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Medical Image Watermarking techniques – A Comparison

[1] Dr. Prasad M R, [2] Dr. Kavitha K J , [3]Mr. Suprith P G, [4]Mr. Hanumanthraju R K, [5]Mr. Ravirayappa

[1]Associate Professor, Department of CSE, Vidyavardhaka College of Engineering,Mysuru
[2]Associate Professor, ECE Department, GM Institute of Technology, Davangere
[3]Assistant Professor, ECE Department, GM Institute of Technology, Davangere
[4]Assistant Professor, ECE Department, GM Institute of Technology, Davangere
[5]Assistant Professor, Jain Institute of Technology, ECE Department, Davangere

Email: kavithakj219@gmail.com

ABSTRACT: Advancement in the field of internet or communication technology has provided new ways to store, access and distribute data in digital format. But these advancements have also introduced new challenges to protect information circulating over networks. One of them is to avoid the risks for inappropriate use of medical information circulating over networks. Even though most of the medical providers are honest there are few who illegally increase the size of their bank accounts through fraudulent claims. On medical basis has been reported worldwide, presenting the agencies with fake data of medical reports. Fraudulent claim includes; Medical identity theft, Billing for services not rendered, up coding of services, up coding of items, unbundling or unnecessary services, kickbacks, beneficiary fraud and duplicate claims. Therefore there is a need of "A systematic development of multiple watermarking schemes and their complete assessment through defining the parameter property such that they can offer a better complementary solution for achieving improved security". In the present work, a hybrid watermarking system is proposed so as to provide authorization, authenticity, availability, confidentiality, data integrity, reliability, and reversibility of the patient's information in the healthcare systems.

Keywords: Watermarking, Medical identity, Authorization, Confidentiality

1. Introduction

The information technology has developed to the great extent such that every human task has become digitized all over the world. Even common persons are very familiar and fond of using the benefits of this digital technology. India, a country of villages is not behind from this advanced technology. Among various applications, Health care system plays an important role in human life and the system has developed such that it provides the provision of online transfer of Electronic Health Records (EHR) (Ales et al 2016), and it includes the collection of Patient's and related electronically stored health information such as demographics, therapeutic history, prescription and allergies, immunization status, laboratory examination results, radiology/scanned images, crucial signs, personal statistics like age and weight, and billing information.

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As EHR is electronically transmitted over insecure network, the crucial content of the document may be accessed by unauthorized persons and may use it for making illegal money or harm someone. The information may also undergo modification either intentionally or by chance. In either case, the patient's life will be in risk (Coatrieux et al 2006).

To avoid unauthorized access and modification, researchers have developed Digital Watermarking (DWM) techniques (Venkatram et al 2014). Basically DWM is defined as "The process of embedding information in to the digital multimedia content" (Vivek and Rajib 2015) and this technique can be used for ensuring authenticity, integrity and confidentiality (Baisa and Suresh 2012; Ritu and Manisha 2016).

DWM techniques provide the proofs of illegal access, tampering, and copyright etc. but not able to avoid the fraud to make use of stolen data. So, until the DWM techniques become robust enough to stop the removal of embedded information, the research continues in this field and till then encoding & encryption techniques combined with DWM may be considered as the optimum method to protect the crucial data. Hence, in this work, hybrid DWM technique is proposed to satisfy all the constraints to meet the desired goals (Mary et al 2016).

Main Issues In Medical Image Watermarking (MIW):

Here we can consider some of the main issues before the implementation of the watermarking technique for medical images (MI):

Issue1: Whether the watermarking technique to be chosen is for complete authentication or content authentication.

Complete authentication refers to the techniques which involves the authentication of the whole image which does not permit the manipulation or modification whereas the content authentication refers to the techniques which involves the authentication of certain content of the information which allows the modifications in the other regions of the multimedia data.

Issue2: Whether the watermarks embedded in the medical images are reversible or non-reversible. In some of the cases, the watermark used is patient detail; in such cases the watermark should be reversible.

Issue3: More number of bits in the watermark information results in the degradation of the MI. The solution should be found to reduce the data payload.

Issue4: The protection of watermark information from unauthorized third parties in case of reversible watermarks. The combination of encoding and encryption is the possible solution to avoid the access of original information.

In the proposed system, all the above issues are considered and thereby to overcome these limitations, the reversible content authenticated watermarking technique is implemented in which encoded-encrypted Quick Response (QR) code watermark is

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embedded in the medical images; as we are aware that the modification in the region of interest in the case of medical images is not desirable as it may lead to failure of diagnosis & thus content based WM is adopted i.e.in this work, only region of non interest (RONI) is subjected to the embedding process; and also the medical images has to be reconstructed even after the extraction of watermark information from the image, thus reversible; the data payload is reduced using QR code; and the security level is upgraded using prime number based encoding and encryption algorithms.

2. Literature Survey

Most of the developed countries have adopted the use of EHR, which indeed helps in quick analysis of patient health within no time, and thereby improving healthcare systems. The Indian government intended to introduce the maintenance of EHR in the country and the respective guidelines for the same is set, validated by NHP CC DC & released by the committee in the year 2014 [101].

In the work of Loan et al (2018), a chaotic encryption-based blind DWM using DCT is proposed for both gray scale and colour images. The CI is partitioned into 8×8 non overlapping blocks prior applying DCT and WM bit is entrenched by modifying DCT coefficients difference of adjoining blocks. In order to provide the two-layer security Arnold transform is jointly used with chaotic encryption of the watermark. But many of the work has proved that the use of chaotic encryption is unsecure and its behaviour is predictable (Akhavan et al 2015) and already as mentioned above, the Arnold transform results in the loss of time.

In the work of Ali et al (2017), crypto based watermarking is proposed for the medical images using DWT-SVD and the system performance is evaluated for different cover images in terms of imperceptibility, strength, payload, and tampering. The authenticity is verified by embedding watermarks in RONI region of the medical image using SVD &DWT. Integrity is validated in two levels: the first one is strict integrity validation, is done in terms of a cryptographic SHA-256 hash watermark, and the second is, content-based integrity validation & is evaluated with a symmetric encryption scheme. Confidentiality is verified by hiding patient's information EPR in the cover image. The maximum PSNR obtained from the proposed algorithm is less than 40dB for all types of medical images. This watermarking algorithm is not capable of handling multi-slice and multi-frame medical images. Some of the research work in the same field is shown in table1.

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Table 1: Contribution of Researchers in MIW field

S.No	Authors & Year	Contribution	Embedded region	Remarks
1	Arjit et al., 2013	Odd-Even embedding algorithm and Differential Expansion Reversible	Whole image	PSNR=55 dB Limiting data payload Suitable for non-reversible schemes and specific images (smooth)
2	Umamageshwari and Suresh., 2014	SHA-1 Advanced Classical cipher DWT JPEG2000	Whole image	Cryptographic security reduces Lossy algorithm Suitable for plain text
3	Adiwijaya et al., 2013	Modified LSB Huffman coding Average intensity of each block of ROI & LSB of-as a watermark	ROI & RONI	ROI region is distorted Less susceptible to manipulation attacks Related watermark information is not considered PSNR=47 to 48 dB
4	Bilal et al., 2019	FCT,SVD, Arnold Transform Machine learning	Whole image (Only Retinal Scan)	PSNR=65dB Time consumption Moderate robustness against attacks
5	Abdallah et al., 2018	Number Theoretic Transform (NTT) Diffie- Hellman	Whole image	Vulnerable Lack of authentication DS cannot be used with Diffie-Hellman Used only for symmetric key

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6	Pooja et al., 2018	DWT DCT Elliptical Curve Diffie Helman(ECDH)	Whole image	Vulnerable to attacks Loss of information Quality-metrics-not evaluated Low datapayload
7	Bin et al., 2019	Reversible data hiding (RDH) CDM IWT Machine learning algorithms	ROI	Optimum PSNR Improved robustness Sobel operator used for segmentation
8	Dayanand G. Savakar *et al* ,2019	DWT+SVD Blind & Non-blind both	Whole Image	Optimum PSNR, SSIM. Embedding capacity is the constraint.
9	Abdulrahman et al. 2019	DCT+DWT	Whole Image	Better transparency with PSNR > 35dB for scaling factor 40.
10	H V Singh and A Rai , 2019	SVD+DWT Blind	RONI	ROI is preserved but Embedding capacity is the constraint.

To overcome the limitations of this technique, the positives of encryption can be combined with efficient DWM and encoding techniques to improve the required salient features of medical images and to safeguard EHR (Mary et al 2016).

3. Watermarking Techniques

A. DWM For MI Using DWT-SVD

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In this work, a watermarking system is implemented using the joint combination of spatial & frequency domain methods; SVD and DWT and the proposed block diagram for the system is shown in figure 1.

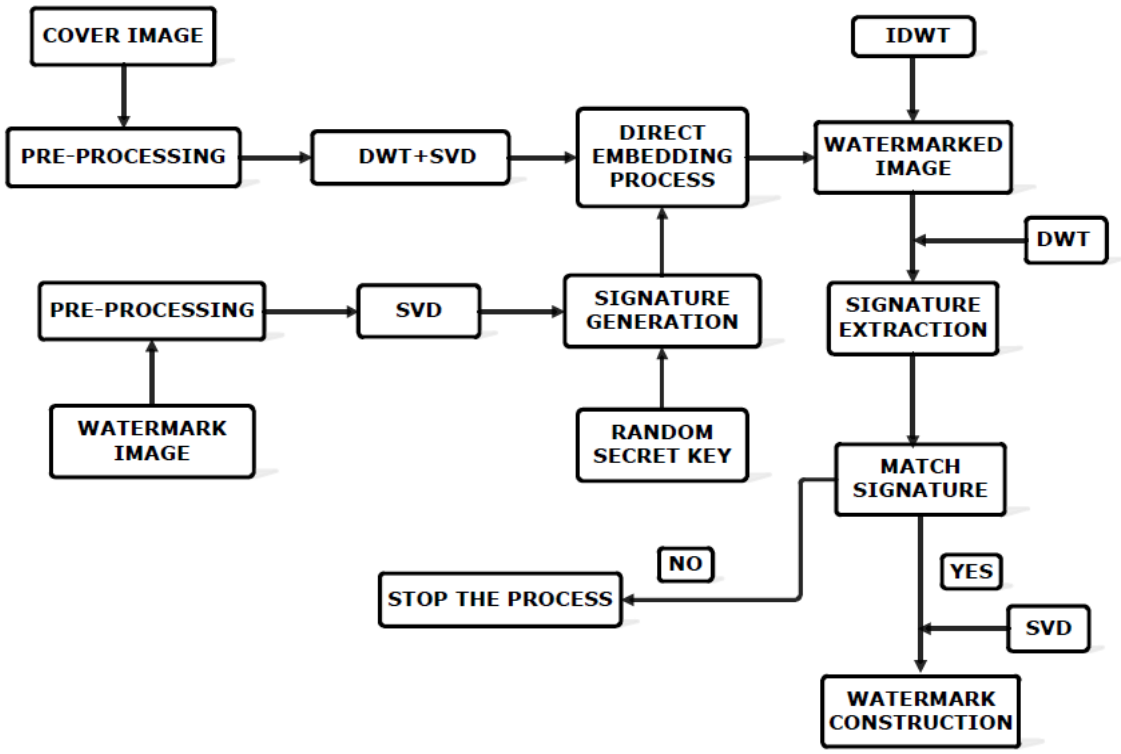

Figure1: MIW using DWT-SVD

In this work, 512-bit signature is generated using 'u', 'v' components of WM along with random key and is embedded in LL-band of MI using direct embedding method. This work employs blind and joint watermarking system. The system is authenticated for random key but is not secure enough to avoid the removal of the WM and also, the PSNR obtained is very less whereas the MSE is very large, which indicates larger degradation of the image and also achieves moderate tampering detection rate.

3.1.1.

Results & Discussion

This work is simulated using MATLAB-2015a, the figure 2 shows the results of embedding and extraction process and the performance of a technique is assessed using various metrics like The Peak to signal noise quantitative relation (PSNR), Mean Square Error (MSE), Mean of correct and wrong secret writing, false acceptance and false rejection ratio (FAR & FRR) as shown in table 1 & 2. The technique is tested for Ultra-Sound MI for its integrity & robustness and the patient information is taken as watermark and its size is 42.3KB.

CI	WM	WATERMARKED IMAGE	EXTRACTED WM

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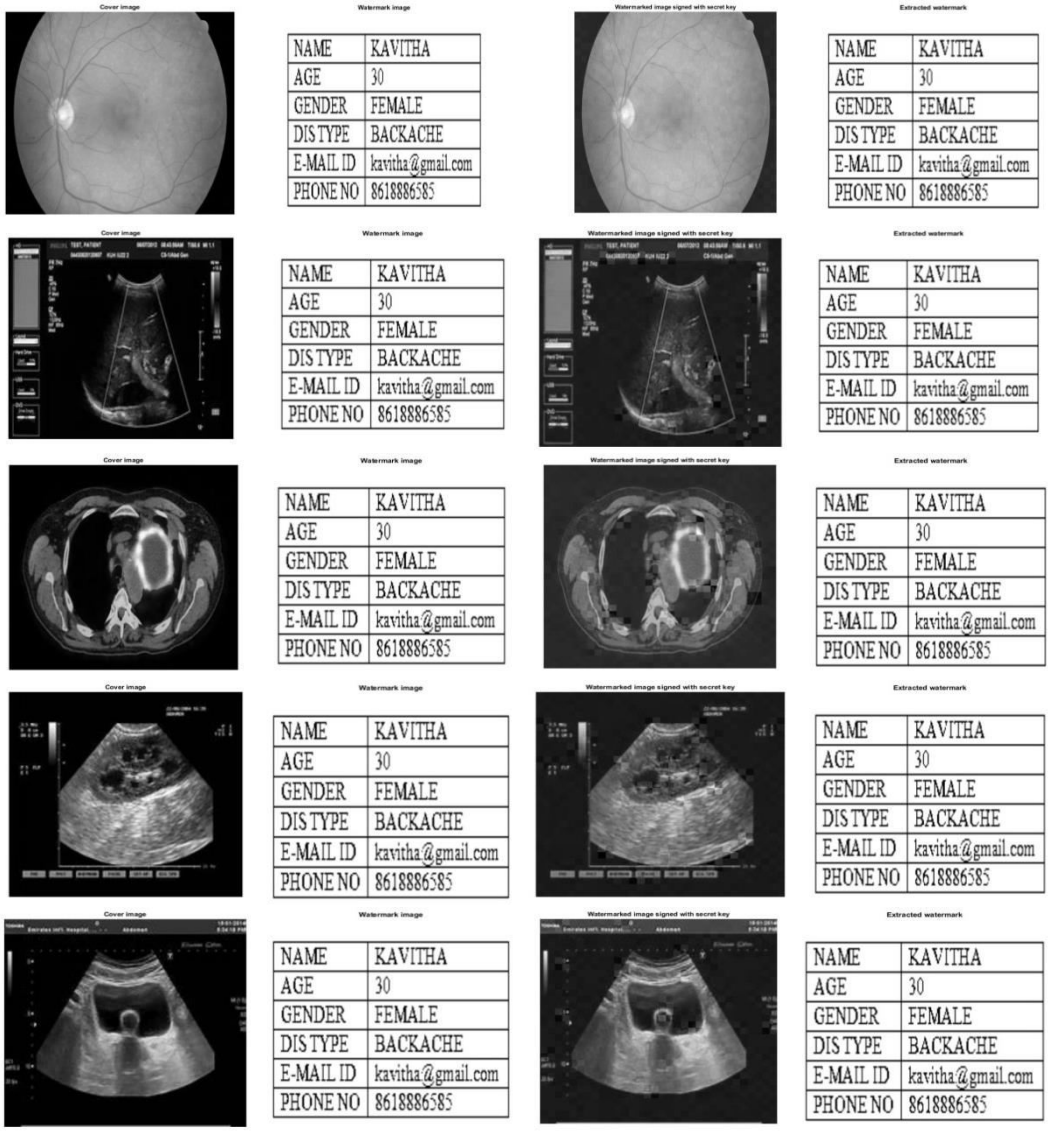

Figure 2: Results of DWT-SVD DWM embedding and extraction process

Table1: DWT-SVD performance evaluation-PSNR, SSIM, MSE

MI	KEYS										SSIM	MSE
	1	2	3	4	5	6	7	8	9	10		
	PSNR											
IMG1	38.2	38.	38.	38.	38.	38.	38.	38.	38.	38.	0.786	1.38

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		7	5	3	3	7	5	3	4	6	3	
IMG2	33.1	33.1	33.2	33.2	33.2	33.1	33.2	33.1	33.2	33.2	0.5791	1.55
IMG3	28.2	28.2	28.2	28.2	28.2	28.2	28.3	28.2	28.3	28.3	0.5279	1.89
IMG4	29.8	29.8	29.8	29.7	29.7	29.8	29.8	29.7	29.8	29.8	0.5013	1.998
IMG5	32.5	32.2	32.4	32.4	32.2	32.3	32.4	32.2	32.5	32.2	0.5464	1.6564

Table2: DWT-SVD performance evaluation-FAR, FRR, Time taken

MI	FAR	FRR	TIME TAKEN IN SECONDS
IMG1	0.41	0.59	106.233220
IMG2	0.37	0.63	130.096546
IMG3	0.35	0.65	78.310201
IMG4	0.34	0.66	122.486537
IMG5	0.27	0.73	118.515078

In this DWM technique, the patient's information in the original format is directly embedded in mid n^{th} bit of LL band of CI and as a result, we can observe the results shown in the table 3.1 results in poor PSNR which shows high degradation of MI which is not desirable for diagnosis; The structural similarity between the two images is also low and the difference between the original CI and the watermarked image is very high which shows a higher degradation of MI. Although SVD is used for the reconstruction of images, the use of DWT results in the fractional value loss and high data payload which in turn guarantees the loss of critical information. To overcome these limitations, DWT is substituted by IWT; arithmetic coding & QR code is used for reducing the number of bits to be embedded in the next paper.

B. DWM for MI using IWT & QR code

In this work, DWM for MI is implemented to reduce the degradation, to evaluate its authenticity & integrity. Although SVD is used to avoid localization in the previous work, the use of DWT results in the fractional loss and thereby to overcome this limitation, DWT is substituted by its family IWT and to reduce number of bits to be embedded, arithmetic coding and QR code is used and also bit plane is used for embedding purpose. The embedding block diagram for the same is shown in figure 3:

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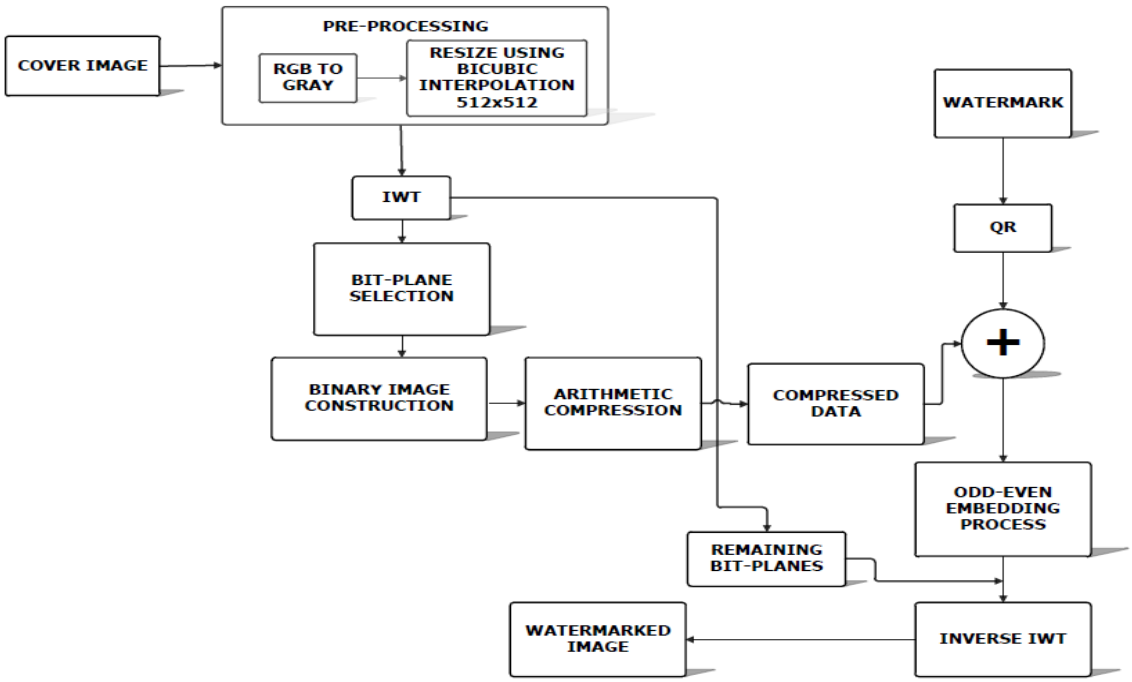


Figure3: MIW using IWT-QR code

In this work, DWM is implemented by using IWT; this work involves pre-processing such as specifying bit plane number in which the WM will be embedded. CH, CV & CD components of CI is used for embedding purpose and these bit-planes are compressed using arithmetic coding to provide space for embedding WM and also related headers are generated to reflect the original bit distribution in the chosen plane and the patient's information WM is encoded into QR code and converted to binary and the compressed data, header and binary WM is embedded into the bit-plane 6 & 7 (LSB bit 1 & 2) using odd-even embedding algorithm.

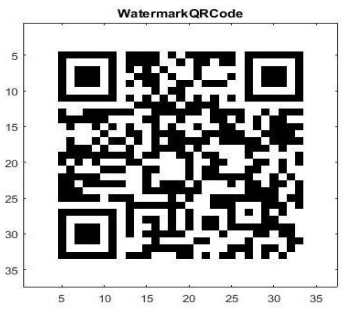
Results & Discussion

This work is simulated using MATLAB-2015a and the algorithm is evaluated in terms of bpp, PSNR, SSIM and MSE. The figure 4 shows the patient detail and its QR code and the results of embedding process are shown in figure 5:

Watermark image

NAME	KAVITHA
AGE	30
GENDER	FEMALE
DIS TYPE	BACKACHE
E-MAIL ID	kavitha@gmail.com
PHONE NO	8618886585

a)



b)

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Figure 4: a) Patient detail b) Patient detail QR-code

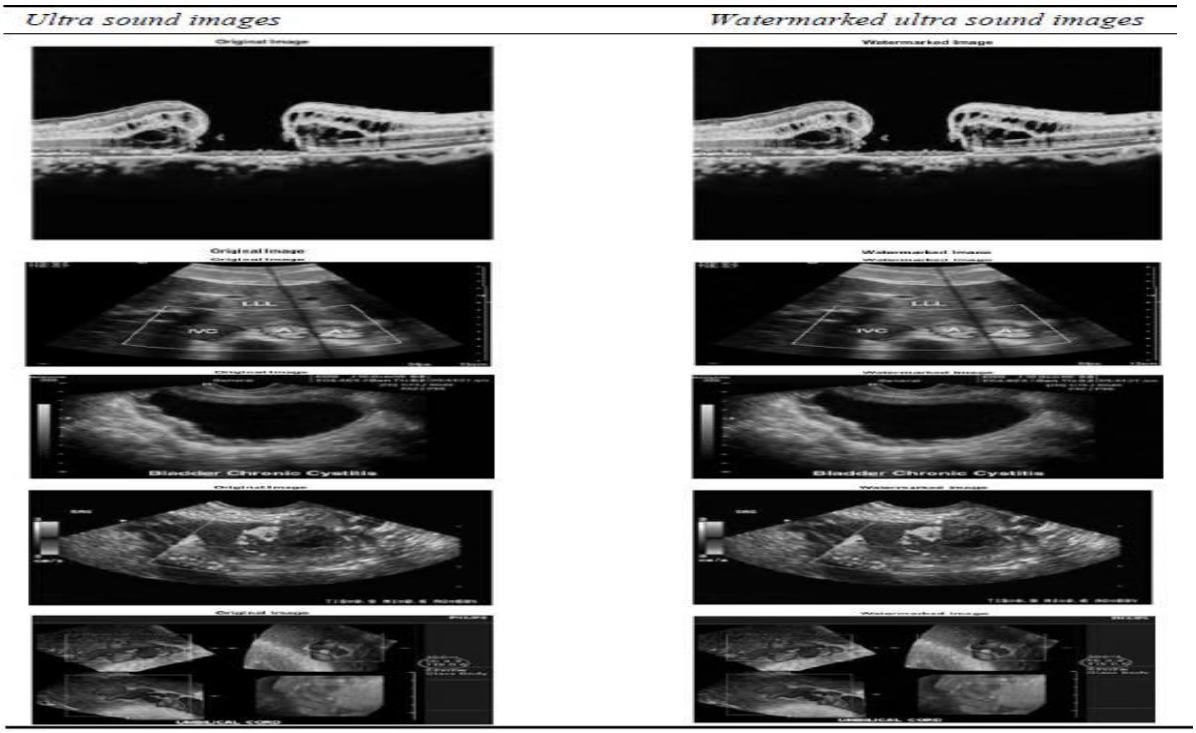

Figure5: Results of TWT-QR DWM Embedding

Table3: BIT-PLANE DWM performance evaluation

MI	BIT-PLANE	PAYLOAD	EMBEDDED BITS	WM LENGTH (bits)	PSNR	SSIM	MSE
IMG1	6	0.001892	95193	39	48.45	0.52	0.935
	7		154195		51.54	0.533	0.68
IMG2	6	0.001892	112474	39	47.52	0.7565	1.084
	7		182928		49.65	0.78	0.70
IMG3	6	0.001892	129935	39	47.17	0.7464	1.13
	7		183496		49.58	0.77	0.72
IMG4	6	0.001892	91185	39	48.38	0.5256	0.95
	7		153677		51.63	0.5484	0.67
IMG5	6	0.001892	93579	39	48.27	0.671	0.9746
	7		172871		49.67	0.693	0.7023

As we can observe in the table 3, the use of arithmetic coding results in good compression ratio and less memory space but at the same time it results in slower compression & decompression speed. The data payload is reduced due to the use of QR-code, as a result it yields less degraded images but at the same, it is observed that, this method results in moderate PSNR for data-payload less than 90000 bits whereas the PSNR starts

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decreasing with the payload greater than 90000 bits and moreover it is non-resistant against various geometric attacks.

C: Hybrid DWM for MI

Considering the limitations of the above techniques and also other traditional methods, we may observe that; The DWM is implemented in two ways: spatial and transform domain; the transform domain is more robust compared to spatial domain but does not provide complete contribution towards the security of the information. The DWM technique does not avoid the fraud cases but however it can help in preventing and reducing illegal use of the data. So, until the DWM system becomes robust enough to prevent the removal of watermark content from it, the research in this field continues. Till the watermarking technique becomes robust, encoding combined with encryption and DWM technique can be considered as one of the best solution for protecting the information.

So, here a hybrid DWM based on IWT, SVD transforms, new prime based encoding technique and encryption for WM is proposed for maintaining integrity, robustness, authentication and confidentiality of MI. In this work, the algorithm is also extended to 3-D MI & 2-D MV. The block diagrams of the proposed system are shown in figures 6, 7 & 8.

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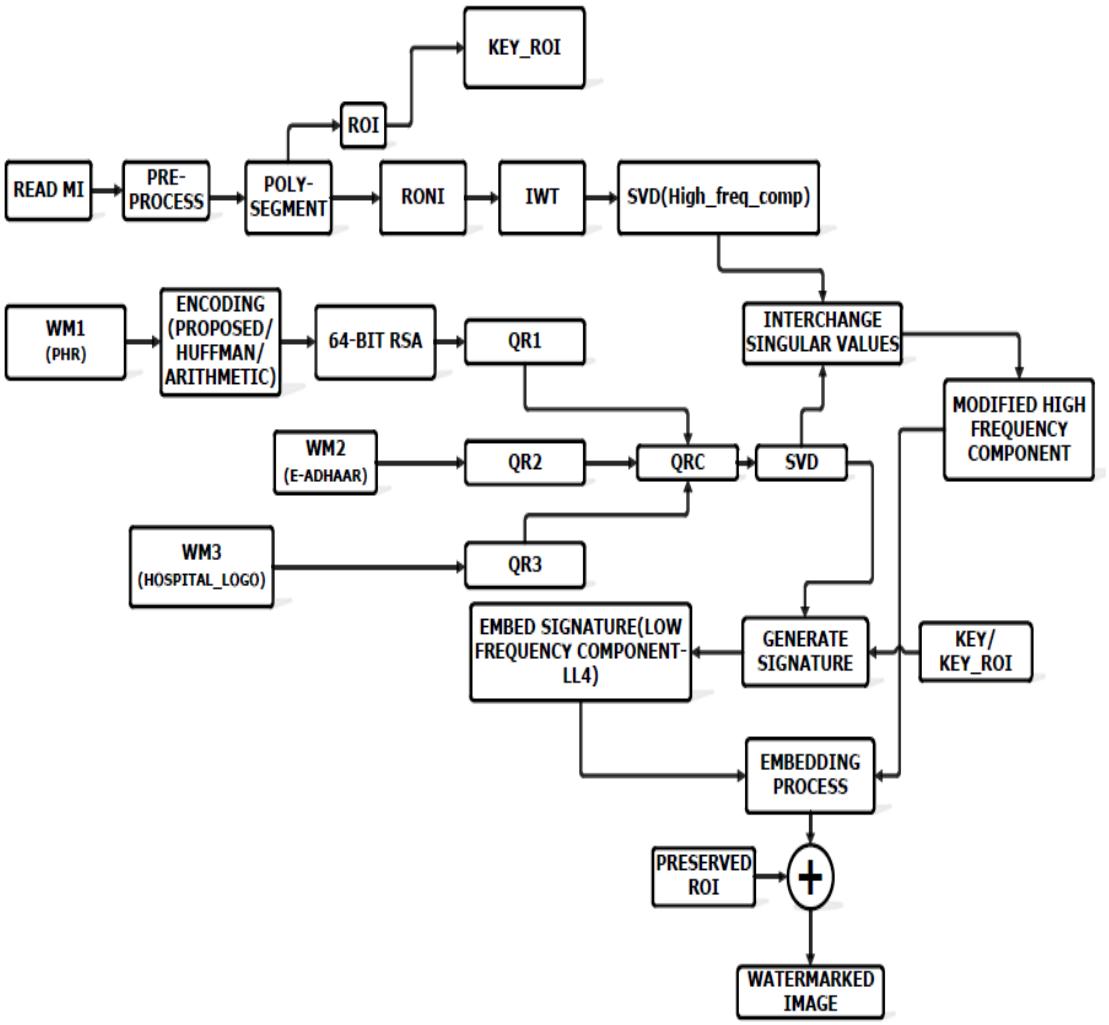

Figure 6: Proposed Block Diagram of WM Embedding Process

This work includes IWT, SVD, Segmentation, use of multiple WMs, digital signature, localisation, encryption; proposed prime based encoding algorithm, QR-code and hybrid embedding process. Initially the MI is resized using bi-cubic interpolation, and subjected to poly-segmentation technique. The key information is obtained from ROI part of MI to ensure no tampering at the other end. The following procedure shows ROI key generation:

$key1 = (k \times ll4) + (q \times hl4) = sum(1d(key1_{array})$

The LL of RONI is decomposed to 4th level using IWT as embedding in this region ensures higher robustness as most of the energy is concentrated in this location. The multiple WMs used in the work increases the security level. The first WM patient detail is applied with encoding and 64-bit RSA encryption and encoded to QR code whereas the other two WMs patient's E-Aadhar and hospital logo are directly encoded into QR-code; followed by the concatenation of three QR-codes and applied with SVD transform.

The proposed prime based encoding algorithm is defined as:

$$\boldsymbol{for\ i = 1\ to\ M/2}$$

$$\boldsymbol{e(i) = (p(i) + p(N) + K(i)) \oplus key}$$

$$\boldsymbol{e(N) = (p(i) + p(N) + K(N)) \ominus key}$$

$$\boldsymbol{N = N - 1}$$

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512-bit signature is generated using 'u', 'v' components of WM and ROI key and embedded in to LL part of RONI followed by IIWT to get watermarked image.

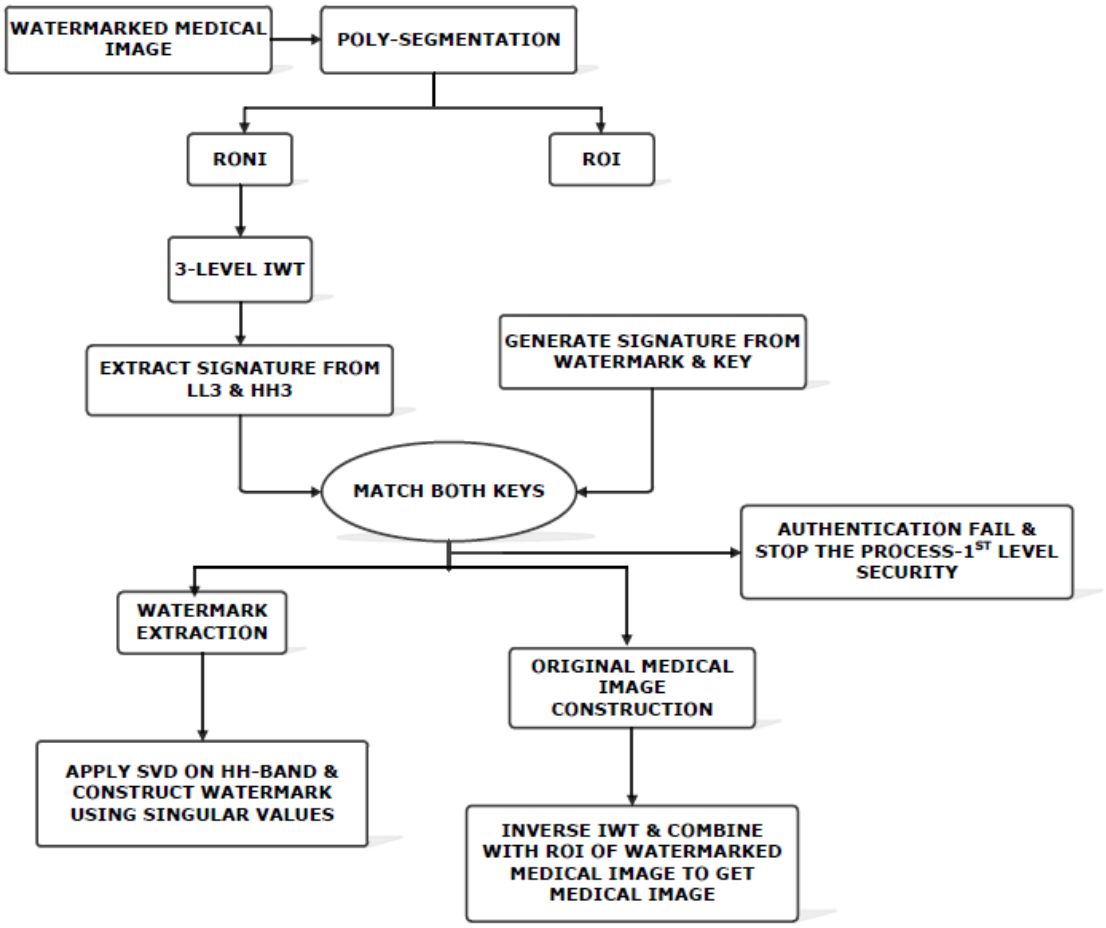

Figure 7: Block Diagram of Proposed WM Extraction Process

At the recipient side, the signature is extracted from RONI region and if it matches it indicates no change in ROI and RONI part of MI.

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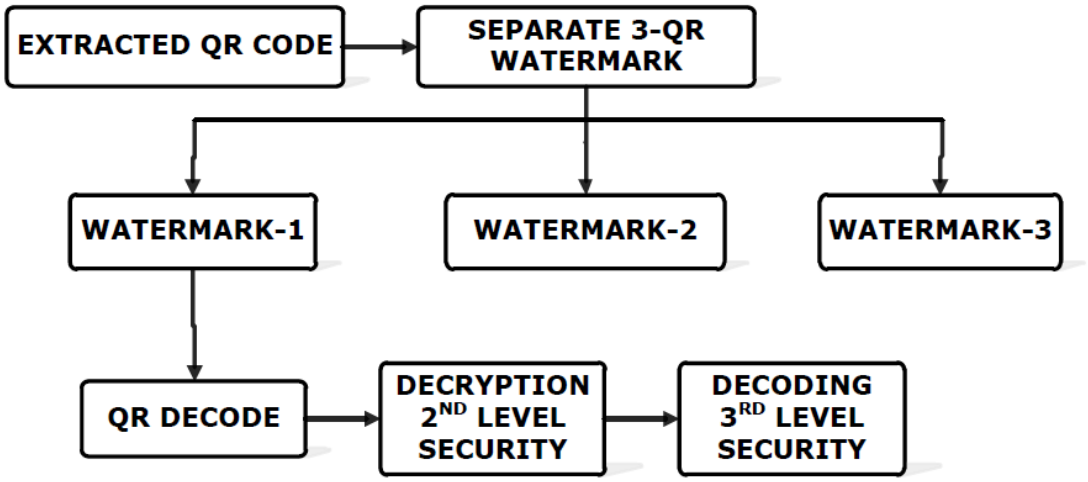

Figure 8: Block Diagram of Generating the Original Patient Information

The extracted QR-code is decatenated, followed by the QR-dcode, decryption and decoding to get reconstructed WM.

Results & Discussion

The proposed algorithm is simulated using Mat lab 2015a. In this work, a combination of SVD and frequency domain technique IWT together with encoding, encryption and QR code is proposed. The main advantage of SVD is, the singular value of image provides the specifications about the geometry of image such as; left and right singular vectors represents horizontal and vertical details of image whereas the singular values specifies the luminance of the image and small variations to such vectors will not affect the image quality (Musrrat et al 2016).

On the other hand IWT is used for lossless data compression and also computation speed of IWT is much higher than that of DWT as it does not involve the fractional part. IWT is implemented using the lifting scheme method which consists of 3 steps; split, predict and update. Another main advantage of using IWT is that it is reversible in nature i.e. the image can be reconstructed without any loss (Balamurugan et al 2014) as its coefficients are stored without rounding off errors.

Moreover combined use of encoding and encryption doubles the security of the information and QR code can ensemble a bigger data. The US medical images used in the simulation process are collected from the online data base (Website is mentioned at the last) and some of MRI images are collected from SS health care centre, Davangere.

Interpretation Of Results

In this work, DWM is implemented for MI & MV based on the hybrid combination of encoding, encryption and transform domain techniques. Here, three encoding algorithms are used for transforming one form of code to another and at the same to reduce number of bits to be embedded. The proposed encoding algorithm is compared with existing Huffman and

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Arithmetic coding techniques. In the case of either Huffman or Arithmetic coding, the main limitation is; both the techniques require the prior probability knowledge of symbols; the coding efficiency of Huffman coding is less than one which is overcome with the introduction of Arithmetic coding whose efficiency is closer to one , but at the same time its performance is limited by the Shannon's noiseless coding theorem; bounds as every message ends with a special end symbol which adds overhead in coding and also its performance is limited by finite arithmetic precision. The proposed encoding algorithm based on the generation of large prime numbers doesn't require the prior knowledge of probability of occurrence of symbols and the implementation of this requires simple adder, multiplier and a modulo2 adder/subtractor. Also it can be seen that the number of bits encoded into QR code is reduced compared to other two techniques.

Also in this technique hybrid WM technique is used where it comprises addition, multiplicative, interchanging embedding methods and localization of values methods are adopted so as to reduce the image degradation. The reversible DWM techniques are developed so as to ensure correct recovery of CI and thereby authenticating it.

4. Conclusion

The proposed work is simulated using Matlab-2017a and is implemented using SVD, frequency domain technique IWT, encoding, encryption, digital signature and QR code. The main objective of this work is to protect patient's MHR and scanned images from the third party access which may be achieved by increasing number of security layers. Also the work is extended to medical videos and more appropriate method has to be found to reconstruct the PHR from the extracted QR code.

In the proposed system 3-level security is provided in terms of proposed encoding-encryption technique with reduced data payload in terms of QR code and digital signature.

The work implemented in this work covers the following objectives:

- To make a detail study on types of health care fraud and its prevention systems.
- To analyze the need and various algorithm for watermarking in Medical Imaging domain.
- Need for Encoding & Encryption algorithms along with watermarking in Medical Imaging domain.
- To develop a reversible visible & invisible watermarking algorithms for MI with reduced payload , and provide security to the patient's PHR and analyze performance and resistance of algorithm to various possible attacks.
- Comparison of the proposed work with other traditional medical image watermarking techniques.
- To extend the proposed watermarking algorithm to 3D medical images and medical videos.

Limitation:

In this work, Data payload in terms of QR code is limited in terms of kilobytes. If more data is encoded in QR code, then at the receiver side the data cannot be extracted from it which leads to the failure of data validation. Care should be taken to see that an optimum data is encoded into the QR code so that the information can be retrieved at the recipient side

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followed by decryption and decoding. The algorithm is also extended to 2D MVs but it results in less quality video and more appropriate method has to be found in future.

In the proposed work, a simple poly segmentation technique is adopted for separating ROI and RONI regions. Instead, the appropriate automatic segmentation technique may be adopted with the help of Artificial Neural Network (ANN) technology which may enhance reliability of the system and the method for evaluating the efficiency, length of the encoded word of the proposed encoding algorithm needs to be developed in the future work.

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