Region-Based Lossless Image Compression for MRI Images

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Abstract – Medical images like MRI produces high-resolution scans, which require a lot of space and a lot time for transmission. Existing lossless compression method retains diagnostic information but they fail to provide high compression. Our work mainly uses Region-Based lossless compression technique where the input is MRI image which is first segmented into ROI (Region of Interest) and non-ROI segments. Wherein ROI part is kept without any loss, while the non-ROI is compressed more aggressively to reduce the size. This technique integrates selection of ROI box, segmentation, classification, DWT and SPIHT encoding for effective compression and reconstruction. In our project the sample of MRI image of 113.3KB was reduced to 34.3KB while retaining the complete diagnostic quality in the ROI. Other features include highlighting the ROI along with automatic report for the parameters of ROI. Results confirms that the technique offers high compression with preserved diagnostic structure, hence suitable for telemedicine and medical purpose.

Key Words: MRI, Lossless Compression, Region-Based Compression, Segmentation, DWT, SPIHT, Medical Imaging.

1.INTRODUCTION

Medical diagnosis relies on MRI scans because of their remarkable capability for capturing structural and soft-tissue information with high clarity. The downside is that the high resolution of MRI images leads to higher storage requirements and longer transmission times, especially when it involves hospital information systems and tele-radiology settings. However, the price to be paid for this high-quality imaging is that MRI files are usually large due to the fine spatial resolution and depth of information conveyed by them.

Efficiency in compression, therefore, is an indispensable component as the field of medicine heads towards a future of digitized storage and diagnosis from any point on the globe. Despite there being many algorithms, not all will be appropriate for medical images. Indeed, in clinical use, small distortions in some regions can affect diagnosis. Because of this , lossless compression is often required so the original image may be perfectly reconstructed. A lossless method has the general disadvantage of a lower rate of compression that makes it an unsatisfactory method when applied to MRI collections. Another important observation made from medical image modalities is that radiologists do not view all regions of an image with equal importance. Only a specific region, known as the Region of Interest (ROI), will contain the information required for diagnosis.

Region-based compression offers an outstanding balance between storage efficiency and diagnostic accuracy, particularly in MRI images. In this work, we present a Region-Based Lossless Compression which that does not lose any diagnostic information from the ROI while significantly compressing the non-ROI region. The system first segments the MRI image and provides the user with the facility to manually select the ROI using a rectangular box. This is done to ensure that radiologists can have control over which portion of the image must remain intact. Then, the image is classified into ROI and non-ROI segments. Both regions undergo DWT and are encoded using the SPIHT algorithm, but with different compression priorities. The ROI is lossless encoded, while the non-ROI is compressed more aggressively, reducing file size and resulting in a slightly blurred appearance, which does not affect diagnostic relevance.

Overall, this research addresses the important challenge that involves balancing diagnostic accuracy with compression efficiency. The proposed region-based approach, by preserving critical details only where necessary, presents a pragmatic and effective solution for medical image storage, transmission, and optimization of clinical workflows.

2. OBJECTIVES:

2.1 To develop a region-based lossless compression technique:
Such a compression methodology would separate MRI images into distinct regions, depending on their visual and structural characteristics, and it would assure the precise lossless encoding of the diagnostic areas for full medical accuracy.

2.2 For accomplishing accurate segmentation of the regions of interest (ROI):
Design a segmentation process that can identify and separate out clinically important regions from the background correctly. This will ensure efficient selective compression without loss of anatomical information.

2.3 To Extract Important Features from Each Region:
Analyze texture patterns, grayscale intensity levels, and structural variations within various regions of the MRI image to drive adaptive lossless compression and improve overall efficiency.

2.4 To implement an effective lossless compression algorithm:
Perform appropriate lossless coding that compresses the identified regions according to their complexity while ensuring that the reconstructed MRI image exactly matches the original pixel by pixel with no loss of data.

2.5 Development of an End-to-End Compression–Decompression Workflow:
Design an end-to-end system that includes preprocessing, segmentation, feature extraction, compression, and decompression, to help the user achieve the original MRI image after reconstruction.

2.6 To Evaluate compression techniques and Quality:
The performance of the proposed method will be evaluated in terms of compression ratio, SSIM, PSNR, and MSE metrics to assure high-quality reconstruction, confirming that the technique outperforms conventional lossless methods.

2.7 Maintain diagnostic quality after decompression:
Ensure that the decompressed images preserve all fine-scale structures, tissue boundaries, and clinical details needed to provide a proper medical diagnosis and radiological interpretation.

2.8 To enhance data storage and transmission in healthcare systems.
Provide a compression solution that reduces storage requirements and speeds up the data transfer in hospital networks, cloud systems, and telemedicine without affecting the integrity of patient images.

3. LITERATURE SURVEY

3.1 The paper [1], provides an overview of classical and region-of-interest (ROI) based image compression methods. It explains how modern systems aim to reduce the image size while maintaining the quality, especially in the field of medical. The paper compares lossless, lossy and hybrid techniques. Special emphasis is placed on ROI-based that preserves the diagnostically important regions while compressing the background. This survey helps identify suitable algorithms for specific applications.

3.2 The paper [2], this paper presents a practical ROI approach for MRI brain images by automatically extracting tumors using SVM followed by the lossless compression of ROI and lossy compression of non-ROI regions. Their results show improved compression efficiency while maintaining the clinically significant image quality.

3.3 The paper [3], this paper focuses on an ROI-based compression approach for MRI brain images, emphasizing the need to preserve diagnostically important tumor regions while reducing overall image size. It introduces an automatic extraction method using SVM classification to accurately separate tumor tissue from non-tumorous areas. The identified ROI is compressed using lossless arithmetic coding to maintain clinical quality, whereas the non-ROI region is compressed with a lossy hybrid method combining DWT, SPIHT, and arithmetic coding. The study evaluates performance using metrics like MSE, PSNR, and classification accuracy, demonstrating improved compression efficiency without compromising diagnostic information.

3.4 The paper [4], this paper highlights the importance of region-based lossless compression. Experimental results show notable improvements in PSNR and compression efficiency compared to traditional JPEG and other methods. The approach supports faster transmission, enhances the storage and maintains the diagnostic integrity. Highly useful for telemedicine and healthcare information systems.

4. METHODOLOGY

The proposed system follows a structured workflow designed to preserve diagnostically important regions of MRI Images while significantly reducing the size of the image. The methodology consists of five major steps:

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- Image Acquisition
- ROI selection
- Segmentation
- Compression using DWT-SPIHT
- Reconstruction and lossless ROI output

A detailed description of each stage with the block diagram is explained below:

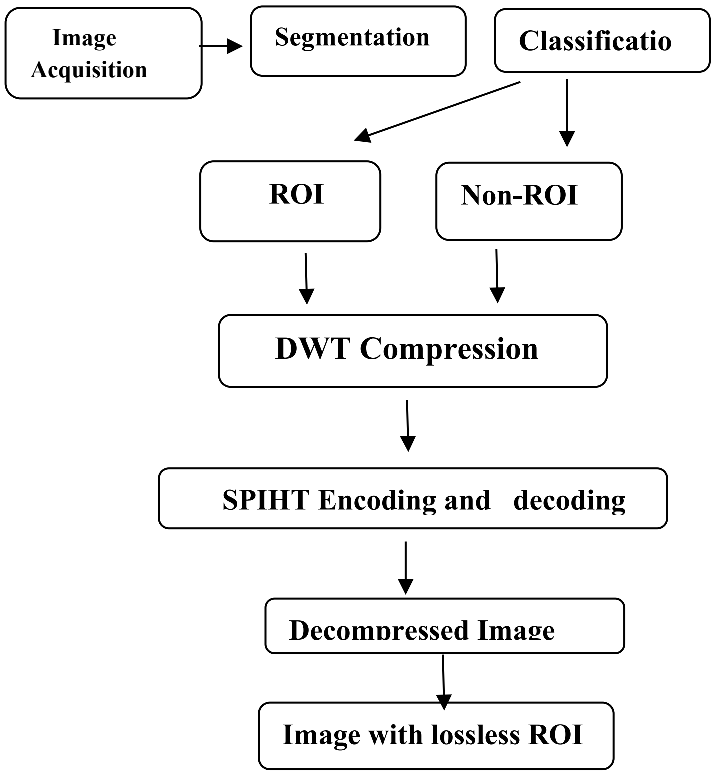


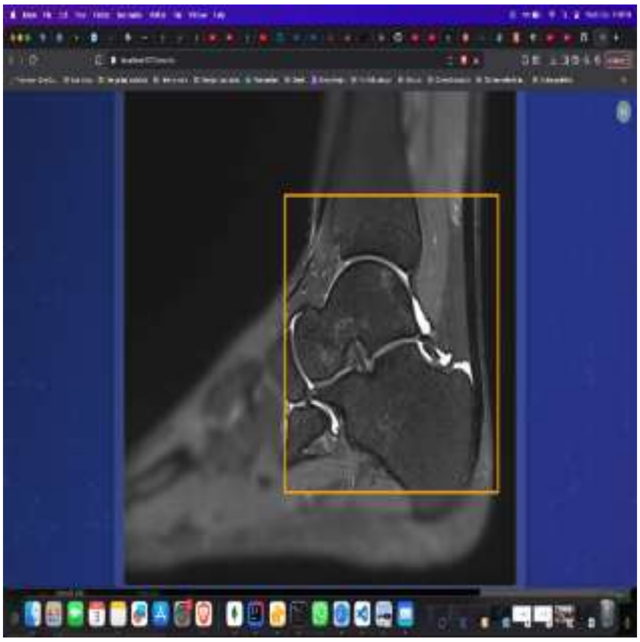
Fig.1 Block diagram of the Algorithm

4.1 Image Acquisition

The process starts with the collection of the MRI images from publicly available datasets. In this study we have used the MRI image from the google and Fast MRI database. All MRI images are in grayscale, as MRI scans store structural information without requiring color channels. Firstly, we have to upload the MRI image on the developed website.

4.2 ROI Selection

The system incorporates a manual step of selecting the ROI to ensure that the important information is preserved. User can specify the region that needs lossless preservation by using rectangular bounding box. This provides flexibility for the clinicians to identify the critical structures such as tumors, lesions, or abnormal tissue contrasts. After the ROI is marked, the coordinated are extracted and used to divide the image into two segments. The ROI zone contains: essential diagnostic information. Non-ROI zone contains: the background and the non-essential part.



4.3 Segmentation

The image is then segmented into ROI and non-ROI portions after identifying the boundaries of the ROI. To prepare both the regions for compression preprocessing is applied like normalization, Noise removal, ROI mask creation. This ensures that the ROI retains full structure during the compression.

4.4 DWT- Based Compression:

Both ROI and non-ROI regions undergo DWT compression (Discrete Wavelet Transform). The DWT decompose the image into low-frequency and high-frequency. This decomposition allows algorithm to represent the critical structure. For ROI all the bands are preserved correctly to ensure lossless reconstruction. For non-ROI removal is allowed to reduce the size and redundancy.

4.5 SPIHT Encoding:

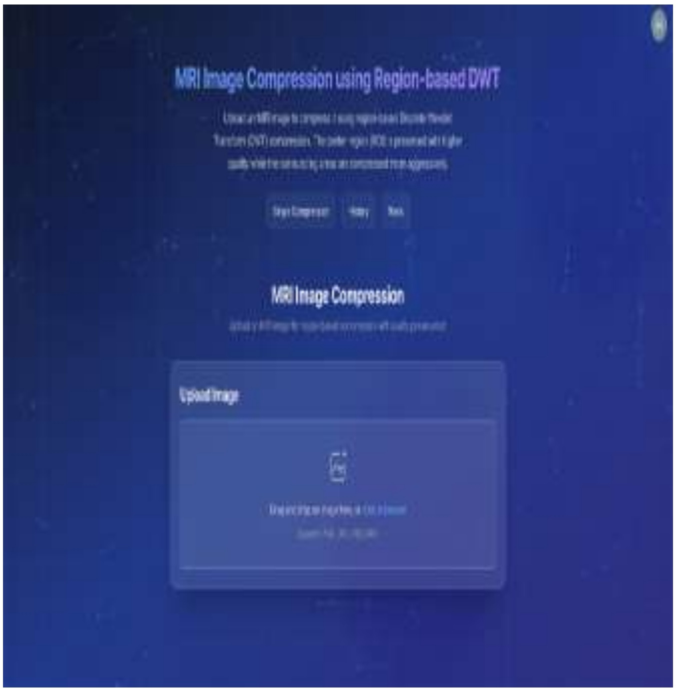
The wavelet coefficients are then encoded by using the SPIHT (Set Partitioning in Hierarchical Trees). For ROI all the coefficients are encoded without modification. Nothing is discarded. For non-ROI high compression is done because it is not the important part. Insignificant coefficients are discarded to reduce the file size. The resulting non-ROI may show a slight blur but does not affect the accuracy.

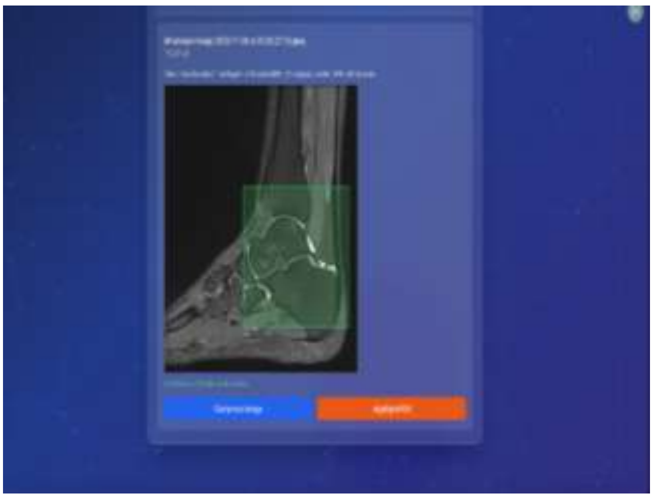
4.6 Image Reconstruction:

During decompression, the steps are done in reverse. SPIHT decoding retrieves the original and compressed coefficients. Inverse DWT reconstructs the spatial image. Then ROI is perfectly reconstructed with compressed fidelity. Then both are combined into a single image. Finally, the output maintains the full diagnostic clarity within the ROI while accomplishing a file-size reduction.

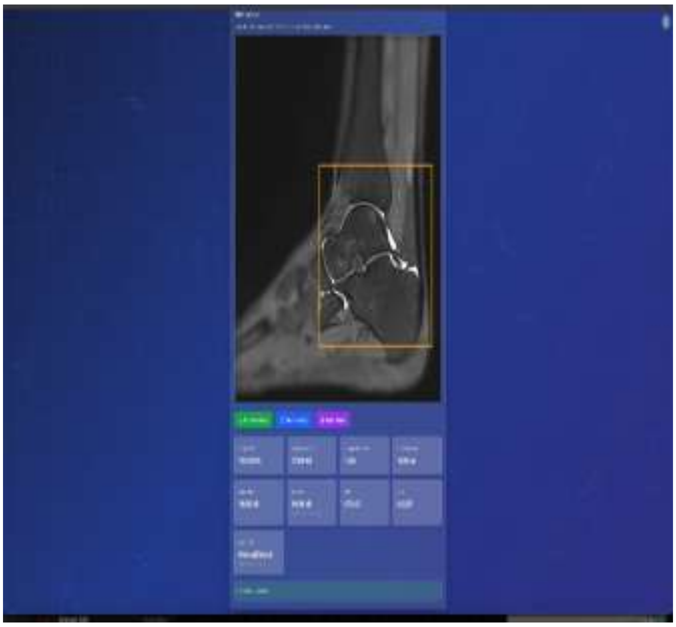
5. RESULT:

The implemented project demonstrated that the region-based lossless compression is very effective for the medical images, where only the specific regions contain the critical information which is necessary to the doctor. Our system is a website that compresses the MRI image using region-based compression. First, we will get a frontend page wherein we have to upload the MRI image then click on upload button. Then we need to select the region of interest or important part in that MRI by a box the finally it will compress the image. We have added feature like low compression, medium compression and high compression. successfully compressed 70% size reduction. The ROI remained unchanged while the non-ROI regions were intentionally blurred to enhance the compression efficiency. Segmentation, ROI highlighting and automatic report generation contributed to better interpretability and usability. Overall, the method effectively balances compression performance with clinical accuracy making it suitable for medical storage, transmission and diagnostics workflow.





Final Output:



6. CONCLUSION

The implementation of a region-based lossless compression technique for MRI images shows that medical imaging data can be efficiently reduced in size while preserving every detail required for diagnosis. MRI scans typically carry large volumes of high-resolution information, and applying uniform compression to the entire image often leads to unnecessary storage consumption. By separating critical anatomical regions from less significant background areas, the proposed method applies compression more intelligently based on the visual and structural needs of each region.

Our system is different from the existing one because in our system we provide the option for low compression, medium compression and high compression. Also, our system able the users to choose the region of interest and also produces the automatic report of the selected diagnostic region also it highlights the region-of-interest.

In summary, this project establishes that region-based lossless compression is a highly effective solution for managing large MRI datasets. It enhances storage efficiency, accelerates image transmission, and integrates smoothly with hospital data systems. Most importantly, it maintains complete diagnostic integrity, making it reliable for real-world medical applications.

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