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Hybrid Approach for Lossless MRI DICOM Image Compression

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Abstract: In the modern medical world, technology has renewed the ways healthcare specialists detect and handling patients. The medical devices are responsible for image acquisition and store the images in standardized format. Medical professional need to store the huge number of images about patients for monitoring and diagnose the disease. It leads to requirement of huge memory space and also requires high bandwidth to transfer the image. Image compression necessary to decrease the memory size and increase the transmission speed with standard bandwidth. The former research presented a lossless technique that compress the image without affect the quality of the image using Huffman coding. This technique maintains the quality of the image when reconstruct the image. The second technique is based on bit level compression. The highest bit levels are compressed using LZW(Lempel–Ziv–Welch) methods. Remaining levels are compressed using JPEG compression method. In the Huffman coding compression is achieved depends on the redundancy in the data. LZW became more complex when dealing with larger dataset. To reduce this problem and to achieve the higher compression ratio and reduce the memory size of the image the new hybridization method is proposed. The proposed method hybrid the LZW and Huffman coding to achieve the highest compression ratio than prior technique. In this research, DICOM MRI images are pre-processed using Ant Colony Optimization (ACO) technique. The pre-processed image is transformed by means of Lempel–Ziv–Welch (LZW) and then apply Huffman coding to encode the image. And decompression process is done by applying Huffman decoding and then inverse LZW inverse transform. The presented method prove that attains greater performance than the former method.

Keywords: *LZW, Huffman, lossless compression, Ant Colony Optimization (ACO), hybridization, MRI image*

1 Introduction

Digitization in the medical field has led to several benefits like fast access, easy manipulation, and effective storage of medical images. The main challenge is the storage and transmission of massive medical data including medical images. For many telematics applications, image compression is essential and crucial to ensuring great service quality. The aim of image compression includes reduced image redundancy and effective data storage or transmission. Medical Image Compression performs an essential role in the medical field where high-quality medical images require extensive storage capacity. Image compression techniques are used to reduce the redundancy of the image data to store or transmit it efficiently. Improvement of compression schemes for medical information is quickly advancing field with developing applications in the medicinal services administrations.

The primary objective of work is to compress the DICOM MRI brain images, which are performed based on lossless compression. The novel HF_LZW lossless compression algorithm was proposed. This algorithm produces a high compression ratio without affecting the quality of the reconstructed output images.

The proposed algorithm was compared with widely used existing algorithms and their performances are evaluated.

The experiments are done with the resultant of the pre-processing phase. Compression ratio, Peak Signal Noise Ratio (PSNR), Memory, and Execution Time are considered performance measures. The experimental results analysis showed that the proposed HF_LZW algorithm performs in an efficient manner than existing lossless algorithms.

2. Literature Review

Beatrice Lazzerini et al. (2010) [3] were proposed The JPEG calculation is a standout amongst the most utilized devices for compacting images. The principle element influencing the execution. The quantization process, which makes use of two tables called quantization tables, is a component of JPEG compression. These characteristics determine the amount of compression and the type of the decoded images. Accordingly, the execution of the JPEG computation depends on the selection of the quantization tables. A two-objective developmental calculation is used in this study to produce a set of ideal quantization tables that offer various trade-offs between image quality and compression. While quality is calculated as the mean squared error between the original and reproduced images, compression is determined as the difference in rate between the sizes of

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the original and compressed images. We discuss using the suggested approach to handle easily understood benchmark images and demonstrate how the quantization tables managed by our technique improve the execution of the JPEG computation as for the default tables suggested in Annex K of the JPEG standard.

Farshid Sepehrband et al. (2011) [5] have phenomenally planned the Medical Image Compression Using Simple Lossless and Near-Lossless Techniques Using Enhanced DPCM Transformation. The lossless and close lossless ompression strategies are propelled which have been profoundly viable in perspective of their magnificent compression proportion and straightforwardness. The methodology contains a change strategy called Enhanced DPCM Transformation (EDT) furnished with prevalent vitality compaction and a fitting Huffman encoding. In the wake of propelling the compression technique, it is executed in different experiments and the results are dissected.

Sandeep Kumar et al. (2013) [13] have efficiently spelled out the Medical Image Compression Using Contourlet Transform. Advanced reports on common image compression have maintained the brilliant execution of contourlet transform, and the augmentation of the wavelet change in two measurements utilizing Laplacian Pyramid (LP) and directional channel banks. In the investigation of medical images, the significant part (ROI) is isolated from whatever remains of the image via means of fluffy C-implies calculation, and from that point to the significant image enhanced contourlet change is performed to tweak the visual brilliance.

Yashpreet Sain et al. (2014) [18] assessed the idea of lossless compression on restorative pictures and displayed an early examination work. Images are should have been compacted keeping in mind the end goal to diminish the storage room and minimize the exchange time over a system. Compression assumes a more indispensable part in the field of therapeutic imaging where a gigantic measure of capacity is required to store these images and recover later for finding. So keeping in mind the end goal to spare the measure of storage room and system data transfer capacity a suitable compression plan should be executed to accomplish ideal compression levels with no loss of important data. In this work, they have explored the idea of lossless compression on therapeutic images and displayed an initial exploration.

Mohamed M. Fouad. (2015) [11] proposed an Integer Wavelet Transform and a Simplified Median-edge Detector Algorithm, Lossless Image Compression A reduced version of the median edge detector algorithm used with JPEG-LS is integrated into a prediction stage in a lossless (LS) picture compression method. A different image is produced after the image has first been changed using the prediction stage. The lossless code word assignment uses the transform coefficients from the integer wavelet transform applied to the difference image. The methodology is straightforward, and the computational cost is kept competitive with other methods.

3. Proposed methodology

In this presented method, medical MRI DICOM image is transformed using LZW (Lempel–Ziv–Welch). After that Huffman encoding is applied to encode the image for compression. The compressed bit stream again reconstructed through Huffman decoding and inverse LZW transformation.

3.1 De noising based on Ant Colony Optimization (ACO):

ACO is a metaheuristic algorithm that attempts to strike a balance between directing and broadening the search. It draws ants via pheromones. Ants converge more quickly toward a solution when their pheromone sensitivity is increased, but they typically find worse solutions as a result.

In common the ants pick the way dependent on the pheromone fixation on it. The pheromone mindfulness in a way is associated with the quantity of the ant's transient through the way, it figures the plan simply to get into a nearby ideal. To maintain a strategic distance from this downside and improve the combined speed of the subterranean insect settlement calculation is planned using ACO through the pheromone. At each emphasis, the ants which have discovered the briefest way in the cycle are named world-class ants. This way of choice system of subterranean insect settlement calculation is registered through regular ants.

For the k-th exploratory ant the likelihood $p_{ij}^{k}(t)$ of time t to move from i −th grid to j-th grid is depicted via utilizing subsequent condition.

$$p_{ij}^{k}(t)=\left\{\begin{matrix}\dfrac{\frac{\eta_{ij}^{\beta}(t)}{\tau_{ij}^{\alpha}(t)}}{\sum_{s\in allowed_k}\frac{\eta_{ij}^{\beta}(t)}{\tau_{ij}^{\alpha}(t)}}, j\in allowed_k\\ 0, otherwise\end{matrix}\right\} \quad (1)$$

Where,

$allowedk$-group of the residual possible situation of the k-th exploratory ant

α, β −Weight of $\tau_{ij}^{\alpha}(t)$and $\eta_{ij}^{\beta}(t)$ on the change over possibility, correspondingly

The ηij is the Local heuristic role of visibility , it is defined via below formula

$$\eta_{ij}(t) = \frac{1}{d_{ij}} \quad (2)$$

The best ant's pheromone inform system is distinct as

$$\tau_{ij}(t+n) = (1-\rho) * \tau_{ij}(t) + \Delta\tau_{ij}(t) + \alpha + \Delta\tau_{ij}^{best}(t) \quad (3)$$

Where,

$\Delta\tau_{ij}(t)$ - pheromone increment of common ants

The $\Delta\tau_{ij}^{best}(t)$ is the pheromone growth of elite ants which discharge on the path $< i,j >$ in the present iteration

$$\Delta\tau_{ij}^{best}(t) = \begin{cases} \frac{Q}{L_{best}}, i,j, \in L_{best} \\ 0, Otherwise \end{cases} \quad (4)$$

Where, Q– stable which depicted the quantity of the pheromone addition

$Lbest$ −length of the path that the k-the lite ant has approved in the present cycle.

Hence the best kernel clustering is achieved which aids in the enhanced recovery of images.

3.2 Compression

Histogram equalization can lead to loss of details if the contrast is already high. To resolve this issue, the proposed method uses Huffman coding with Lempel-Ziv-Welch Compression [19]. The proposed HF_LZW algorithm is a hybridization of existing lossless Huffman Encoding (HF) and Lempel-Ziv-Welch (LZW) compression algorithms. The LZW algorithm performed as transform and inverse transform in the encoder and decoder in the proposed framework. Huffman encoding algorithm is performed as encoding and decoding of the proposed system. Fig 1 show the flow diagram of proposed system.

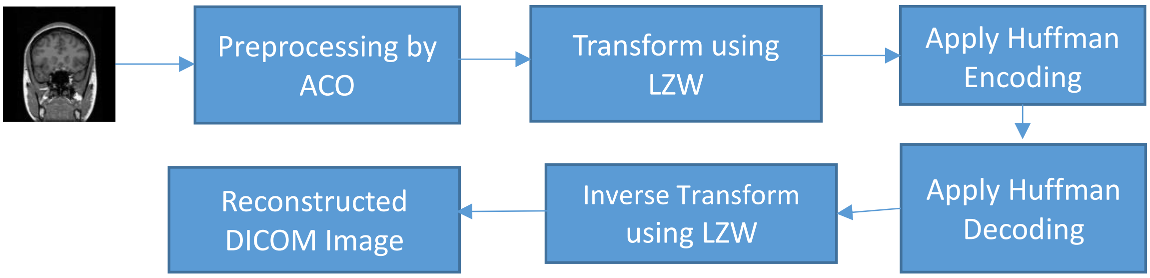

Fig 1: Flow Diagram of proposed system

In the presented method LZW is utilized to build the dictionary with hash function (modulo operation) to store the intensity values of the image. After built the dictionary the symbol (values) are ordered using min heap binary tree and encode using Huffman code.

Hash function:

In the LZW (Lempel-Ziv-Welch) compression algorithm, a dictionary is built to store patterns that have been encountered during the compression process. The dictionary is usually implemented as a hash table for efficient lookup.

hash_value = (prefix_code XOR next_intensity) % table_size

In this formula:

prefix_code is the code representing the current pattern in the dictionary.

XOR is bitwise operation carried out between prefixnode and next intensity.

next_intensity is the next intensity value encountered in the input stream.

table_sizetable_size is the size of the hash table or dictionary.

Min Heap Tree

Min heap is a binary tree where the root node value is less than it children. Swap the new element until the min heap property is satisfied.

The formula to find the parent index of a node at index i is given by: ⌋parent(i)=⌊2i−1⌋

The formulas to find the left child and right child indices of a node at index i are given by: leftChild(i)=2i+1 rightChild(i)=2i+2

Lempel-Ziv-Welch with Huffman coding

The presented method uses LZW for transformation of pre-processed DICOM image. Symbols could represent pixel intensity values. Initialize a dictionary with individual symbol as entries. Iterate through the input data at each step and find the longest sequence of symbol that matches an entry in the dictionary. The dictionary is updated regularly to store entries. Output the code for the matching in the dictionary.

Output of the LZW technique then given as input to the Huffman encoding technique. The symbols are arranged in decreasing order. uses a tree in the first step, where the leaves stand for groups of symbols rather than single symbols. The method functions by building a binary tree with nodes. These could be kept in a typical array. An internal node or a leaf node is the two types of nodes. It is simple to read the code backward from a leaf node since all nodes begin as leaf nodes, which have both the symbol itself and a connection to a parent node. Give the two tree branches the codes 0, and 1. The tree is built by choosing three symbols with the lowest probabilities at each stage and combining them into one parent symbol with that symbol's combined probability.

The results indicated a better compression ratio and a minimum length of compressed codes compared to conventional Huffman coding and enhanced LZW approaches. An LZW algorithm with parallelized binary search tree is utilized to decrease the time multifaceted nature of word reference creation in encoding and decoding. The standard binary search tree is not thread-safe due to its dynamic additions and cancellations. Parallelized Binary Search (PBS) is utilized for seeking if the pattern STRING+CHAR is accounted for in the respective dictionary. The inclusion operation creates the dynamic set indicated by the binary search tree to modify. The binary-search-tree property must keep on holding when the tree structure is adjusted. At the point when the inclusions are worked in parallel by a few threads, extra care ought to be considered to ensure that at least two new nodes would not be connected at a similar part of the tree. Furthermore, the contentions can cause information misfortune and memory spill. A legitimate synchronization technique for parallel inclusion from different threads must be embraced to keep any potential clashes.

Proposed Algorithm

Input: Enhanced DICOM MRI images

Output: Reconstructed compressed DICOM MRI images

```
function compressed_data = lzw_huffman_compress(data)
 % LZW compression
dictionary = containers.Map('KeyType', 'char', 'ValueType', 'int32');
for i = 0:255
dictionary(char(i)) = i;
end
current_code = 256;
current_sequence = "";
lzw_result = [];
for i = 1:length(data)
char_i = data(i);
new_sequence = [current_sequence, char_i];
if isKey(dictionary, new_sequence)
current_sequence = new_sequence;
else
lzw_result = [lzw_result, dictionary(current_sequence)];
dictionary(new_sequence) = current_code;
current_code = current_code + 1;
current_sequence = char_i;
end
end
if isKey(dictionary, current_sequence)
lzw_result = [lzw_result, dictionary(current_sequence)];
end
% Huffman coding
huffman_result = huffman_encode(lzw_result);
compressed_data = struct('lzw_result', lzw_result, 'huffman_result', huffman_result);
end
function encoded = huffman_encode(data)
frequencies = histcounts(data, 'BinMethod', 'integers');
symbols = find(frequencies > 0);
% Generate Huffman tree
huffman_tree = huffmantree(frequencies);
  % Generate Huffman dictionary
huffman_dict = huffmandict(symbols, huffman_tree);
% Encode data using Huffman coding
encoded = huffmanenco(data, huffman_dict);
end
```

4 Experimental results

The experimentation assessment is accomplished in the MATLAB software for the both existing and proposed methods. The implementation has been done and the results of present method and existing method were correlated with each by means of performance metrics called compression Ratio, Peak signal Noise Ratio, execution time.

The evaluation of proposed method prove that the present method produces greater outcome than the previous system. The proposed compression technique can be effectively compressed then it will be decompressed with reduced quality. The MRI DICOM images were taken from the database.

In fig 2 input MRI DICOM images that are taken for the compression process. And Fig 3, pre-processed image for the compression which is done using Ant Colony Optimization

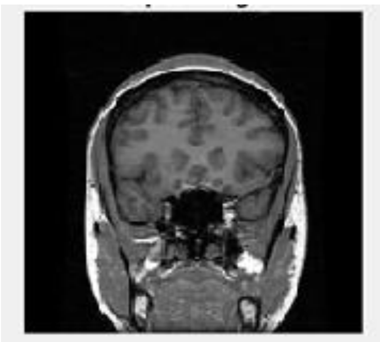

Fig 2: Input Image

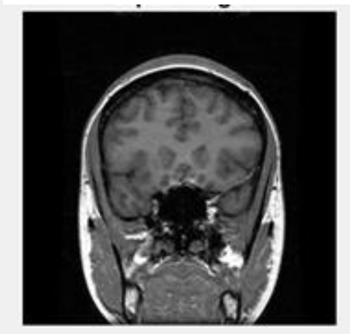

Fig 3: Pre-Processed image

In fig 4, Final result after compression by using HLZW has been shown. In fig 5, Reconstructed image has been shown after decompression.

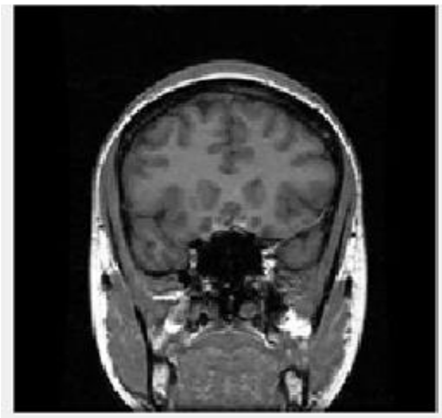

Fig 4: compressed image

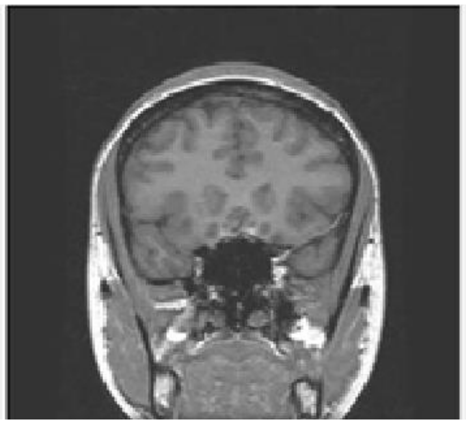

Fig 5: Reconstructed image

Performance Factors

The effectiveness of the proposed and current algorithms is examined using a variety of performance factors. The performance factors of this phase of research work are Compression Ratio, Peak Signal Noise Ratio (PSNR), Space-Saving, and Execution Time.

Compression Ratio (CR)

Compression Ratio (CR) is defined as the ratio between the uncompressed image size and the compressed image size.

$$CR = \frac{Original\ Uncompressed\ Image\ Size}{Compressed\ Image\ Size}$$

The compression ratio comparison represented in table 1. And in Fig 6, the evaluation chart of compression ratio performances of present algorithm and previous algorithm.

Table 1 Compression Ratio Comparison

IMAGE/ COMPRESSION ALGORITHM	HF	AC	LZW	HLZW
Image1	1.27	1.94	2.33	**3.38**
Image 2	1.10	1.85	2.25	3.56
Image 3	1.25	1.98	2.40	3.85
Image 4	1.30	1.97	2.60	3.96

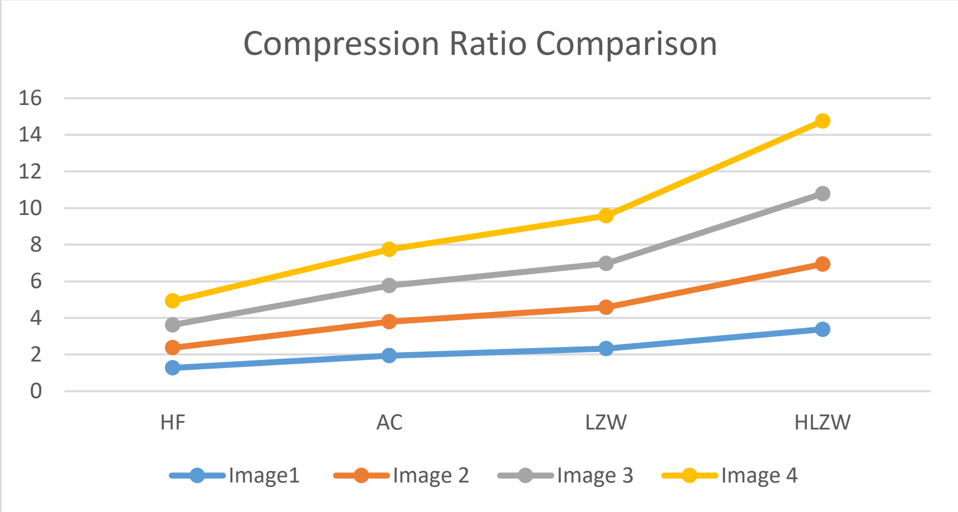

Fig 6: compression ratio comparison

Peak Signal Noise Ratio (PSNR)

Peak Signal Noise Ratio (PSNR) is used to compare quality of the original and compressed images. The PSNR is defined by

$$PSNR = 10.log_{10} \frac{MAX}{\sqrt{MSE}}$$

$$MSE = \sum_{MN} \frac{[l1(m,n) - l2(m,n)]^2}{M * N}$$

The PSNR comparison represented in table 2. And in Fig 7 the evaluation chart of PSNR comparison of present algorithm and previous algorithm.

Table 2 PSNR Comparison

IMAGE/ COMPRESSION ALGORITHM	HF	AC	LZW	HLZW
Image1	20.51	21.06	24.46	**24.81**
Image 2	20.40	20.98	24.23	24.89
Image 3	20.46	21.35	24.56	25.23
Image 4	21.23	21.85	24.75	25.45

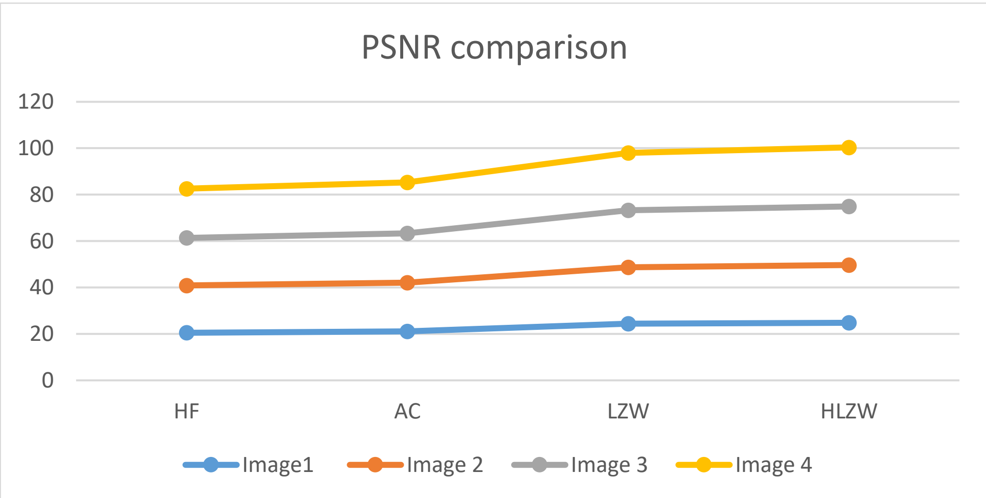

Fig 7: PSNR comparison

Memory Usage

Memory Usage can be defined as memory space utilization is reduced in a computer system through compression algorithms, The memory usage is defined by

$$MU = Original\ Uncompressed\ Image\ Size - Compressed\ Image\ Size$$

Execution Time

Time taken for compressing the MRI images is measured.

Table 3 Execution Time Comparison

IMAGE/ COMPRESSION ALGORITHM	HF	AC	LZW	HLZW
Image1	1386	1081	638	**600**
Image 2	1212	1098	559	**516**
Image 3	1200	998	524	500
Image 4	1180	900	500	480

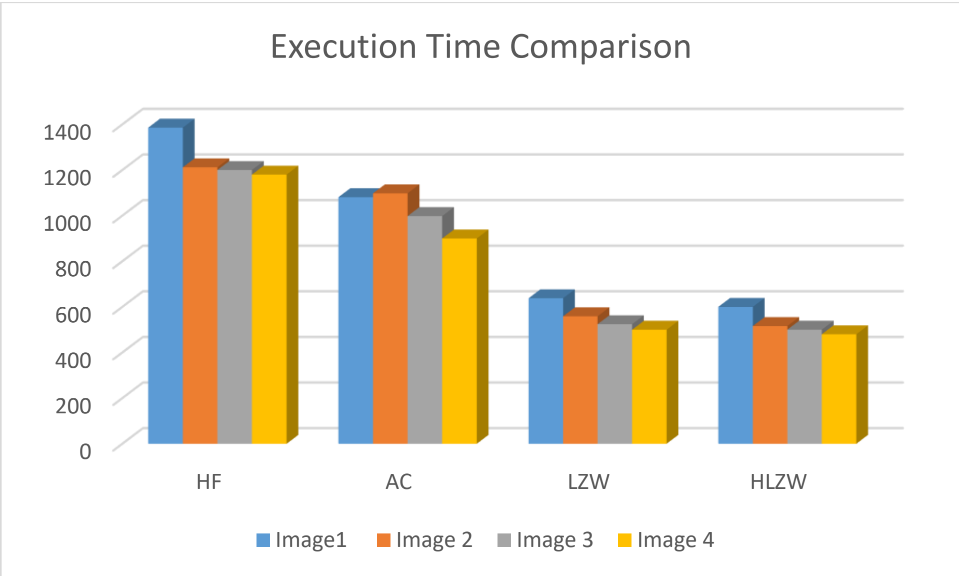

Fig 8: Execution Time comparison

5 Conclusion

Medical Image Compression performs an essential role in the medical field where high-quality medical images require extensive storage capacity. The primary objective of this work is to compress the DICOM MRI brain images, which are performed based on lossless compression. In presented work the novel HF_LZW lossless compression algorithm was proposed. This algorithm produces a high compression ratio without affecting the quality of the reconstructed output images. The proposed algorithm's performance was compared to that of commonly used existing algorithms. Peak Signal Noise Ratio (PSNR), Compression ratio, memory, and Execution Time are considered performance measures. The experimental results analysis showed that the proposed HF_LZW algorithm performs in an efficient manner than existing lossless algorithms.

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