**A Hydrocephalus MRI compression using an autoencoder**

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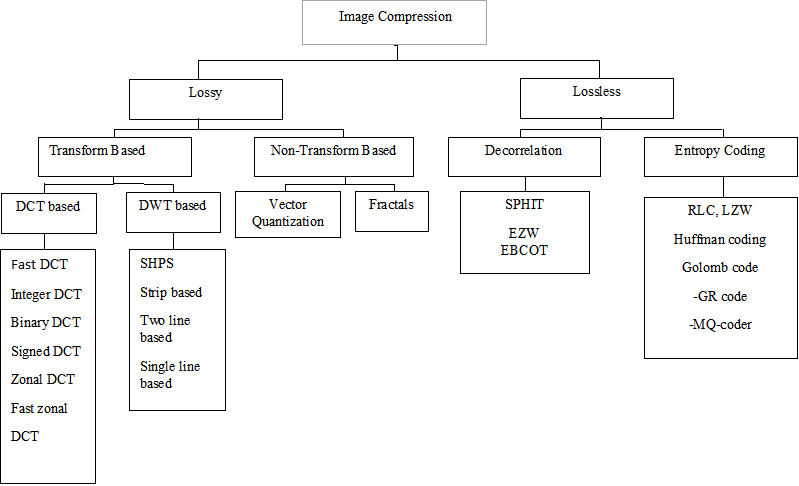
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**Abstract.** Image compression is a terminology which is defined by encoding an image file in such a way that the encoded file takes lesser storage than the original file. The objective of the MRI compression is to reduce the size of multiple MRI and to upload them to the cloud so that they can securely store in the web and retrieve from there when needed. For the last few decades, various MRI compression strategies have been proposed by different researchers to satisfy the demand of the medical society. This article demonstrates an encoding and decoding MRI compression methodology which is applied on Hydrocephalus MRI dataset. The compression methodology begins with a MRI preprocessing step where the raw input MRI taken from the custom dataset is resized, converted to specific format and customize so that it can be delivered to the constructed model as input. In the next steps, custom dataset is segregated into training and testing set, so that the proposed model can be trained and tested. In the next phase, each Hydrocephalus MRI, taken from the custom dataset, is compressed by the trained proposed autoencoder architecture. The performance of the proposed autoencoder architecture for the MRI compression is tested in terms of multiple parameters. Existing image compression algorithms are compared with the proposed compression architecture with respect to various compression measuring metrics. From this comparative study it can be concluded that the proposed compression architecture dominates other compression approaches and reached to the level of state of art performance. A unique compression technique, an efficient parametric performance, and its application on Hydrocephalus custom MRI dataset shows the proposed model uniqueness. In future, the application of the proposed compression architecture on a cloud based environment may be expected.

**Keywords:** Hydrocephalus MRI**,** Autoencoder based compression architecture, MRI Preprocessing, Lossless and Lossy MRI compression, Compression Ratio

# Introduction

Image compression is a terminology which is defined by encoding an image file in such a way that the encoded file takes lesser storage than the original file. The objective of the image compression is to reduce the size of images efficiently so that it can be transmitted over the internet platforms, uploaded on the cloud, and serves image restoration purpose meaningfully for the future use. Image compression technique can be categorized into two sub categories, popularly known as lossless and lossy compression technique. Both of the techniques are classified into multiple categories based on the way of compression. A full pictorial representation of image compression classification can be observed with the help of **Figure. 1.**

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**Figure. 1** Shows various image compression classification techniques

The advantage of image compression is that it enables us to store more images with less storage usage conveniently in personal computers or servers and retrieve it as and when required. There are also several disadvantages of image compression such as degraded image quality, and important details in the image are lost that might be hard to recover. Data is also lost by a significant amount while compressing images, and this might prove to be a determent to us in some cases. In a dataset all the images need to be compressed keeping the same compression rate in mind. Variable compression rates for different images may not be useful for us when training the model. During and after image compression, multiple challenges maybe faced by the researchers. When an image is compressed the finer details of colour, contrast and sharpness are reduced. Hence, the encoded image quality may drastically reduce in comparison with the original image. It may be observed that even after decoding, the decoded image may not remain the same as the original image as ideally it should be. One such observation can be noticed in the **Figure. 2** given below.

|  |  |  |
| --- | --- | --- |
|  |  |  |
| (a) | (b) | (c) |

**Figure. 2** Shows a brain MRI compression result (a) original image (b) encoded image (c) decoded image

For the diagnosis of various brain disease patients in the government, public and private hospitals multiple MRI or CT images are generated. One such brain disease is hydrocephalus. When an MRI scan is done on a hydrocephalus suspected patient, lots of images are produced as a result. These images are of extremely high quality, and hence consume a lot of space. Thus, each set of images, for just one scan on a particular area of a patient’s body, is going to consume a lot of space in the given storage medium. Our objective is to build a MRI compression model so that the MRI images of hydrocephalus suspected patients can be compressed and archived easily, effectively and efficiently. It has been found that majorly the hospitals and medical centers in the rural areas are using outdated devices, or devices having low end specifications to store MRI images of the hydrocephalus or other brain disease patients as a result of low budget and lack of funding. In this situation, we can going to propose a new auto encoding-decoding based MRI compression model, which maybe prove to be beneficial for archiving and compressing MRI images of hydrocephalus patients. Our proposed model is capable of compressing hydrocephalus MRI images at a faster rate. Compressed images take very less time for transmission on the web, over the cloud and the server. Our model utilizes less storage space, which in turn helps us to store more images in the hard disk (or any other storage medium). When transferring these compressed images, less bandwidth is consumed due its smaller file size, and as a result less cost is incurred.

This article is divided into various sections. In section 2, some of the latest work allied to the proposed article title and some of the major and popular compression techniques as mentioned in **Figure. 1** is highlighted and briefly explained. The section 3 of the article, highlights proposed methodology, built-in architecture and the flow of the overall procedure. The section 4 of the article portrays various tables, graphs and outputs to establish the performance of the compression model in comparison with some of the other popular and established compression methodologies.

1. **Existing Methodologies**

Finding an image compression algorithm on Hydrocephalus MRI is very difficult and rare. As we are dealing with image compression algorithm and MRI images, hence this section first of all we are trying to highlight some of the existing, popular and general image lossy and lossless compression algorithms along with their pros and cons, performance analysis in context to our problem definition. All these generic lossy and lossless image compression techniques performance and analysis can be observed in the **Table. 1.** Secondly, it has been observed that over the years multiple methodologies related to medical image compression have been proposed by different researchers. Though it has been found that rarely a very few researchers are going on the Hydrocephalus MRI compression technique, still various researchers works on MRI compression we have considered and analyzed as well. All these existing methods performance and analysis is highlighted in **Table. 2.** All these methods are well appreciated but in context with our problem the results can be improved. In-depth analysis of these methodologies has proven to be very competent to identify the downsides. Identification of these drawbacks helps us to update, modify our algorithm and code and to calculate the performance parameters.

Lempel–Ziv–Welch (LZW) [1] is an efficient lossless generic compression strategy which provides satisfactory compression ratio after applied on larger generic dataset. But it takes larger amount of compression and decompression time and sometimes provides inappropriate and unacceptable images. The Huffman Coding [2] is a lossless generic compression technique which may be applied to MRI or CT image dataset. The technique suffers from low compression ratio and applicable for small amount of data. The Embedded Zerotree Wavelet (EZW) method [3], has been proposed by Shapiro, is a lossy generic algorithm applicable to data. Hence, the feature of the original image may not persist in the decompressed image. The Run Length Encoding (RLE) [4] is an easiest and effective generic lossless compression algorithm applied on data and images. It has been observed that RLE algorithm is providing almost same Hydrocephalus image after compression from the original image. The Shannon Fano coding scheme [5] is highly recommended when the entire code block of the data is not demanded. The scheme fails to give any guarantee on generation of codes, generation of optimal codes and produces no unique code. The Arithmetic Coding [6] is a lossless compression algorithm which is invented to compress data not images like CT or MRI. When applied on Hydrocephalus MRI it has been observed that the compression ratio is too low in contrast with other existing lossless generic compression algorithm. We have also come to a conclusion that the some of the distinguishable features of the original Hydrocephalus MRI is lost due to this type of compression ratio and decompression.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Serial No**. | **Year** | **Author(s)/Company** | **Name of the compression algorithm** | **Disadvantage/Remark** | **Performance** |
| 1 |  | Abraham Lempel et. al. | LZW [1] | Generic algorithm, not Hydrocephalus MRI compression specific | Compression Ratio = 2.203 |
| 2 |  | David Huffman | Huffman Coding [1] | Generic algorithm, not Hydrocephalus MRI compression specific | Compression Ratio = 3.71 |
| 3 |  | Shapiro et. al. | EZW [2] | Generic algorithm, existing feature of the Hydrocephalus disease may be destroyed due to compression decompression strategy | Compression Ratio = 1.664 |
| 4 |  | Hitachi Corporation | RLE [3] | Generic algorithm, provides dissatisfactory compression result on Hydrocephalus MRI | Compression Ratio = 1.55 |
| 5 |  | Claude E. Shannon et. al | Shannon–Fano [3] | Generic algorithm, invented to compress data not Hydrocephalus MRI | Compression Ratio = 1.9825 |
| 6 |  | Youngjun Yoo et. al | Arithmetic Coding [3][5] | Generic algorithm, huge space complexity, lower application results on Hydrocephalus MRI | Compression Ratio = 1.36 |

**Table 1.** Representation of different lossless and lossy techniques of MRI compression

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **SNo.** | **Year** | **Author(s)** | **Main Methodology** | **Advantages** | **Disadvantages** | **Performance** |
| 1 | 2022 | Alex Cazañas-Gordón et. al. | Digital Compression in Medical Images | It uses digital compression tool which is efficient in achieving and transmission of medical images. | There can be a chance of legal ramification due to the use of lossy compression | The compression ratio obtained during MRI compression is 2.546. |
| 2 | 2022 | Sr.J.Rani et. al. | Medical Image Compression using DCT with Entropy Encoding and Huffman on MRI Brain Images | This methodology provides compressed images with minimal quality loss. | It results in downfall of image quality due to decreasing encoding time. | 1.576 is the compression ratio gained during MRI compression using DCT. |
| 3 | 2021 | Monagi H. Alkinani et. al. | Medical Image Compression Based on Wavelets with Particle Swarm Optimization | Superior performance in medical images with high detail | It lacks in intelligence techniques which acclerates the compression technique to a convergent nature. | The compression ratio 1.534 is obtained while using Wavelets with Particle Swarm Optimization. |
| 4 | 2021 | Saravanan. S et. al. | CT, MRI Image Reconstruction using Deep  Autoencoder with Boltzmann Machine Training  Architecture | It retains structural quality of medical images | Computational time is slightly higher than transform based methodologies | The Peak Signal to Noise Ratio is 11.3 for MRI reconstruction using Deep Autoencoding technique. |
| 5 | 2021 | Prakash Tunga P. et. al. | Compression of MRI brain images based on automatic  extraction of tumor region | This method uses arithmetic coding for ROI compression which provides descriptive information of the tumor viz. tumor size and location |  | The MRI compression based automatic  extraction of tumor region have achieved average Compression Ratio of 1.36. |
| 6 | 2020 | Veronica Corona et. al. | Regularized Compression of MRI Data: Modular Optimization of Joint Reconstruction and Coding | No additional processing is required at the decompression stage | It lacks automated parameter optimization. | The modular optimization of joint reconstruction of MRI attained a PSNR value of 10.41. |
| 7 | 2020 | Gajendra Sharma | Analysis of Huffman Coding and Lempel–Ziv–Welch (LZW) Coding as  Data Compression Techniques | It provides greater compression ratio and appropriate for larger data | Requires more compression  and decompression time and inappropriate for smaller data. | In image compression using Huffman and LZW they have achieved compression ratio of 4.319 and 2.203 respectively. |
| 8 | 2020 | Narayana Prakash S et. al. | MRI image compression using multiple wavelets at different  levels of discrete wavelets transform | If images with low frequency content are present, this method is capable to produce significantly better results. | Due to high computational complexity and high acceleration, which results in degradation in image quality. | Using discrete wavelets transform they have got a compression ratio of 2.005. |
| 9 | 2020 | R Pandian et. al. | Characterization of Alzheimer MRI Image based on Image  Compression Techniques | Avoids alteration of information present in images | As Symlet 2 is asymmetrical in nature, leading to inconsistency in first level decomposition. | The compression ratio obtained is 2.3 for Alzheimer MRI Compression technique. |
| 10 | 2019 | Nirajan Bist et. al. | Improved Image Compression using Lossless Huffman Encoding | Requires less compression  and decompression time and appropriate for smaller data. | It provides less compression ratio and inappropriate for larger data. | Using lossless Huffman encoding the compression ratio obtained is 3.71 for improving image compression. |
| 11 | 2019 | Md. Atiqur Rahman et. al. | Lossless Image Compression Techniques: A State-of-the-Art Survey | For Shannon Fano coding procedure we do not need to build the entire codebook. | Shannon–Fano Encoding sometime fails to produce an optimal tree. | Lossless image compression using Shannon Fano encoding yields a compression ratio of 1.9825. |
| 12 | 2019 | Shuai Liu et. al. | A Fast Fractal based Compression for MRI  Images | This methodology is able to reduce the compression time drastically. | Error prone and less compression ratio in some specific areas | The Fast Fractal compression has gained a compression ratio of 3.75. |
| 13 | 2019 | Nassir H. Salman et. al. | Run length Encoding based Lossless MRI Image Compression LZW and Adaptive Variable Length Coding | RLE works best on large data having redundancy | Does not have satisfactory efficiency when used along with LZW compression. | In Run Length Encoding method of MRI compression, they have attained a compression ratio of 1.55. |
| 14 | 2019 | Ruchi Agarwal et. al. | Multiple Image Compression in Medical Imaging Techniques  using Wavelets for Speedy Transmission and Optimal Storage | It can also perform on low resolution images at low bit rate | At very low bit rates, coding of lossy compression scheme shows blurry part in background | Using wavelets for speedy transmission and for optimal storage, the compression ratio achieved is 2.375 |
| 15 | 2017 | R. Sujitha et. al. | Wavelet based thresholding for image denoising in MRI image | Yields satisfactory results while keeping the methodology simple | As Haar wavelet is discrete in nature, resulting in denoising of images slightly challenging. | The PSNR of 8.58 is achieved for image denoising using thresholding. |
| 16 | 2017 | D. J. Ashpin Pabi et. al. | Tri-mode dual level 3-D image compression over medical MRI images | Quality of reconstructed images is retained | Does not work on coloured images | With Tri-mode dual level 3-D image compression, they have got compression ratio of 1.404. |
| 17 | 2014 | A.M.Raid et. al. | Image Compression using Embedded Zerotree Wavelet | User can control desired bit rate. | Properties of the image affects the performance. | Compression Ratio of 1.664 was achieved using EZW. |
| 18 | 2014 | V. Anusuya et. al. | Lossless Compression on MRI Images Using SWT | This method is specialized to function on 3D brain images | The proposed methodology works only on brain scan images, but not on scanned images of other body parts | SWT method have yielded a compression ratio of 1.752 for general lossless compression. |
| 19 | 2013 | Prof. Bipin D. Mokal et. al. | Image Compression For MRI (Seam Carving method) | Works well in eliminating irrelevant data | Non optimal compression level may lead to loss of critical features in medical images | Using Seam Carving methodology the compression ratio is 1.435. |
| 20 | 2008 | Jan-Yie Liang et. al. | Lossless Compression of Medical Images Using Hilbert Space-Filling Curves | It is effective in encoding because of enhancing of locality of differences due to Hilbert's space filling curve. | Yields better results on only non-medical images such as colored human portrait images and scenery images | Hilbert Space Filling Curve has attained a compression ratio of 1.77 for lossless compression of MRI |

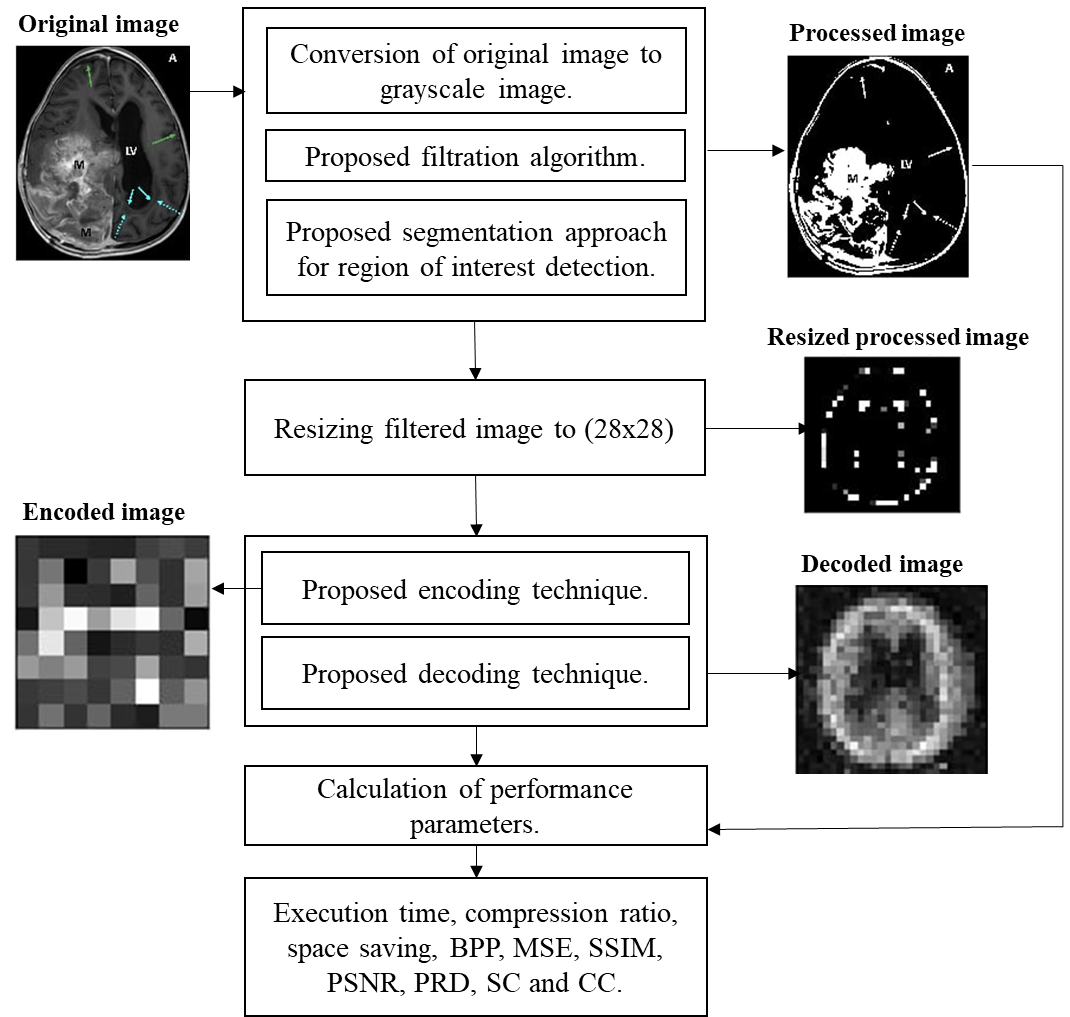
After evaluation of the above recent research papers, most of the methodologies have been accurately working on the problem of MRI compression and are well accepted in the medical society. But, these techniques has some backslides on certain aspects such as efficiency and timing. Hence, it can be inferred that there is a massive demand on the aspect of an effective compression technique which can solve the above flaws.

1. **Existing Methodologies**

In the previous years, a large number of researchers had developed a lossy or lossless method of MRI compression technique. A faction of these research had proved to be successful, and had been commended by the medical society. But they still had their shortcomings. We observed that some of the methods were either specific to certain datasets or some images.

1. **Proposed Methodology**

Our proposed methodology focused on medical image compression from a custom hydrocephalus dataset using image compression algorithm using a convolutional approach. We have proposed a block diagram to show the main concept of the methodology at a glance as shown in **Fig. 1.**



**Fig. 1.** The built-in architecture of MRI compression technique using a convolutional approach

* 1. **Algorithm**

Our algorithm is divided into 8 steps. The algorithm takes a custom hydrocephalus dataset, as an input from the dataset [10] and produces an encoded image and a decoded image. The algorithm is as follows:

**Algorithm:** An unstructured MRI compression technique using a convolutional approach

**Input:**

**Output:**  encoded image and decoded image

1. Read an image from the dataset.
2. Convert the image to a grayscale image,.
3. Preprocessed using the following formula and 5x5 kernel:

(1)

Where,

= Processed Image

= Standard Deviation

= th row in the grayscale image

= th column in the grayscale image

1. Perform segmentation on using the following equation:

If pixel then,

,

Otherwise,

, provided maximum pixel value = 255

Where,

= grayscale image

= a pixel of an image in position

= selected threshold value in our algorithm. It is tested after the trial-and-error method.

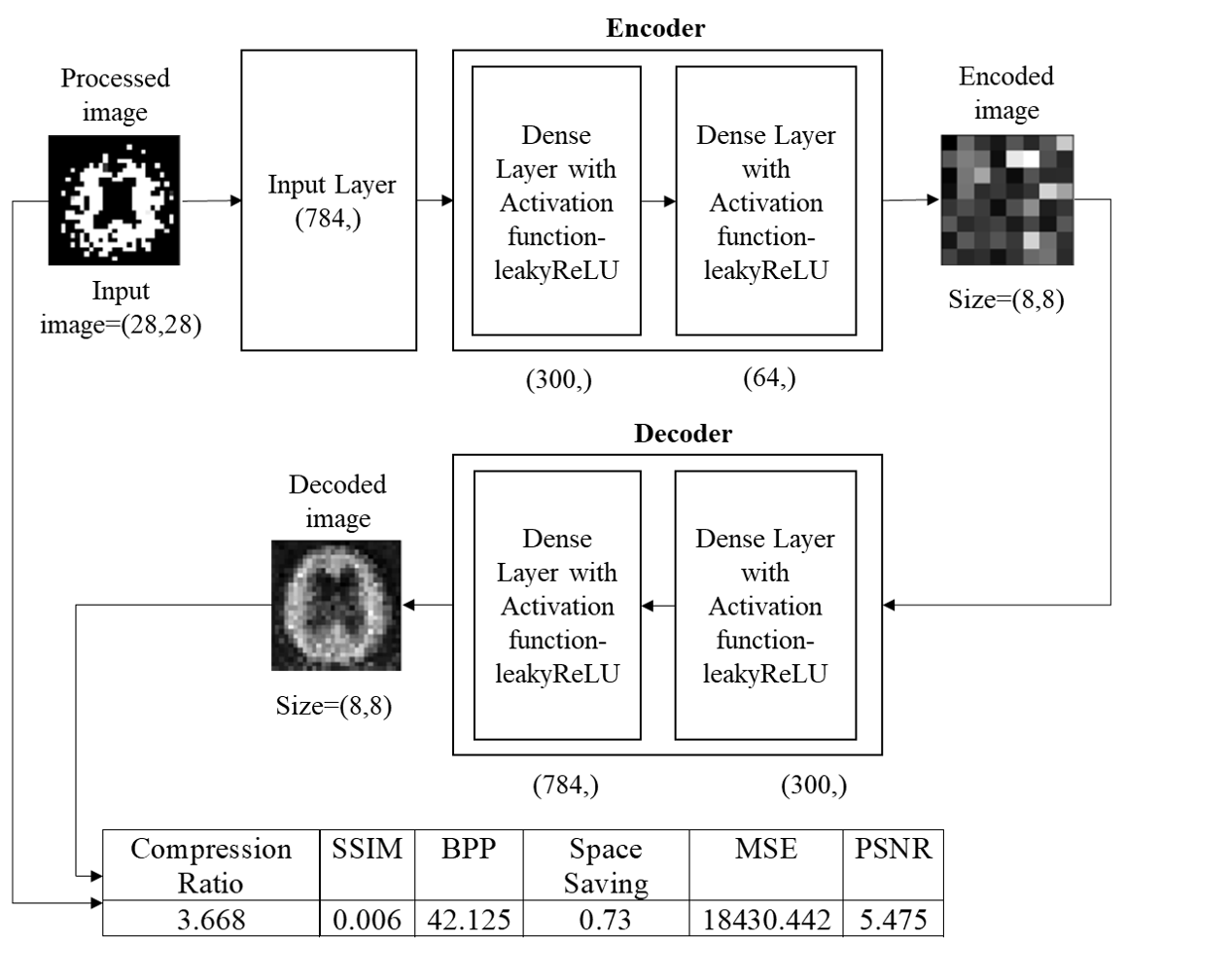
1 = Light

0 = Dark

1. Resize into a 28 X 28 image.
2. The proposed convolutional architecture each has an input x of size 28x28x3 is feed into it. In the convolutional architecture following layers are observed:
   1. Encoder Architecture
   2. One input layer which accepts input of size 784.
   3. One dense layer of output size 300 with an activation leakyReLU function.
   4. One dense layer of output size 64 with an activation leakyReLU function.
   5. Decoder Architecture
      1. One input layer which accepts input of size 64.
      2. One dense layer of output size 300 with an activation leakyReLU function.
      3. One dense layer of output size 784 with an activation leakyReLU function.
3. Segregate the whole dataset [10] into two sections. We select 80% MRI from the dataset [10] for training purposes and 20% MRI from the dataset [10] for testing purposes.
4. We feed the training and testing data into the designed convolutional model architecture to generate result.

**3.2 Model Architecture**

Training and testing phase can be explained with the help of a model architecture as shown in **Fig.2.** the architecture accepts preprocessed MRI image and displays encoded and decoded images along with performance parameters for the same.

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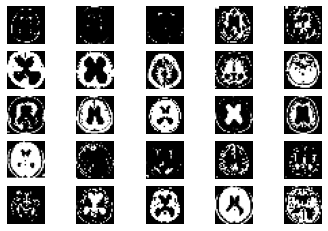
**Fig.2.** Training and testing phase using proposed model architecture

1. **Experimental results**

We consider a custom hydrocephalus dataset, which contains 132 images. The size, colour, and format of images in the dataset are similar in nature, whereas the resolutions of the images are different. The format of the images is ‘.jpg’ by nature.

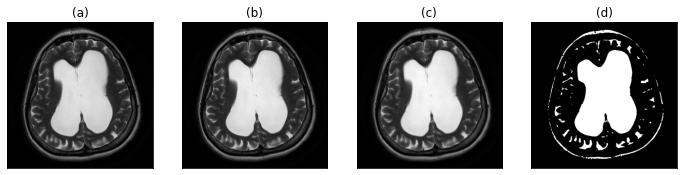
We have applied our algorithm in the python environment, version 3.8, with the hardware configuration of the Intel Core i3 5th Generation processor,4GB DDR3 primary memory (RAM), and an integrated graphics card. Anaconda as a distributor of Python version 3.8 is used. jupyter notebook version 6.3.0 as an open web interface is used as a programming platform for the implementation of our algorithm.

After reading the images from the local machine we have achieved the following results as shown in **Fig. 3.**



**Fig. 3.** Samplesof hydrocephalus dataset

After reading all the images from the dataset each image will pass through the various steps of the algorithm as shown in **Fig. 5.**

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**Fig. 5.** (a) original image (b) gray-scale image (c) image after applying proposed filtration method (d) proposed segmentation approach for the region of interest detection

We are splitting our dataset [10] into training and testing sets. 80% of the MRIs are used for training and the rest is used for testing. After the execution of our proposed algorithm, we observed that the number of training samples are 104, number of testing samples are 26 whereas training shape values are (104, 28, 28). Our proposed convolutional layered architecture is trained. It is used to train on n number of samples (104 in our case). With the changes of several iterations or epochs, the total time consumed by the algorithm is calculated.

**Table 2:** An example of the training phase.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SNo.** | **Epoch No.** | **Time Taken (s)** | **Loss** | **Value Loss** |
| 1. | 1 | 1 | 0.2193 | 0.1604 |
| 2. | 2 | 0 | 0.1407 | 0.1219 |
| 3. | 3 | 0 | 0.1159 | 0.1086 |
| . | . | . | . | . |
| . | . | . | . | . |
| . | . | . | . | . |
|  |  |  |  |  |
| 18. | 18 | 0 | 0.0517 | 0.0842 |
| 19. | 19 | 0 | 0.0494 | 0.0835 |
| 20. | 20 | 0 | 0.0473 | 0.0831 |

* 1. **Performance parameters**

In this work, the compression techniques use a wide number of performance measures to compute their efficiency and performance.

**Table 3:** Various performance parameters

|  |  |  |
| --- | --- | --- |
| **Serial No**. | **Name of the performance parameter** | **Equation** |
| 1. | Compression Ratio [10][1] | CR = |
| 2. | Mean Square Error [10] | MSE= |
| 3. | Bits per Pixel [10] | BPP = |
| 4. | Structure Similarity Index [10] | SSIM = |
| 5. | Correlation coefficient [10] | CC = |
| 6. | Peak Signal to Noise Ratio [10] | PSNR=20 |
| 7. | Percent rate of distortion [10] | PRD = |
| 8. | Structural Content [10] | SC = |

**Table 4:** Calculation ofperformance parameters for each image

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **SNo** | **BPP** | **Compression Ratio** | **MSE** | **SSIM** | **PSNR** | **PRD** | **Structural Content** | **CC** |
| 1. | 338 | 1.538 | 17142.986 | 0 | 5.79 | 99.665% | 10.081 | 0.0040 |
| 2. | 333 | 2.261 | 1421.007 | 0 | 16.605 | 99.55% | 475.408 | 0.0065 |
| 3. | 333 | 1.967 | 3585.557 | 0 | 12.585 | 99.541% | 129.134 | 0.0072 |
| . | . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . | . |
| 25. | 341 | 1.757 | 37420.317 | 0 | 2.4 | 99.659% | 4.243 | 0.0020 |
| 26. | 339 | 1.664 | 35073.048 | 0 | 2.681 | 99.625% | 3.669 | 0.0023 |

**Table 4** displays performance parameters of 26 randomly selected original samples from the dataset. At the end, we have found that our proposed algorithm can be used for medical image compression from MRIs. As the data is balanced, we are considering the results to be satisfied. Comparing it with other existing methodologies a satisfactory result is observed as shown in **Table 5.** We can conclude that our proposed methodology overpowers the existing compression algorithms.[1][2][3][5]

**Table 5:** Comparison chart

|  |  |  |
| --- | --- | --- |
|  |  |  |
| **Serial No**. | **Name of the compression algorithm** | **Compression ratio** |
| 1. | LZW [1] | 4.319 |
| 2. | Huffman coding [1] | 2.203 |
| 3. | EZW [2] | 1.6647 |
| 4. | RLE [3] | 1.5766 |
| 5. | Shannon–Fano [3] | 1.9825 |
| 6. | Arithmetic coding [3][5] | 2.2059 |
| **7.** | **Proposed methodology** | **5.646** |

1. **Conclusion**

In this paper, we have proposed an Autoencoder algorithm. This algorithm is capable of compressing and storing generated images from medical equipment contained in the custom hydrocephalus dataset, collected from the web resource. It is responsible for encoding the original image, and decoding the image, and finally comparing the decoded and original image. In addition, we have also generated BPP, Compression ratio, MSE, SSIM, PSNR, PRD, Structural content and CC values, through which we can compare our proposed method with existing methods [1] [2] [3] [5]. The experimental result shows that after applying the proposed and existing methods [1] [2] [3] [5] on the Custom hydrocephalus dataset, our technique is producing a Compression ratio of 5.646. This result is considered to be satisfactory, and based on this result we can say that the proposed algorithm overpowers the efficiency of the existing method. Due to high performance, novelty, ease of use, our proposed method is useful to develop any mobile or web applications in the future. Our method can be tested on various medical equipment generated images datasets to identify the generic performance of the proposed method in the future. The performance of our method may be increased by making necessary modifications in the algorithm.

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