Robust Medical Image Watermarking Technique

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Abstract

Transmission of medical images among remote places is a general practice in telemedicine. Medical images may be modified intentionally or accidentally as the transmission of these may take place through unsecure networks such as internet. Before making any diagnostic decisions, the medical practitioner has to verify the integrity of region of interest (ROI) in the received medical image in order to avoid wrong diagnosis. Watermarking can be used for checking the integrity of medical images. We propose a novel medical image watermarking method based on IWT and LZW. This proposal verifies the integrity of ROI, precisely identifies tampered blocks inside ROI, provides robustness to the data inside region of embedded non-interest (RONI) and recovers original ROI.

Keywords: Watermarking, ROI (Region of Interest), RONI (Region of Non-Interest), IWT (Integer Wavelet Transforms), LZW(Lempel-Ziv-Welch).

Introduction

Telemedicine utilizes media transmission and data advancements to give clinical medicinal services at remote zones. It improves access to medicinal administrations that are not accessible in inaccessible country zones. With the utilization of telemedicine, patients living in remote networks can benefit medicinal finding from far away experts, so the patient need not venture out to visit doctor for discussion. Telemedicine licenses transmission of therapeutic and imaging information from one spot to other, dependability of information and helpful interchanges among patient and restorative staff. Restorative pictures help doctors to discover reasonable demonstrative systems for treating the patients [1, 2]. Medicinal pictures are likewise essential in assessing the recuperation of patients from their treatment [3]. Amid transmission, restorative pictures might be changed by gatecrashers purposefully or assaulted by some other unintentionally. The genuineness of medicinal pictures should be checked by the master as area of interest (ROI) of pictures can be changed or altered. This checking helps in maintaining a strategic distance from wrong determination. Watermarking is observed to be a successful and promising instrument in this context [4].

A considerable lot of the medicinal pictures contain at least one imperative territory called ROI and the rest of the part is called area of non-interest (RONI). Substance of ROI is critical for demonstrative basic leadership. It is better not to insert any information inside ROI. In the meantime, any adjustments or alters caused to ROI amid transmission of the therapeutic picture ought to be recognized and the first ROI must be recouped precisely. This recuperation helps in maintaining a strategic distance from wrong finding just as retransmission of the therapeutic picture. For the most part, the recuperation information of ROI is installed inside RONI [5-12]. At the point when any change or alter is identified inside ROI of the got medicinal picture, at that point the data installed inside RONI is extricated and is utilized to recuperate the first ROI. Specialists have built up various medicinal picture watermarking strategies for alter discovery and recuperation.

(1) Embedding mutilation inside ROI of the picture [13, 14].

(2) There is no validation information of the picture or ROI of picture to check straightforwardly whether the picture or ROI is altered. Along these lines all blocks in the picture or ROI must be checked in a steady progression to recognize the nearness of alters. This checking procedure prompts wastage of time when the picture or ROI isn't altered [15-18].

(3) Accurate recognizable proof of altered blocks inside ROI is beyond the realm of imagination as normal estimations of blocks are utilized for identifying the altered blocks [15-17].

(4) There is no talk on robustness of the watermark information installed inside picture of RONI [17-20].

In this paper, we propose a novel block-based medical image watermarking technique using integer wavelet transform (IWT) to achieve the following objectives:
(1) Avoid embedding distortion in ROI by not embedding any data inside ROI.
(2) Accurately identify tampers inside ROI.
(3) Recover the original ROI when the ROI is tampered.
(4) Provide robustness to the data embedded inside ROI.

2. Literature Survey

So far many block based watermarking methods were produced for distinguishing altered regions inside return on initial capital investment of medical pictures and recouping unique return on initial capital investment when any alter is distinguished inside it. Zain and Fauzi [21] proposed a plan, where the restorative picture is fragmented into 8 × 8 blocks and afterward a mapping is set up between the blocks for inserting the recuperation data of each block into its comparing mapped block. Afterward, each block is further partitioned into four sub blocks of size 4 × 4 and afterward a 9-bit watermark is produced for each sub block. The created 9- bit watermark of each sub block is implanted into LSBs of the initial 9 pixels of the sub block in the comparing mapped block. At beneficiary's end, the watermarked therapeutic picture is isolated into blocks of 8 × 8 size and after that the mapping between the blocks is determined as done in inserting method. Afterward, each block is additionally separated into four sub blocks of 4 × 4 size and afterward a 2-level recognition plot is connected for distinguishing altered blocks. This 2-level recognition plot recognizes altered blocks, where level-1 discovery is connected to sub blocks of blocks and level-2 discovery is connected to blocks. At the point when an altered block is distinguished, the comparing mapped block is distinguished and after that recuperation information implanted in mapped block is extricated. This recuperation information is utilized to supplant the pixels in altered block. Major

Disadvantages of this strategy are as per the following. (1) If both block and its mapped block B are altered then it won't be conceivable to recuperate unique picture. (2) This strategy does not utilize any confirmation information for the whole restorative picture to check straightforwardly whether the picture is altered. In this way, all blocks in the picture must be checked consistently to identify the nearness of alters. This checking procedure prompts wastage of time when the picture isn't altered. (3)A tampered block can't be recouped with unique pixels of the block as this technique utilizes normal of pixels inside the block to recoup the pixels in the altered block.

Wu et al. [22] created two block based strategies. In the second strategy JPEG bit-string of the selected ROI is generated and then divided into fixed length segments. Afterward, the restorative picture is partitioned into blocks and after that hash bits are determined for each block. These hash bits are utilized as verification information of the blocks. In each block of picture, hash bits of the block and one section of JPEG bit-string of ROI invested are both inserted utilizing strong added substance watermarking method. At that point all blocks are consolidated to get watermarked restorative picture. At recipient's end, the watermarked restorative picture is separated into blocks as done in inserting method. From each block, hash bits of the block and a section of JPEG bit-string are both extricated. For each block, hash bits are determined and afterward contrasted with the removed hash bits with check whether the block is altered or not. In the event that the block with ROI is distinguished as altered then the JPEG bit-string portions separated from all blocks are utilized to recuperate the return on initial capital investment. Inconveniences of this strategy are as per the following: (1) it is absurd to expect to get ROI when tampered (2) this strategy requires more work to create recuperation information of recovery data of ROI and embed it into all blocks of medical image.

Chiang et al. [17] proposed two block based methods based on symmetric key cryptosystem and altered contrast extension (DE) method. The main strategy has the capacity to recoup the entire medicinal picture, while the second technique can recoup just return on initial capital investment of therapeutic picture. In the primary technique, the medicinal picture is partitioned into 4 × 4 estimate blocks and after that normal of each block is determined. Afterward, the normal estimations of all blocks are connected and at that point scrambled utilizing two symmetric keys K1 and K2 in request to build the level of security. At that point, Haar wavelet change is connected to all blocks to distinguish smooth blocks. The encoded normal estimations of the considerable number of blocks are implanted in the distinguished smooth blocks. At the beneficiary's end, the implanted information is removed from watermarked picture and at that point decoded utilizing the keys K1 and 2 to get the normal estimations everything being equal. Afterward, normal qualities are determined for all blocks and after that contrasted with separated normal qualities with distinguish altered blocks. At the point when an altered block is distinguished the pixels in altered block are supplanted with the extricated normal of that block. The second strategy is equivalent to the first strategy aside from that the bits of pixels in blocks of return on initial capital investment are inserted rather than normal estimations of all blocks in the whole picture. Entanglements of these plans are as per the following: (1) the two strategies require more opportunity for implanting information into therapeutic picture as all blocks of the restorative picture must be changed into recurrence space and afterward smooth blocks must be recognized for inserting information and (2) They are not utilising any authentication data for the entire ROI to check whether the ROI or the entire image is tampered.

Memon et al. [23] actualized a mixture watermarking strategy. In this method, the medical picture is sectioned into ROI and RONI. At that point, a delicate watermark is inserted into LSBs of ROI. RONI is separated into blocks of size NxN and afterward an area map demonstrating embeddable blocks is generated. A robust watermark is installed into embeddable blocks of RONI utilizing number wavelet change (IWT). Afterward, the area map is installed into LL3 of each block utilizing LSB substitution technique. At last, ROI and RONI are joined to get watermarked picture. At recipient's end, the watermarked medicinal picture is portioned into ROI and RONI. At that point, the vigorous watermark is extricated from RONI furthermore, is utilized for checking verification of picture. Delicate watermark is separated from RONI and checked outwardly to know the nearness of alters inside return on initial capital investment. Two inconveniences of this strategy are as per the following: (1) there is no determination of how the first RONI is recuperated when the return on initial capital investment is altered also, (2) the time multifaceted nature of this technique is more as it has to create area map before implanting information.

Tjokorda Agung and Permana [16] built up a reversible technique for medical images whose return on initial capital investment estimate is more thought about to size of RONI. In this technique, the first LSBs of all pixels in medicinal picture are gathered and after that LSB in each pixel is set to zero. Afterward, the medicinal picture is divided into return on initial capital investment and RONI locales. At that point, return on initial capital investment and RONI are isolated into blocks of sizes 6 × 6 and 6 × 1, individually. A mapping is shaped between blocks of ROI for putting away recuperation data obstruct into its mapped RONI. The evacuated unique LSBs are packed utilizing RLE procedure and after that implanted into 2 LSBs of 6 × 1 blocks in RONI. At collector's end, the watermarked medicinal picture is fragmented into return on initial capital investment and RONI as done in implanting procedure. Then, the method proposed by Zain and Fauzi [2] is connected just to return on initial capital investment part to identify alters inside ROI and recoup unique ROI. The unique LSBs that were installed in RONI are separated and after that re-established to their positions to get the first medicinal image. This technique has the equivalent disadvantages as the methods proposed by Liew et al. [3, 4].

Al-Qershi and Khoo [13] built up a reversible ROI based watermarking plan. At sender's end, the medicinal picture is fragmented into return on initial capital investment and RONI. Afterward, information of patient what's more, hash estimation of return on initial capital investment are both implanted into ROI utilizing the procedure created by Gou et al. Packed type of RONI, normal estimations of blocks inside ROI, implanting map of RONI, implanting guide of RONI, and LSBs of pixels in a mystery zone of RONI are implanted into RONI utilizing the strategy of Tian. At long last, data of return on initial capital investment is installed into LSBs of pixels in a mystery zone. At beneficiary's end, return on initial capital investment data is removed from a mystery zone and is utilized to recognize return on initial capital investment and RONI locales. From the distinguished RONI area packed type of return on initial capital investment, normal estimations of blocks inside ROI, implanting guide of return on initial capital investment, installing guide of RONI, and LSB of pixels in mystery zone are extracted. Using the extricated area guide of ROI, patient's information and hash esteem of RONI are extricated from ROI. At that point, hash estimation of return on initial capital investment is determined and contrasted and extricated hash esteem. In the event that there is a bungle between the two hash esteems then the return on initial capital investment is partitioned into 16 × 16 blocks. For each block, the normal esteem is determined and contrasted and the relating normal esteem in the separated normal qualities. In the event that they are not equivalent at that point the block is set apart as altered and supplanted by the comparing block of the packed type of ROI. Two detriments of this method are (1) removing the implanted information from RONI without realizing the inserting guide of RONI and (2)use of compacted form of RONI as recovery data for the RONI.

Al-Qershi and Khoo [24] proposed a plan dependent on two-dimensional contrast extension (2D-DE). At sender's end, the restorative picture is separated into three districts: ROI pixels, RONI pixels, and outskirt pixels. Afterward, the connection of patient's information, hash estimation of RONI, bits of pixels inside RONI, and LSBs of outskirt pixels are compacted utilizing Huffman coding and afterward inserted into RONI utilizing 2DDE strategy. This inserting creates an area map which will be linked with data of return on initial capital investment and at that point installed into LSBs of fringe pixels. At recipient's end, from fringe pixels in the watermarked medicinal picture both data of return on initial capital investment and area map are separated. Utilizing this ROI data, return on initial capital investment and RONI are distinguished. The removed area map is utilized to separate patient's information, hash estimation of RONI, bits of pixels inside ROI, and LSBs of fringe pixels from RONI. The process for distinguishing altered blocks is equivalent to the one utilized in [8]. Each altered block is supplanted by the relating block of pixels in the 4 Universal Diary of Telemedicine and Applications removed return on initial capital investment. The LSBs of fringe pixels are supplanted utilizing the removed LSBs from RONI. A noteworthy disadvantage of this conspire is that it is material to just medicinal pictures whose RONI estimate is less (up to 12% of size of the whole picture).

Al-Qershi and Khoo [25] built up a cross breed RONI based technique. At sender's end, the restorative picture is isolated into three locales: RONI, RONI, and fringe pixels. Afterward, patient's information and hash estimation of return on initial capital investment are inserted inside return on initial capital investment utilizing adjusted DE method. The return on initial capital investment area map along with compacted type of RONI and normal powers of obstructs inside RONI is then inserted into RONI utilizing DWT technique. Then, size of watermark that is embedded into RONI also, return on initial capital investment data is implanted inside outskirt pixels utilizing the same DWT technique. At recipient's end, ROI data is extricated from border pixels and is utilized to distinguish ROI and RONI districts. Packed type of ROI, normal powers of blocks in RONI, and location map of ROI are removed from the recognized RONI region. Using the removed area map of ROI, patient's information and hash estimation of ROI are removed from ROI. The strategy for recognizing altered blocks and recouping ROI is equivalent to in [8]. Two inconveniences of this method are (1) use of packed form of ROI as recuperation data for the ROI and (2) appropriateness to just pictures whose estimate is no less than 512 × 512.

Disadvantage of this plot is that unique picture can't be recouped when it is altered.

3. Proposed Method

3.1 Segmentation of the medical image

In the proposed method, the medical image is segmented into two regions: ROI and RONI pixels. In a medical image, the ROI area is generally marked by a physician interactively and is in any irregular shape. In the proposed method, the ROI area is marked by a physician and is represented by an enclosing rectangle. The enclosing rectangle is indicated by the coordinates of its vertices. A medical image may contain number of ROI areas. The medical images with one ROI area are considered in the present work and the ROI data is generated by concatenating all the binary values of data pixels.

3.2 Cohen Daubechies Fauraue (CDF) (2, 2) IWT Segmentation of the medical image

After generating the watermark data, it is embedded inside RONI using IWT. In the proposed method, CDF (2, 2) IWT is used as it has best coding performance when compared with other transforms. When CDF (2, 2) IWT is applied on an image or a block of an image of size M × N then the image or the block is decomposed into one approximate sub-band and three detailed sub-bands denoted by LL and LH, HL, HH of size M/2 × N/2. These sub-bands contain both positive and negative values with different magnitudes. Hiding data in LL sub-band leads to high degradation in the quality of image. Data embedded inside HH sub-band has less robustness. Concealing data in middle frequency sub-bands (LH and HL) results in good perceived quality and robustness.

3.3 Generation of Watermark

In the proposed method, watermark is generated by concatenating ROI recovery data and hash value of ROI. ROI recovery data is generated by concatenating the bits of pixels in ROI. ROI hash value is generated by applying SHA-256 on ROI.

3.4 Embedding the watermark data into RONI

To embed the watermark data into RONI, the RONI area of the medical image is divided into non-overlapping blocks of size 8 × 8 each. Then, IWT is applied up to one level on each block to generate low, middle and high frequency sub-bands LL, HL, LH and HH. Three bits of watermark data are embedded in each coefficient of the middle frequency sub-bands (HL, LH). As an example, if a coefficient in any of the middle frequency sub-bands is 27 and the three bits to be embedded are 1,1 and 0, then the coefficient 27 is replaced with 30 which is obtained by replacing three LSBs in the binary representation of 27 (00011011) with 1,1 and 0. The detailed embedding process is explained as follows:

1. Divide RONI into blocks, each of size 8 × 8.
2. Repeat the following steps for each block B in RONI until all bits of the watermark data are embedded.
3. Apply IWT up to one level on B.
4. Embed three bits of watermark data in each coefficient of middle frequency sub-bands LH, HL of B.
5. Apply inverse IWT on B.

The block diagram of embedding procedure is shown in Figure 1.

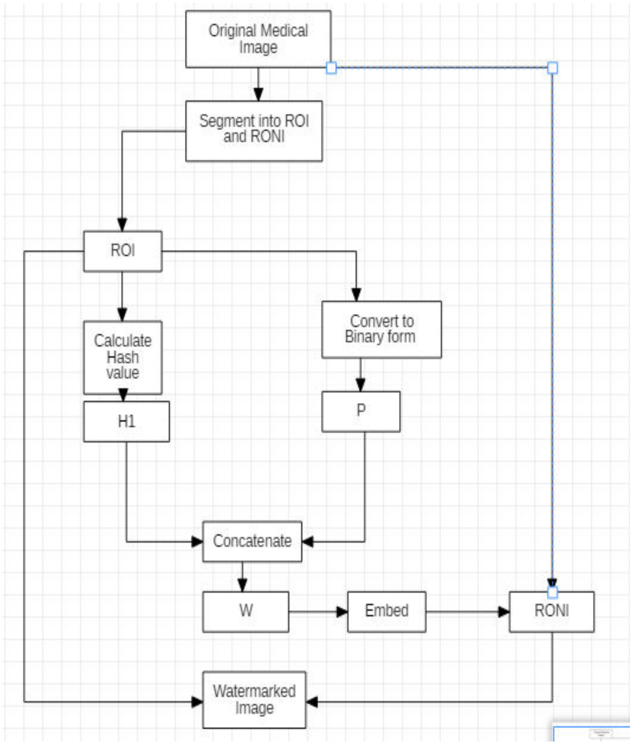


Fig 1: Block diagram of embedding algorithm

3.4 Extracting the embedded data from RONI

At receiver's end, the following procedure is used to extract the watermark data from RONI

Divide RONI into blocks of size 8 × 8 each.

1. For each block B in RONI, repeat the following steps.
2. Apply IWT up to one level on B.
3. Extract 3 bits of the watermark data from the three LSBs in each

coefficient of the middle frequency sub-bands LH, HL of block B.

4. Apply inverse IWT on B.

The block diagram of extraction procedure is shown in Figure 2.

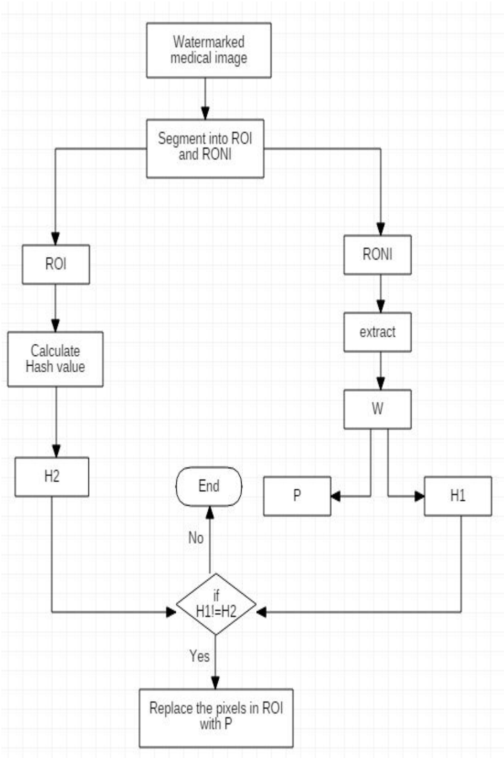
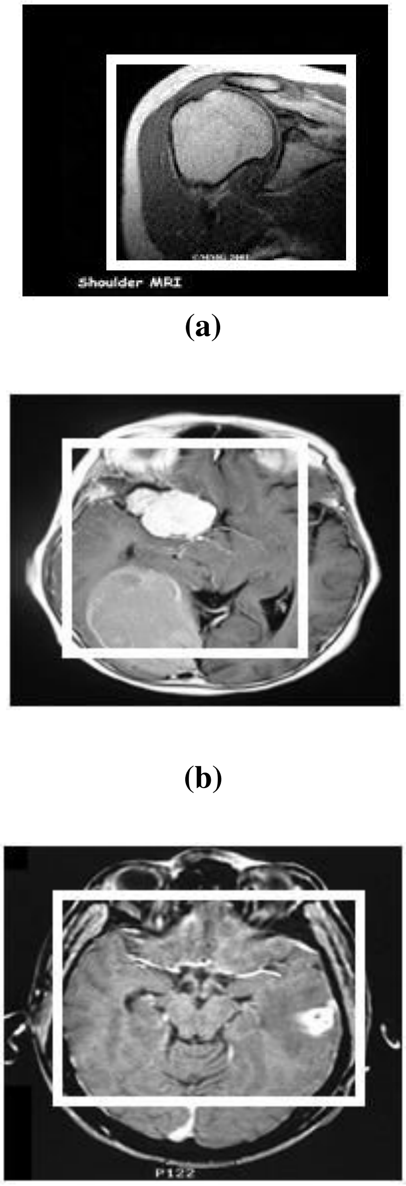


Fig 2: Block diagram of extraction algorithm

4. Results

The measurements utilized in the trials that we directed are: (I) Peak Signal to Noise Ratio (PSNR) and weighted PSNR (WPSNR) [27] for estimating the nature of watermarked restorative pictures, (ii) Mean Structural Similarity Index (MSSIM) [28] to quantify the auxiliary comparability among unique and watermarked medicinal pictures. Analyses have been led on 20 therapeutic pictures of CT examine methodology, 20 medicinal pictures of attractive reverberation imaging (MRI) examine methodology, 20 medicinal pictures of ultrasound methodology and 20 medicinal pictures of PET output methodology. All these pictures are 8 bit restorative pictures. The ROI of these restorative pictures is demonstrated by an encasing block shape as appeared in Fig. 3



(a)

(b)

(c)

Fig 3: Original Medical Images (a) MRI of shoulder (b) CT scan of brain (c) MRI of brain

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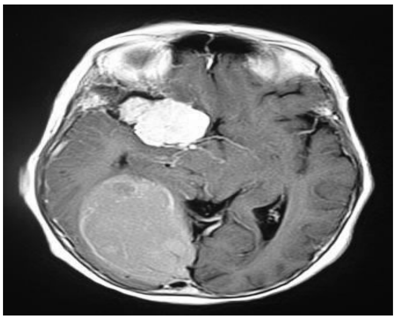
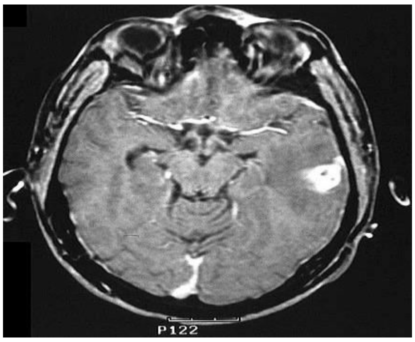
(a)



(b)



(c)

Fig 4: Watermarked medical images (a) MRI of shoulder (b) CT scan of brain (c) MRI of brain

Fig.4 demonstrates the watermarked therapeutic pictures that are gotten by implanting watermark information (hash estimation of ROI and recuperation information of ROI) into RONI of unique restorative pictures. Table 1 depicts the subtleties of unique restorative pictures that are appeared in Fig. 4. It likewise portrays the estimations of PSNR, MSSIM of the watermarked restorative pictures which are appeared in Fig. 4. These measurements are utilized to check the handiness or productivity of the proposed strategy. Table 2 delineates the average estimations of PSNR, MSSIM. These normal qualities are gotten by leading tests on 80 therapeutic pictures of various modalities. A therapeutic picture watermarking method is said to be successful if the estimation of PSNR of watermarked also as reproduced medicinal picture is >40 dB

Modality of image	Size of ROI	Size of recovery data	PSNR	MSSIM
MRI of shoulder	93x108	53 763	43.78	0.9516
CT scan of brain	95x100	67 340	50.35	0.9071
MRI of brain	112x99	59 984	45.87	0.9654

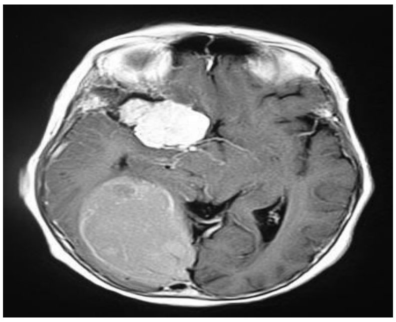
Table 1: Medical images of different modalities and values of metrics

Modality of image	Average PSNR	Average MSSIM
MRI of shoulder	45.5320	0.9898
CT scan of brain	40.0801	0.9812
MRI of brain	42.6723	0.9672

Table 2: Average performance of proposed method

The proposed strategy is compelling as the estimations of PSNR is above 40 dB for every therapeutic picture of various modalities and sizes. Fig. 5 demonstrates the recuperated therapeutic pictures which are acquired by extricating the implanted information from watermarked medicinal pictures (whose ROI isn't altered as well as are not assaulted).

(a)



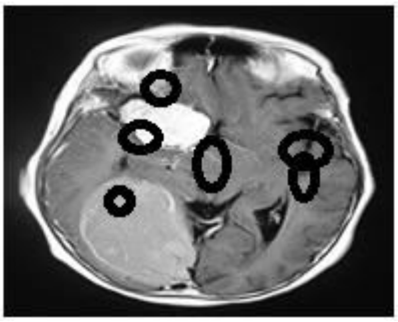
(b)

(c)

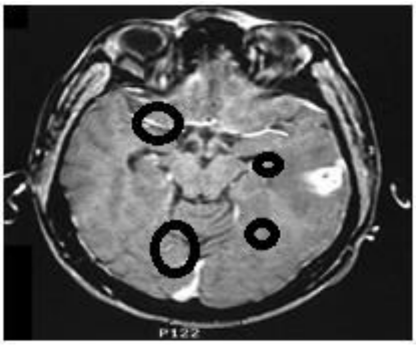
Fig 5: Recovered Medical Images (a) MRI of shoulder (b) CT scan of brain (c) MRI of brain

To check the execution of the proposed strategy as far as exact recognizable proof of altered or changed blocks, estimations of a portion of the pixels inside ROI of watermarked medicinal pictures have been changed. Fig. 6 demonstrates the watermarked medicinal pictures with alters inside ROI. The proposed technique precisely distinguished altered or changed hinders inside ROI. It likewise recuperated the first ROI with no misfortune and the recouped or reproduced therapeutic pictures are appeared in Fig 7.

(a)



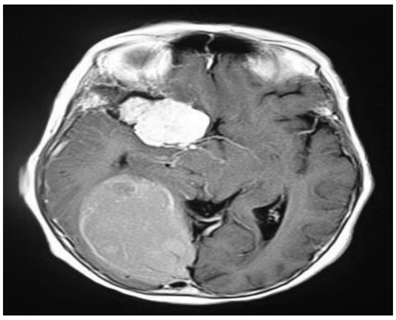
(b)



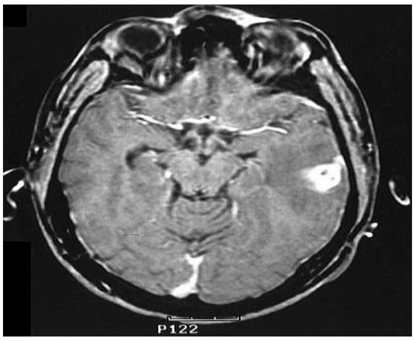
(c)

Fig 6: Medical Images with tampers inside ROI (a) MRI of shoulder (b) CT scan of brain (c) MRI of brain

(a)



(b)



(c)

Fig 7: Reconstructed Medical Images (a) MRI of shoulder (b) CT scan of brain (c) MRI of brain

In the proposed technique, the watermark information (hash estimation of ROI and recuperation information of ROI) is installed into RONI of medicinal picture. A few assaults (Gaussian noise, salt and pepper noise, JPEG compression and low-pass filtering) have been connected on watermarked restorative pictures so as to check the dimension of power the proposed strategy is giving to the information implanted inside RONI. These assaults are accidental assaults that the therapeutic pictures may experience amid their transmission. Normalized Correlation (NC) is used to gauge the closeness between the inserted and separated information. The estimation of NC is determined utilizing

$$\mathrm{NC} = \frac{\sum_{i=1}^{n} w(i) \times w'(i)}{\sqrt{\sum_{i=1}^{n} w^2(i)}\ \sqrt{\sum_{i=1}^{n} w'^2(i)}} \qquad (1)$$

where n is the extent of the information, w shows the bits in inserted information also, w′ shows the bits in extricated information. Estimation of NC is between 0 also, 1. Esteem 1 of NC shows that the extricated information matches with the implanted information. In the event that the watermarked restorative picture is attacked during its transmission, at that point the hash estimation of ROI that is removed from RONI does not matches with recalculated hash estimation of ROI in the got watermarked medicinal picture. Along these lines the collector replaces the pixels in ROI of assaulted picture with the ROI recuperation information that are separated from RONI. In this case, the first ROI may not be recouped precisely. Table 3 delineates the estimation of NC between the installed and removed ROI recuperation information when different kinds of assaults have been connected on the watermarked medicinal pictures that are appeared in Fig. 4.

Modality of watermarked image	Type of attack	Value of NC
MRI of shoulder	No attack	1
	Gaussian noise (variance =0.0001)	0.9538
	Salt and pepper noise(density=0.005)	0.9642

	JPEG compression (compression ratio=90%)	0.9638
	Low-pass filtering	0.9451
CT scan	No attack	1
	Gaussian noise (variance = 0.001)	0.9457
	Salt and pepper noise (density =0.005)	0.9813
	JPEG compression (compression ratio = 90%)	0.9507
	low-pass filtering	0.9521
MRI of brain	no attack	1
	Gaussian noise (variance = 0.001)	0.9380
	salt and pepper noise (density =0.005)	0.9365
	JPEG compression (compression ratio = 90%)	0.9712
	low-pass filtering	0.9630

Table 3: Results of applying various types of attacks on the watermarked medical images of different modalities

It is clear from Table 3 that the proposed technique remakes an estimated ROI (extremely near unique ROI) when the watermarked therapeutic picture experiences unexpected assaults amid their transmission.

Table 4 demonstrates correlation between the proposed strategy and best in class strategies. This correlation demonstrates the additional highlights given by the proposed technique or the benefits of the proposed technique when contrasted and the recently created techniques.

5. Conclusion

In this paper, we proposed a novel restorative picture watermarking system for distinguishing the alters inside ROI of therapeutic pictures and recovering ROI. The proposed strategy precisely recognizes the alters inside ROI and recuperates the first ROI when it is altered. It gives heartiness to the watermark information which are implanted inside RONI. It very well may be utilized with medical pictures of various modalities and sizes. Future improvement gives an extent of broadening the strategy so it very well may be utilized with the restorative pictures whose ROI estimate is vast.

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