The proposed diagonal scanning method:

- The image is sub-divided into two diagonal halves and stored into two arrays and both halves are encoded in parallel fashion diagonally as shown in Fig.5 as we proceed from the center diagonal to top and bottom of the image.
- The length of the scanning lines for coding decreases and number of comparisons will reduce as we move from center to top and bottom of the image.
- The correlation between the pixels is exploited when current line is encoded compared with respect to previous line, using modes and definition of picture elements, which will help in reducing the time to encode drastically and as well as results in improved compression ratio.
- Whenever horizontal coding mode occurs, MRH uses RH prefix free coding words proposed by author [17], which will help in achieving improved compression as the average length of the code words is 7.7046bits/symbol compared to 8.6270 bits/symbol for MH code words.

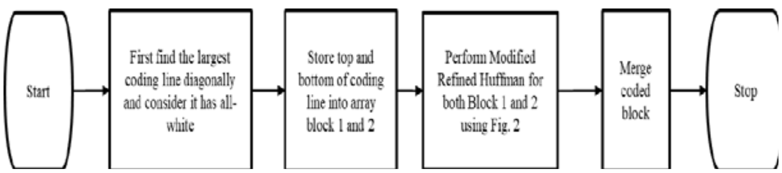


Fig. 4: Flow diagram of the proposed diagonal encoding

Highlights of proposed MRH:

Comparing Fig.2. and Fig.4., it can be seen that in the existing MMR the size of scan line remains the same where as in the proposed MRH the size of scan line decreases with every successive scan, thus helping in improving compression ratio. For example, let us consider an image X which is of size of 6*6 performing encoding on X using MMR needs to scan 36 pixel positions. However, using proposed MRH for encoding image X needs to scan 21 pixel positions. As the proposed model the encoding line size reduces with every successive scan line.

Thus, MRH aids in attaining a better performance than the MMR. Encoding is carried out in both directions in a parallel fashion, thus improving the performance of computing time. Further, the MRH overcomes the limitation of Modified READ (MR) i.e. the MR is dependent on K-factor where every K^{th} line is encoded using 1-D modified Huffman (MH) encoding. As a result, MR and MH are not efficient for encoding greyscale images and increase computation time.

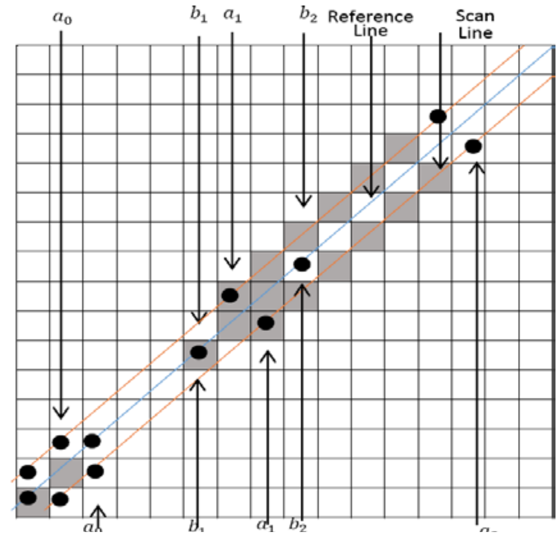


Fig. 5: Proposed Modified Refined Huffman (MRH): Two rows of an image, the transition pixels are marked with a dot.

To overcome, MRH considers diagonal all-white pixels as the first line which is a reference line and every successive line is encoded with respect to reference line and continued in both directions diagonally as shown in Fig.5. This helps in achieving a better compression and reduced computation time for medical images which is experimentally proved in the next section below.

IV. RESULT AND ANALYSIS

This section describes performance evaluation of MRH over the existing MMR. The algorithm of both MRH and MMR are implemented using C # 6.0 Microsoft dot net frameworks 4.0, C++ and MATLAB 2016b. The experiments are conducted using windows 10 operating system, Intel I-7 quad core class processor, 16GB RAM and 4 GB dedicated CUDA Graphic Processing Unit. Performance is evaluated in terms of Compression Ratio (CR), Encoding Time (ET), Decoding Time (DT) and Compression Memory Utilized (CMU) for bi-level and grey scale images. We have considered three cases, in first case study we considered bi-level images obtained from [18].For second case bi-level images from [16] and in last case study, we considered greyscale images.

A. Performance evaluation by considering bi-level document images:

Firstly, this work considers the performance evaluation of bi-level document images for MRH over the existing MMR [15] in terms of CE, EPT, DPT and CMU. The bi-level document images used for analysis are obtained from [18], the first 8 CCITT document images are considered for analysis. All images have same resolution of 200 dpi and same dimension of (W*H) of 1728*2339. The outcome achieved is tabulated in Tables1 and 2. The results shows that the proposed MRH attained good outcome over the standard MMR method in terms of CE, CMU and computation time considering both EPT and DPT. The image 8 has attained highest compression efficiency of 37.15% and image 4 has achieved the least CE of 15.33%. An average CE enhancement of 17.29% is attained by the MRH over the standard MMR technique. The proposed, MRH compression method utilizes less memory usage when compared to that of the standard MMR compression method. An average memory usage minimization of 2.07% is attained for MRH compression technique over the standard MMR compression technique.

Table 1: Performance Evaluation of Compression Efficiency and Compression Memory Utilization

Images	Compression Efficiency		Compression Memory Utilized(bits)	
Bi-level	**Proposed MRH**	**Existing MMR**	**Proposed MRH**	**Existing MMR**
1	47.387	39.159	456626176	474959872
2	61.320	49.911	457134080	472010752
3	30.432	25.343	462970880	472938112
4	15.336	12.910	458014720	468649600
5	28.018	23.352	452780032	463550080
6	43.332	35.786	450174976	451240512
7	15.472	13.016	448634880	450471040
8	37.155	30.823	450093056	459847296
AVG	**34.807**	**28.787**	**454553600**	**464208408**

Similarly, the MRH reduces the computation time compared to the existing MMR. The computation time performance is evaluated in term of EPT, DPT, and Overall Processing Time (OPT) and shown in Table 2. An average EPT of 0.0123s (seconds) is attained for presented MRH and 0.088s is attained for standard MMR method. An average EPT minimization of 28.47% is attained by MRH compression method over the standard MMR compression method. An average DPT of 0.0033 seconds is achieved for MRH compression method and 0.0046s is attained by the standard MMR compression method. An average DPT minimization of 29.37% is attained for MRH over the standard MMR compression method.

An average OPT of 0.096s is achieved by the proposed MRH and 0.0128s is attained for the standard MMR compression method. An average OPT minimization of 24.56% is achieved by the proposed MRH compression method over the standard MMR compression method. The results attained demonstrates significant performance enhancement of proposed MRH compression method over the standard MMR compression method in terms of CE, EPT, DPT, OPT and CMU.

Table 2: Performance Evaluation of Encoding Processing Time, Decoding Processing Time and Overall Processing Time

Images	EPT (Secs)		DPT (Secs)		OPT (Secs)	
Bi-level	**Proposed MRH**	**Existing MMR**	**Proposed MRH**	**Existing MMR**	**Proposed MRH**	**Existing MMR**
1	0.055900	0.070836	0.003700	0.005154	0.092903	0.075990
2	0.048311	0.091983	0.003200	0.005422	0.051511	0.097405
3	0.084118	0.095432	0.003641	0.004268	0.087760	0.099700
4	0.141076	0.231287	0.003285	0.004953	0.144361	0.236239
5	0.085556	0.102907	0.003263	0.004614	0.090819	0.106521
6	0.063926	0.079626	0.003193	0.004746	0.069120	0.083372
7	0.164324	0.210008	0.003246	0.004740	0.168570	0.213748
8	0.065258	0.108475	0.002999	0.003663	0.068257	0.112138
AVG	**0.088559**	**0.123819**	**0.003316**	**0.004695**	**0.096663**	**0.128139**

B. Performance evaluation considering bi-level images obtained from [16]:

Secondly, this work considers experimental analysis of the bi-level multimedia images obtained from [16]. The bi-level multimedia data considered for evaluation are shown in the Fig. 5 and has four images mentioned as 1,2,3,4. Images considered for experiment analysis possess identical dimension (Width*Height) of 256*256 with identical resolution of 72 dpi. The analysis is shown in the Fig.7. Where the results are compared with 7different algorithms. In the graph 1, 2, 3 and 4 indicates four images of Fig.6. From Fig.7, It can be seen that an average compression ratio performance for 7 cases are, LZW is 2.077, Deflate is 2.45, Packbits is 1.175, CCITT G3 is 1.725, CCITT G4 is 3.675, JBIG2 is 10.375, ES [16] is 8.16, and for the Proposed MRH it is 13.28. The results attained shows that the proposed MRH model has achieved significant compression ratio performance improvement than the other state-of-the-art models mentioned above. An average CE enhancement of 35.25% is attained for presented MRH compression method over the state-of-the-art standard compression method of [16].

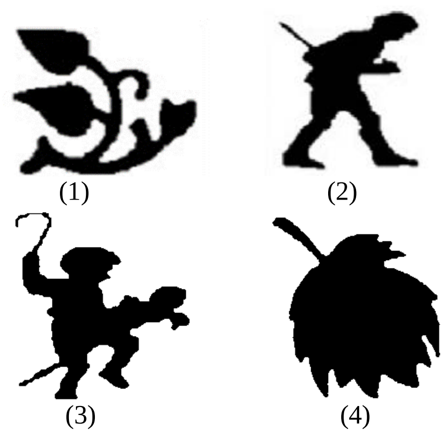


Fig. 6. Experiment result of MRH evaluated on bi-level images [16].

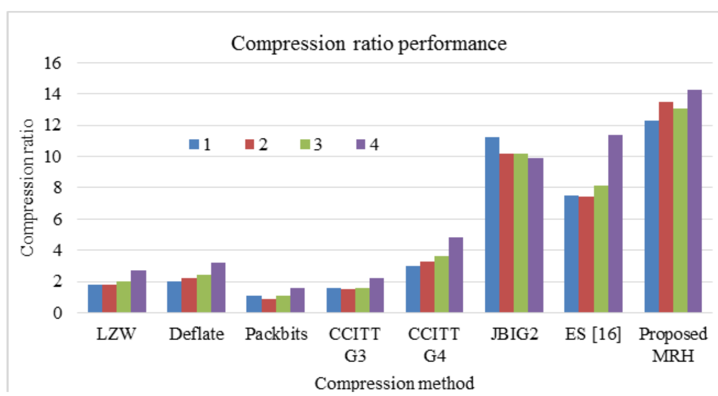


Fig. 7. Compression efficiency performance for bi-level images.

C. Performance evaluation by considering greyscale images:

Thirdly, this work considers the performance evaluation for greyscale images for the proposed MRH over the standard MMR compression method in terms of CE, EPT, DPT and CMU. The grey scale images used for analysis are obtained from [17, 25], 4 medical images in healthcare domain, 1 finger print image used for adoption of security purpose and 3 images are considered for general purpose analysis which are shown in the Fig.8. The grayscale images are first converted in 8-bit planes (binary images) are as shown in the Fig.9 for one image. These binary images are uncompressed individually. Encoding is performed individually on each bit plane using MRH to get compressed image. At the decoding stage, decoding is carried exactly in reverse manner of encoding and finally decoded planes are reconstructed into single grey scale image. All images have same resolution of 200 dpi and identical dimension of (Width*Height) of 1728*2339.

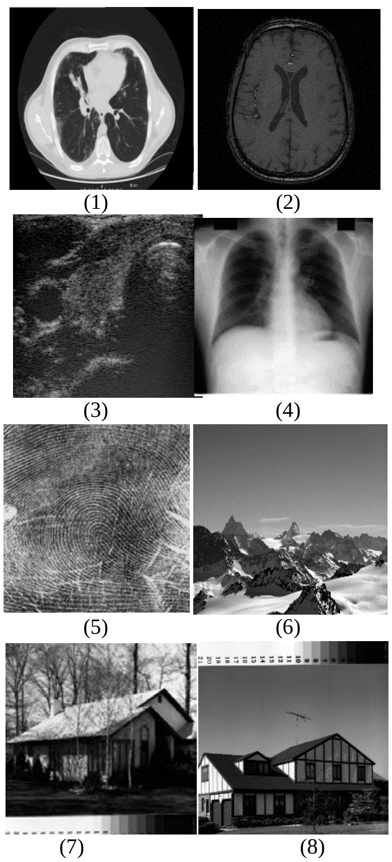
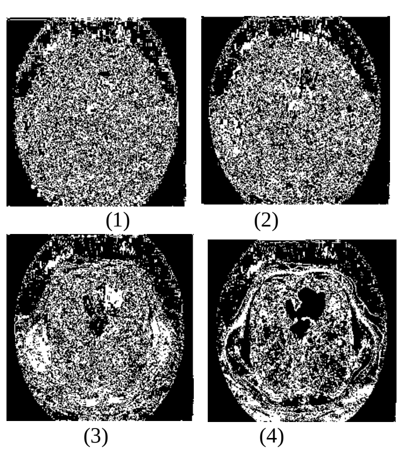


Fig. 8. Input greyscale images considered for Experimental analysis



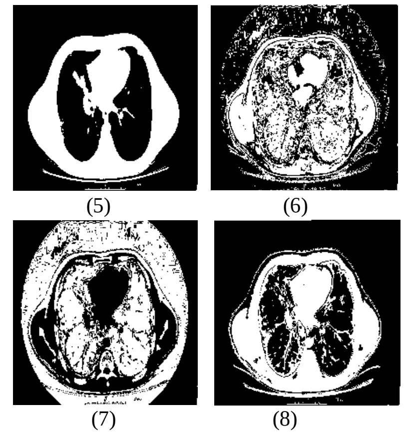


Fig.9. Bit Plane image slices for case 2 of figure 8 for the first image

The results are tabulated in Tables 3 and 4. The results attained shows that the proposed MRH compression method attained good enhancement over the standard MMR compression method in terms of CE, CMU and Overall Processing Time (OPT). The image 7 has attained highest compression ratio of 8.44 and image 5 has attained least compression ratio of 1.766. An average CE enhancement of 26.12% is attained by the proposed MRH compression method over the standard MMR technique. The proposed MRH utilize minimal memory compared with the standard MMR compression method. An average memory usage minimization of 0.855% is attained by the proposed MRH compression method over the standard MMR technique.

Table 3: Performance Evaluation of Compression Efficiency and Compression Memory Utilization

Images	**Compression Efficiency**		**Compression Memory Utilized (bytes)**	
Grey scale	**Proposed MRH**	**Existing MMR**	**Proposed MRH**	**Existing MMR**
1	5.20003917	4.32704463	470840320	481044480
2	6.74430279	5.48884566	471483904	471900672
3	3.97636152	1.80069617	471150080	467564836
4	4.15974388	3.41584634	470495232	466710016
5	1.76633518	1.49408582	470983680	480972032
6	3.38835620	2.85985586	471059456	469613696
7	8.44619462	7.01375034	471300096	473582464
8	6.28980533	5.29579735	471182848	489611904
AVG	4.99639234	3.96199027	471061952	475125012

Similarly, the MRH reduces OPT compared to the existing MMR compression method. The computation time performance is computed considering EPT, DPT, and OPT. An average EPT of 0.09s, an average DT of 0.0044s and an average OPT of 0.094s is attained by the proposed MRH compression method. An average EPT of 0.102s, an average DT 0.0077sand an average OPT0.11s is attained for the standard MMR method shown in Table 4.

An average ET minimization of 11.76 %, an average DPT minimization of 42.8% and an average OPT time minimization of 14.54% is attained for proposed MRH compression method over the standard MMR compression method. The result obtained demonstrates enhancement of presented MRH compression method over the standard MMR compression method in terms of CE, EPT, DPT, OPT, and CMU.

Table 4: Performance Evaluation of Encoding processing time, Decoding processing time and Overall processing time

Images	EPT (Secs)		DPT (Secs)		OPT (Secs)	
Grey scale	Proposed MRH	Existing MMR	Proposed MRH	Existing MMR	Proposed MRH	Existing MMR
1	0.064886	0.066709	0.004188	0.037532	0.069074	0.104241
2	0.060936	0.063913	0.004554	0.003437	0.065490	0.067350
3	0.061155	0.053824	0.004268	0.003481	0.065423	0.057305
4	0.010043	0.016759	0.004438	0.003582	0.014481	0.020341
5	0.088905	0.070336	0.004008	0.003409	0.092913	0.073744
6	0.135104	0.240620	0.004347	0.003534	0.139451	0.244154
7	0.090044	0.098004	0.004031	0.003619	0.094075	0.101623
8	0.209413	0.210595	0.004399	0.003204	0.213812	0.213799
AVG	**0.090061**	**0.102595**	**0.004279**	**0.007725**	**0.094340**	**0.110320**

IV. CONCLUSION

The increasing demand for remote online health care services across various sectors and users has resulted in the increased sharing and storing of healthcare/medical diagnosis data. The cost per bit of storing data on cloud platform has come down which resulted in increased adoption of cloud based health care services. Minimizing cost per bit on such platform is most desired. Compression is an efficient mechanism for minimizing cost on such platform. The medical images stored on cloud platform are accessed by resource starved heterogeneous platform such as smart phones, smart devices etc. Therefore, minimizing the memory and computation time is most desired along with good lossless compression performance.

This paper presented an efficient lossless compression named MRH for greyscale (medical) images. The model presented overcomes the limitations of few of the state-of-the-art techniques by adopting diagonal encoding and parallel computing for compressing an image. Experiments are conducted for wide variety of images and performance of the MRH is evaluated in terms of CE, OPT, and MU over the other state-of-the-art techniques, such as, LZW, Deflate, Packbits, CCITT G3, CCITT G4, JBIG2, MMR and LM back propagation algorithm.

MRH achieved good compression ratio performance over the existing MMR. An average compression efficiency enhancement of 17.29% and 26.12%is achieved by the MRH over the MMR considering bi-level document images and greyscale images respectively. For another case, results are compared with LM back propagation algorithm which is a Neural Network based compression algorithm. An average CE enhancement of 35.25% is achieved by MRH over Neural network based compression algorithm considering bi-level images. The MRH attains good performance improvement in terms of EPT, DPT, and OPT and CMU over its stat-of-the-art technique.

An average improvement of 28.37%, 29.37% and 24.56% and 2.07% is achieved by the MRH compression method over the standard MMR Method, respectively for bi-level document images. An average enhancement of 26.12%, 0.855%,11.76 %, 42.8%, 14.54% are achieved by the MRH compression method over the standard MMR compression method, respectively, for greyscale images. The overall outcome achieved shows that, the proposed MRH is a good scalable, efficient and robust performance compression technique and applicability of MRH for different application services.

In future work, we would consider implementation of RH and MRH compression techniques as an efficient Fronthaul compression technique for future generation wireless communication network such as C-RAN. An attempt will be made to increase the bit rate, speed of transmission and reduce the bandwidth using the proposed MRH compression technique.

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