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A Retinal Image Compression and Decompression Algorithm Relies on Regions of Interest

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***Abstract*—In any medical organization, there are large number of medical images are available. To keep the improvement records of the patient, it is necessary to take the medical images in regular basis. It is very much important to store those images for future references as well as a doctor's notes. These large numbers of images are needed to be stored in storage place and also to be transmitted from one storage place to another medical sector. Due to the controlled bandwidth of transmission channel and storage capacity, medical images should be compressed before storage and transmission. The privacy and security of medical images are essential. Compression should be done in such a way so that no one can access the patient data without decryption key. In this work, we have proposed a novel compression algorithm which compress the clinically relevant region of medical image as well as decryption algorithm to reconstruct original image with 100% fidelity, so that minimum space will be taken to store those images sequentially. The suggested technique is quantitatively tested against 25 eye OCT images to assess the vision loss caused by sub-retinal fluid buildup and 89 fundus images of DIARETDB1 database to find vascular structure. When compared to existing approaches in the literature, the created algorithm produces equivalent or even superior compression ratio.**

***Index Terms*— Retinal image, binary image, region of interest, lossless compression algorithm, decryption algorithm and compression ratio.**

I. INTRODUCTION

In today's medical imaging area, image compression [1] is quite important. It is required to reduce storage space and to speed up the transmission rate. Image compression is the process of coding that represents an image with the minimal bits possible. In daily basis large number of medical images are captured and used. It is desired that either single image or sequences of images of patients be stored to a storage device with safety for future reference of patients. There are two forms of compression available: Lossy and Lossless compression. Lossy compression is ideal for natural pictures like photos, when slight data loss is acceptable. But for diagnosis purpose medical images like OCT, MRI, CT etc. require lossless compression, so that expert can extract every single feature of that image because a minor loss can cause adverse effects. In medical imaging, several lossy compression methods [2] have been investigated. However, the loss must not be diagnostically substantial in order for the specific medical concern to be addressed. To attain a high compression proportion and safety for

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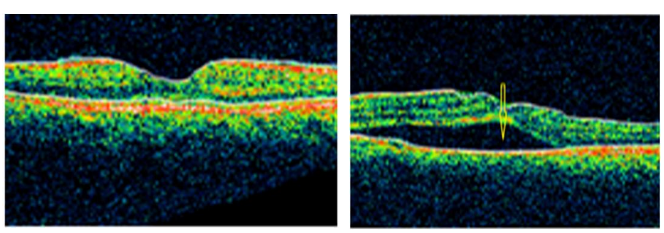
medical images, we propose a novel compression and decryption algorithm with fidelity and it is also helpful in transmission of those images from one medical organization to another. When a patient goes through any diagnosing screening program, huge amount of data is generated and archiving those generated data also becomes an expensive and difficult challenge. To overcome this difficulty, we have used region-based compression method which represents an improvement in compression efficiency. In this study, our concern is only Optical coherence tomography (OCT) [3, 4] images and fundus images of retina.

Accumulated fluid [5] in the retina detaches the retinal layers, resulting impaired vision. The macula, which is positioned between the retinal pigment epithelium and the outer segments of the eye, thickens as a result of fluid buildup in the macular portion of the eye. Fig. 1 shows the OCT images of sub retinal fluid accumulation inside human retina. The region of interest is the accumulated fluid section. In Fig. 2, a fundus image of retina is shown with red blood vessels. In eye image analysis and computer-assisted diagnosis [6], accurate blood vessel recognition is critical. Aside from its use in Diabetic Retinopathy early detection, the vascular tree may also be used to assess premature retinopathy, quantify vessel diameter for cardiovascular disorders etc.

In the present work, a novel lossless compression and decompression algorithm has been proposed. Decryption, also known as decompression, is the process of de-coding to retrieve the original picture from a compressed image. The procedural blocks are shown in Fig. 3.

II. Literature Survey

Every day, a slew of new medical picture compression approaches emerge. The literature on data compression and coding is extensive, and scholars have approached these issues from several angles. A block categorization compression approach based on adaptive thresholds is proposed. This approach may be used on any form of medical picture, including OCT, MRI, CT, and X-rays [7]. Authors [8] developed a unique compression strategy based on lossless image compression in medically important regions and lossy compression everywhere. In [9], a compression approach based on region of interest (ROI) is proposed, which is a combination of shape-adaptive wavelet transform and scaling-based ROI. According to the shape information, the samples inside the object and background are modified with shape-adaptive wavelet transforms as needed. But as this method depends on shape and the length of each object is not constant, computational cost and computational complexity is generally higher than conventional method. A wavelet transform of medical pictures (MRI and CT scan) followed by a coefficient correlation analysis is proposed in [10]. In this paper, the result is tested on 4 medical images only. Three lossless data compression algorithms, RLE, Delta, and Huffman encoding, are compared in this work [11], with the author claiming that the Delta approach is the best of the three. Binary, grey level and RGB images are examined for testing purposes. The author [12] demonstrated how to acquire linked components in binary images using a deterministic finite automaton technique. For six different types of images of different size, improved encoding performance was achieved in terms of computational complexity and memory use. The JPEG technique was compared to an effectual two-stage block coding solution [13] of binary images. It was established that the outcomes were improved by 22-24 percent. In binary image coding and compression, a new technique was used to develop an ant colony algorithm [14] based on real ant behaviour. For binary image compression, the echolocation system in dolphins provided another chain coding scheme [15]. The image reconstruction technique saves the starting coordinates of the dolphins' positions as well as their motions. For multiple image formats, a lossless soft compression approach [16] is presented to eliminate both spatial and coding redundancy simultaneously.



(a) (b)

Figure 1. OCT Image of Human Retina (a) Healthy eye without fluid accumulation. (b) Fluid buildup between two layers (yellow arrow)

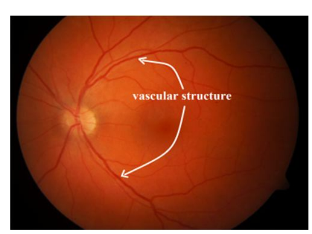


Figure 2. Human Retinal Fundus Image

Shape, structure and length were used as crucial characteristics for picture compression in most of the techniques discussed above. However, in this work, we offer a unique ROI-based lossless compression methodology that

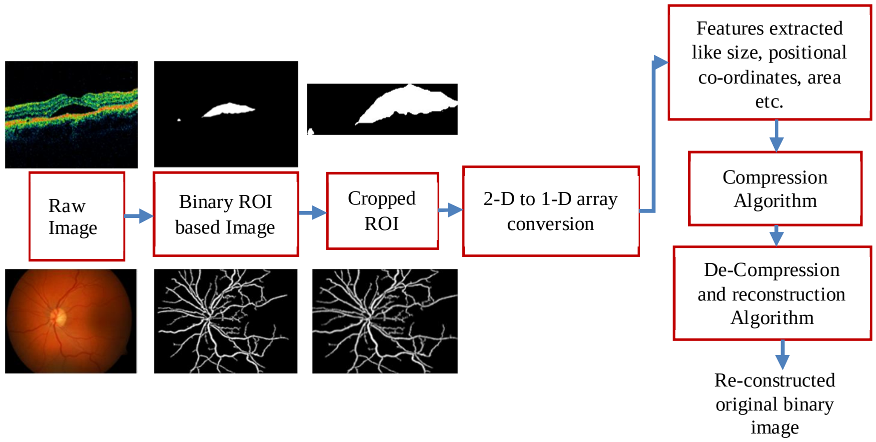


Figure 3. Sequential steps of the entire progression

uses the location of ROI/Non-ROI pixels as well as a decryption algorithm to recreate the original picture faithfully. When compared to other approaches in the literature, our proposed compression method achieves equivalent or even superior results.

III. Methodology

In OCT images and fundus images (Fig. 1 and Fig. 2), one can visualize the fluid filled region and blood-vessel. However, an optical quick look cannot accurately determine the proportion of efficacy. In [17], how fluid portion is extracted effectively is explained. K-mean clustering is used to cluster the images into different segments followed by median filtering. Finally, intra-retinal fluid region is extracted and outer retinal fluid region is discarded using RFAD (Retinal Fluid Automatic Detection) algorithm and fluid region is extracted in binary. In our previous study [18], to extract the blood-vessel, a contrast enhancement method and adaptive thresholding was used with fixed window size and threshold value. Extracted fluid region and blood-vessel in binary are shown in Fig. 4 (a and b).

In this paper, source image is the binary image of ROI. The proposed approach entails the following stages in order: cropping, conversion from 2D image array to 1D array, compression algorithm and decryption algorithm. A flow diagram of compression algorithm is depicted in Fig. 5. Using cropping algorithm first we have found the extreme left and extreme right ROI pixel co-ordinate and maximum and minimum ROI pixel co-ordinate. Using these co-ordinates, only ROI region has been cropped and unwanted background has been removed. Here cropping algorithm is used to handle lesser amount of data, so that output response becomes faster. However, cropping does not provide any advantages of images with blood-vessel. Then this 2-D image data is converted to

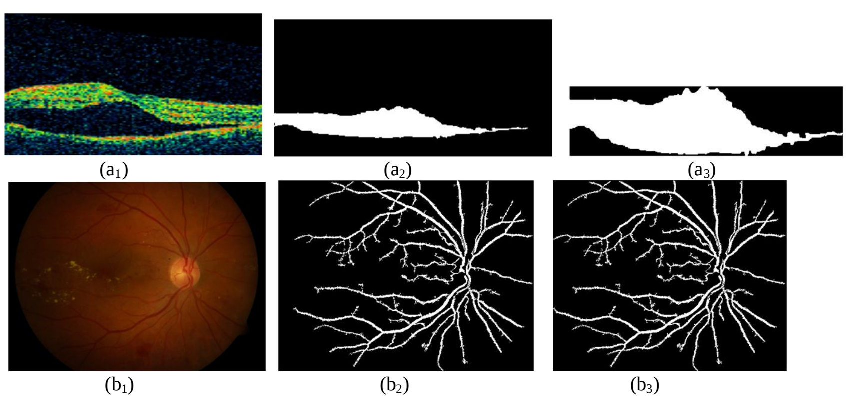


Figure 4. Images of region of interest (a_1) Original OCT Image (a_2) Accumulated fluid portion only in binary (a_3) Cropped fluid portion (b_1) Original Fundus Image. (b_2) Segmented blood-vessel (b_3) Cropped image.

1-D data. In this data array, there are two types of pixel values-one is ROI pixels and other is non-ROI pixels. Here one novel algorithm is proposed to compress the image data and also to decrypt the original image from compressed data. Initially, it is checked that quantity of which pixel value is more. In Fig. 4a, non-ROI pixel values are less compared to ROI pixel values. So, positions of the non-ROI pixels are fetched to an array. Along with the position values some important parameter like size of original image and cropped image value also been fetched for reconstruct the original image from compressed image and some initial particular array cells are chosen for these important parameters. Then this position array is processed. Firstly, if n represents any particular position and P represents the position array then by subtracting *P(n)* from *P(n+1)* element, a new array *P1[ ]* is constructed without changing the important parameter values like size of the original and cropped image. If $P_1[\ ]$ array contains same value data stream, then one counter will run and the count value is stored in new array $P_2[\ ]$ and just before the count value one ‘0’ value is stored for understanding which one is count value. Other values of $P_1[\ ]$ are transferred to $P_2[\ ]$ array without alteration. For effective data transmission, each data element converted to 8-bit binary data. Here we have chosen the most significant bit (MSB) as a sign bit. Because each bit is needed to be distinguish whether it is non-ROI pixel values or ROI pixel values or size of the original and cropped image values. A signed number ‘-1’ is used here to represent the ROI pixel value only and ‘0’ is used to represent the non-ROI pixel value and ‘-3’ is used to represent the number of rows, number of columns of the binary image. As we have converted each array element into 8-bit binary data where one bit is dedicated for sign bit, so maximum data range should be +127. If any array element value is more than 127, then

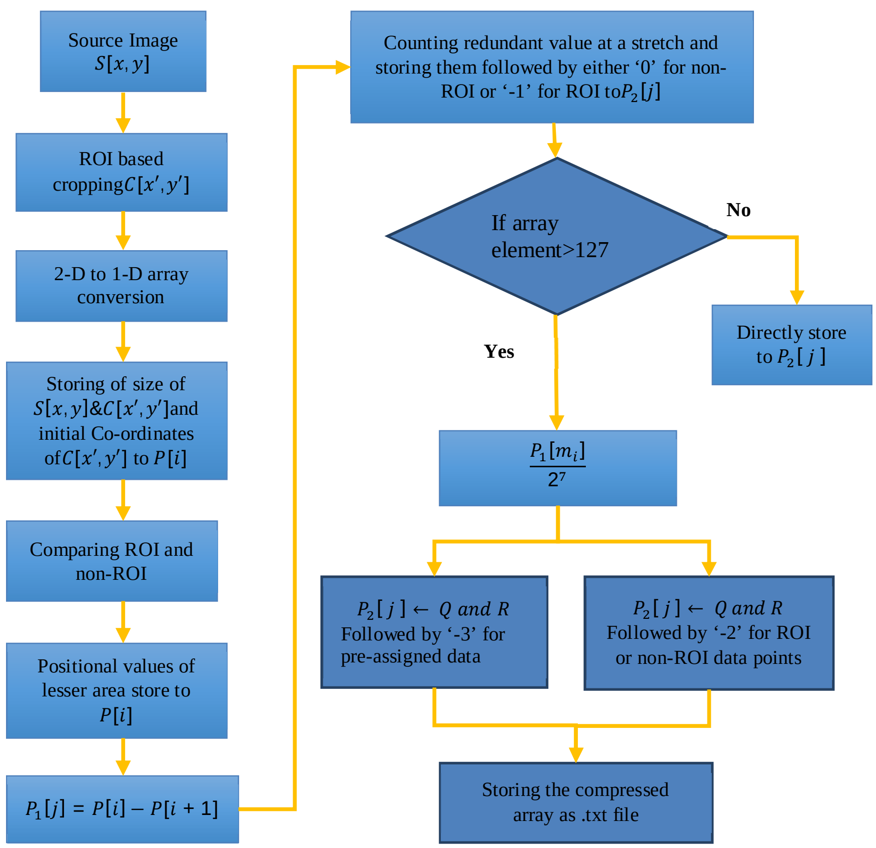


Figure 5. Flow diagram of ROI based compression algorithm

using modulo-2^7, first that data element is divided by 127 and then quiescent and reminder values are determined and fetched to the processed array followed by ‘-2’. This step is repeated for non-ROI pixel value, ROI pixel value and rows and columns values of original and cropped image. In this way we have constructed a one dimensional array and we have used notepad or .txt format to store this array in a storage device.

One decryption approach is described here for reproducing the actual image faithfully from the compressed array. The code numbers '0', '-1', '-2' and '-3' are first decoded to find the values of non-ROI pixels, ROI pixels and size of the original and cropped image values. Then initial position array is generated again along with the size of original and cropped image values. To get the original image back, firstly a one-dimensional array is created of cropped image size and all the element values are chosen as one. Then position array is injected into the new array. We know position array contains the position of non-ROI pixels if there is a smaller number of non-ROI pixel compared to ROI pixel in the cropped image. After injecting the position array, each position is taken to be zero value as non-ROI pixel is represented by zero. Then this 1-D data is converted to 2-D data again to get the array data in image form. In this way cropped image is reconstructed and by applying the same procedure, original image is also reconstructed without losing any information.

IV. RESULT AND DISCUSSION

On a dataset of 25 OCT pictures, the suggested method is tested. These images are collected using Carl Zeiss stratus OCT. 89 fundus images of the DIARETDB1 [19] database for blood-vessel is also tested using the proposed method. The retinal pictures are captured with a field of view of 50^0.

Several parameters such as compression time (CT), compression ratio (CR) and saving percentage (SP) are measured to evaluate quantitatively and analysis of comparative study of the proposed algorithm. The performance parameters are as follows:

$$CR = \frac{Uncompressed\ file\ size}{Compressed\ file\ size} \tag{1}$$

$$SP = \frac{Uncompressed\ file\ size - Compressed\ file\ size}{Uncompressed\ file\ size} \tag{2}$$

The redundancy of the source data has a significant impact on the compression algorithms performance, as seen in table I. In comparison to OCT pictures with fluid areas, fundus images with blood vessels are more complicated, and we obtain a lower compression ratio for fundus images. We have also reconstructed the original image with 100% fidelity using decryption algorithm. So, using these two algorithms one can manage to store the data with less amount of space and high security, because without decryption algorithm one cannot open the original image. As the compression ratio is high and compressed data of image is stored in a 1-D array, so it is very much helpful for data transmission also.

In this work, we have processed the binary image of fluid region and this fluid region can segregate whether the eye is healthy or unhealthy. If eye is detected as unhealthy eye, then patient should go through further continuous treatment process. After that if fluid region is continuously decreasing with each screening, which can be

TABLE I. PERFORMANCE ANALYSIS USING PROPOSED METHOD

Image No	Image Type	Size of Cropped Image in Dimension	Size of Compressed Image in Dimension	Compression Ratio	Saving Percentage	Compression Time in sec
Image 1	OCT Images	96 × 164	1 × 894	17.61: 1	94.3 %	0.3322
Image 2		171 × 586	1 × 5612	17.85: 1	94.4 %	0.3346
Image 3		112 × 983	1 × 5854	18.8: 1	94.7 %	0.3349
Image 1	Fundus Image	1148 × 1379	1 × 102148	15.49: 1	93.5 %	0.6712
Image 2		1142 × 1351	1 × 98108	15.72: 1	93.6%	0.6842
Image 3		1148 × 1337	1 × 114800	13.37: 1	92.5 %	0.6235

Table II. Performance Comparison Results

Work	No of image	Method of Compression	CR
Ramesh *et al.* [10]	4 (2 MRI and 2 CT)	MICWDP	5.51: 1
Zukoski *et al.* [8]	24 (chest X-ray)	Hybrid compression methodology	4.5: 1
Mouring *et al.* [14]	8	Ant Colonies based lossless compression	15.85:1
Matnee *et al.*[13]	5	Two- Stage Block Coding Method	4.222:1
Xin *et al.* [16]	Fashion-MNIST dataset	Shape Recognition based soft compression	3.598:1
Proposed method	25 (OCT)	ROI based lossless compression	17.58: 1
	89 (Fundus)		12.17:1

detected by the binary image, one can say eye condition of that patient is improving. So, fluid region in binary image is our main concern. That is why our proposed algorithm is only applicable on binary image but not RGB image. Like other previous compression methods [9, 12, 16], our proposed method does not depend on shape or length of the object and there is no structure preserving issue and this method is fully automated.
The performance parameter is comparable to and better than the prior reported values, as shown in table II.

V. Conclusion

In this work, we present a novel methodology to compress the clinically relevant region of eye OCT and fundus image. Here we have used lossless compression and better compression ratio is achieved compare to the other relevant method depicted in table II. A decryption technique is proposed in this work, which allows the original image to be restored faithfully. Decryption algorithm also restricts the unauthorized access. Binary image is the source image, which contains only the clinically relevant areas, of our proposed algorithm. As we know binary images have only one bit per pixel, so they can only represent two gray values. It reduces the algorithm complexity and also the processing time. This strategy is most useful following a diagnosis of the region of interest in a medical imaging. It may also be used in healthy medical images when the anatomical structure is the focus of attention.

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