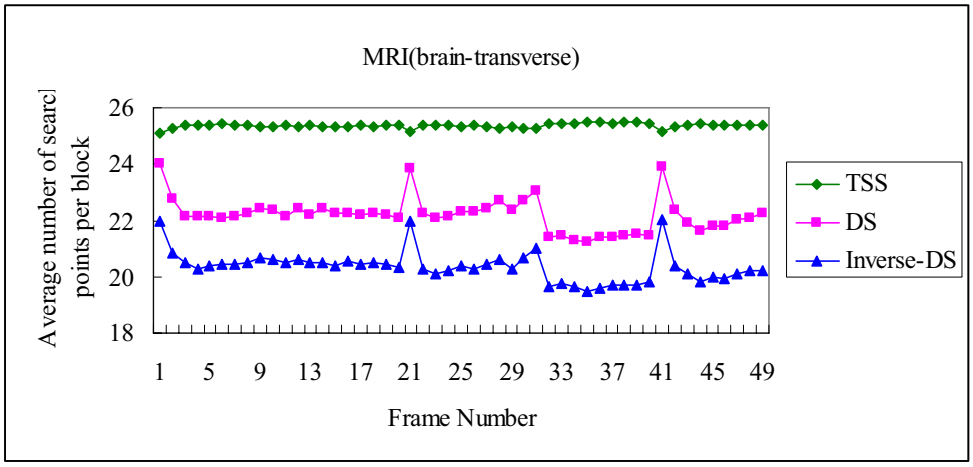

Figure 7 Comparison of average search points of Brain_1