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Enhancing Privacy of information with Data Embedding in Medical MRI Images Based on Segmentation and HVS Model

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Abstract

The development of communications technology and the arrival of Medicine modern equipment in the health domain has caused the diagnosis and treatment methods to be considered from a distance and medical centers are equipped with telemedicine systems. Forensic medicine organizations with daily clients and outpatient examinations such as accident clients, Conflict returns as well as spousal abuse. Doctors and employees of the organization also serve as one of the powerful arms of the judiciary, following up on important cases in the medical, laboratory, and psychiatric commissions So that they can take steps to realize the rights of the people. Patient data security has become a serious concern for professionals and one of the methods is using data embedding to the protection against these risks. In this method, medical informatics, telemedicine, and forensic medicine organizations has played a pivotal role and any mistake in the reporting can be catastrophic. The main purpose of this research is to present data on EPRs with Enhancing data embedding Based on SSIM and HVS with the help of medical image segmentation and focus on brain MRI images. In this study, innovations include the addition of the HVS block based on the SSIM criterion to meet transparency and robustness conditions. Selection of the embedding coefficient K is considered adaptively depending on the degree of uniformity of the N - ROI region with the image quality factor. The coordinates of ROI areas in one of the DCT and DWT conversion blocks have been demonstrated to have better performance at Concealment EPRs. The choice of coefficients αf, k which consists of the optimization frequency sensitivity function and spatial property is comparatively done to match the visual perception of the visual system. The present study aims to improve the effectiveness of the proposed method, improve the security level, and the confidentiality of patient information, and integrate the storage of patient information and image. The simulation results of the proposed method, considering the parameters of embedding and transparency in comparison with other methods, have been done using evaluation criteria including MSE PSNR, NC, SSIM, and BER.

Keywords: Data security, Data Embedding, Electronic Patient Record, SSIM, Human Visual System model

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1. INTRODUCTION

Nowadays, with the advancement of information technology in medical sciences and computer networks, the image communication system has created the possibility of transmission, storage, retrieval, and display of medical images at different points. Security is one of the most important issues in the field of information and communication technology in medical informatics, which in recent years due to the growing use of the World Wide Web, has plagued users and caused the failure of medical databases [1].

Medical imaging technology services have undergone a complete revolution in recent years and the use of medical imaging systems, radiobiological imaging, and transfer from one place to another has led to practical and targeted development. Healthcare systems make significant use of medical image processing to improve service quality. The application and importance of digital medical imaging systems in equipment such as teleradiology, orthopedic teleology, and oncology systems, in improving patient outcomes, has provided new solutions so that medical professionals can be in the process of improving patients. Also, digital medical imaging and access to the latest technologies and services of patient imaging, have provided a new opportunity for the development of medical and health departments. Embedding the medical image in the field of empowering physicians in accessing and securing the transfer of patients' electronic records plays an important role in improving the performance of medical systems [2, 3].

Forensic medicine is one of the main and most important branches of modern forensic science, the main purpose of which in most countries is to determine the cause of death of people who have lost their lives for various reasons. Forensic pathologists have a set of tools, equipment, and techniques to determine the cause of death, the most common of which is an autopsy. Advances in technology and knowledge around the world have been instrumental in increasing the accuracy of forensic pathologists' diagnoses [4]. Forensic medicine organizations face clients and outpatient examinations every day, such as accident clients, conflict clients, and spouse abuse. As one of the powerful arms of the judiciary, doctors and employees of the organization follow important cases in the medical, laboratory, and psychiatric commissions so that they can take steps to realize the rights of the people [4]. If in hospitals it is a matter of preserving life and survival, in specialized centers of autopsy and autopsy halls it is a matter of reviving the truth, Doctors, and technicians working in the autopsy room work to restore the right to work, because corpses now have no eloquent language, and it is the doctors and forensic staff who can revive the right and soothe the heart [5].

Forensic examinations include a review of the victim's medical history, external examinations, body scans, internal examinations, and autopsies to determine the cause of death in full detail. During these examinations, the physician and forensic

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pathologist will need the cooperation of specialists such as toxicologists, set histopathologists, microbiologists, as well as geneticists. The key theme of the Forensic Medicine Organization is the accreditation, documentation, monitoring, and evaluation of quantitative and qualitative control of medical records data to provide services and improve information retention and confidentiality of information recorded in medical records [5].

In digital medical systems, the distribution and maintenance of medical records is a fundamental process. For example, during the transfer of medical images to record COVID-19 patient data in surgery, it may be necessary to send details of the disease and medical images to a pathologist or radiologist. This information must be protected to protect the patient's privacy. Disclosing patient information without a license is against the laws of the Ministry of Health and Medical Services. Some of the basic requirements of the data embedding method are imperceptibility, message capacity, robustness, and security. Therefore, one of the most important challenges and problems of the electronic health record system that they face is the transfer of confidential medical information without distortion [6]. In the medical data embedding system, by secretly hiding the electronic patient records (EPRs) inside the medical image, an invisible connection is established between the sender and receiver of the data. Medical image segmentation is also an important process in image analysis in clinical applications that aims to divide the image into non-overlapping regions [7].

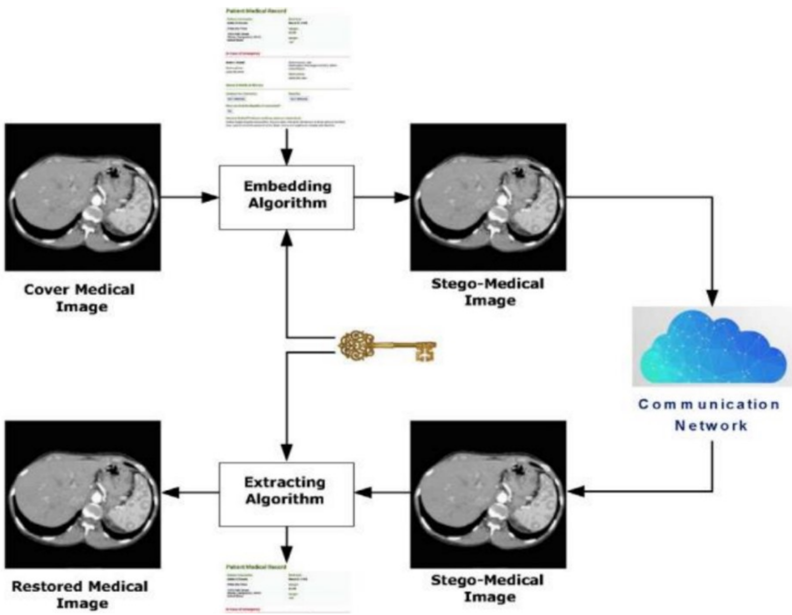

Figure 1. Electronic surveillance of patients' medical records [1]

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Methods of embedding digital medical images are few and require more attention and development. Data embedding in files and communication through telemedicine facilitates communication. In Figure 1, the mode of electronic surveillance of electronic patient records is shown. With the advent of new technologies in medical science and the use of engineering in medicine, there has been a significant improvement in the level of medical, Forensic Medicine organizations, telemedicine, and legal and electronic health services. In medical cases, patients contain very sensitive information that should not have access to unauthorized persons and prevent threats and attacks on patients' medical data, in addition to protecting privacy[8].

2. METHODS

Today, technology and hardware systems are known as reliable and economical tools for integrating the application of various applications in health-therapeutic environments. In countries where there is a shortage of medical facilities in rural areas, telemedicine can be a major advantage for the common people, but with enormous potential, it poses a threat to many dangers. The ethical obligations of physicians in a commitment to non - disclosure of information and knowledge about medical treatment are sufficient knowledge of the medical care, the type of illness, the type of condition, and treatment procedures [9]. Ethical obligations of physicians in the commitment not to disclose information and knowledge in deciding about medical operations, sufficient knowledge of the medical record, type of disease, complications, and treatment methods of the patient, Therefore, to ensure the accuracy of medical data, we need to provide ways to secure medical images during transmission [9].

Considering the efficiency of the mathematical model of the human visual system (HVS) in data-embedded methods, in the design and simulation of data embedding in digital medical images, the model is used to satisfy an invisible condition of the electronic patient record in medical images. Most data embedding algorithms do not consider the slightest change in medical images. Since the treatment of patients depends on the exact medical image, this distortion cannot be ignored [10]. The general block diagram of the MRI medical imaging method using the human visual perceptual analysis system is shown in Figure 2. HVS block has been used to satisfy the transparency requirement after embedding the data EPR in the MRI medical image. The location of this block is such that it can provide the condition of transparency of the proposed method by analyzing the final image and changing the parameters of the algorithm. In the following, the steps of implementing the diagram block are fully explained [11].

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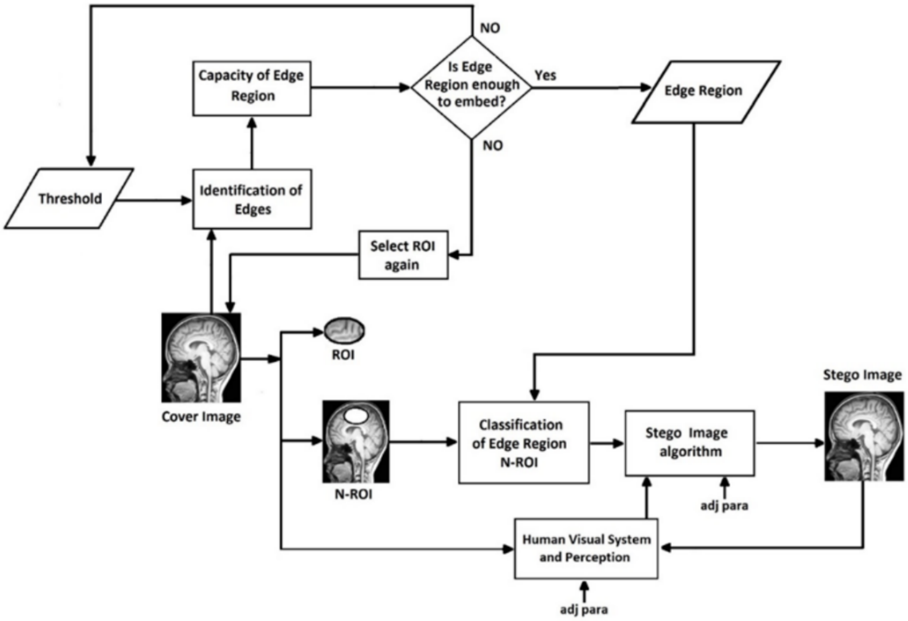

Figure 2. Block diagram of the proposed method of embedding EPR data in brain MRI images

2.1. First Step

The embedding method starts by dividing the cover image into ROI and N-ROI regions. We use the edge detection algorithm to identify the appropriate area that does not have uniform surfaces. Then based on the patient's EPR file size and the number of required pixels selected from the cover image, the threshold value is modified, and if the area is not suitable for the data embedded, the ROI region is re-selected with the new coordinates. ROI region selection can be done manually by a specialist doctor or automatically with the help of image segmentation [12, 13].

The medical image usually contains a specific region of disease information, referred to as the ROI region. It is very important to protect this region against any change in the correct diagnosis of the disease. A rectangular or elliptical ROI region by a specialist or automated physician is determined using a vector that specifies its coordinates and initial size. After identifying the appropriate ROI, the medical image becomes a binary image. Pixels with a value of 1 belong to the ROI region, while those with a value of 0 belong to the N-ROI region, as shown in Figure 3. The data EPR is embedded only in the N-ROI region blocks and changes in the ROI region are avoided. ROI coordinates are required during the extraction process to identify the embedded incubation region. So, The ROI coordinates are

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collected with a secret message to extract the data to be embedded, and the ROI coordinates are embedded in the initial block of the cover image [14, 15].

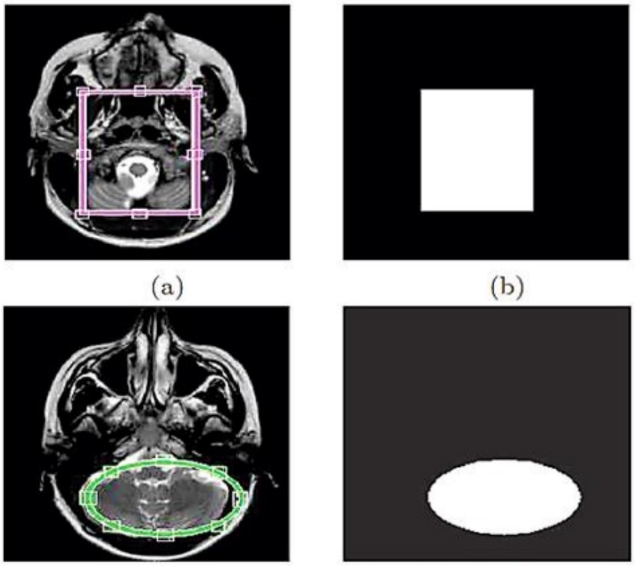

Figure 3. (a) and (c) of ROI cover images, (b) and (d) binary related to ROI image

2.2. Second Step

The data capacity and image quality are two important factors that need to be considered when embedding the method. However, some of these factors are contradictory. Data capacity is a basic measurement for evaluating the performance of the embedding method, which refers to the number of bits that can be embedded in the cover image. High data capacity is an attractive feature that most embedding methods have attempted to achieve [16]. The data capacity of the message is represented by Eq. (1).

$$K\frac{L}{MN}(bpp) \quad (1)$$

Where L is the maximum number of message bits that can be embedded in the image. M and N are the width and height of the cover image, respectively. First, the symbols and parameters used in the medical image embedding algorithm are stated. The cover image I with dimensions $N \times M$ and consisting of G selected gray level and hidden EPR data W which will be considered as a binary image with $P \times Q$ dimensions. xnm the number of gray levels of the MRI image and Wnm the values of the EPR data levels [17].

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$$I=\{x_{nm}, n\in\{0,1,\ldots,N-1\}, m\in\{0,1,\ldots,M-1\}\tag{2}$$
$$W=\{W_{nm}, n\in\{0,1,\ldots,P-1\}, m\in\{0,1,\ldots,Q-1\}\tag{3}$$
$$x_{nm}\in\{0,1,\ldots,G-1\}\tag{4}$$
$$W_{nm}\in\{0,1\}, W_0\cdot W_1\tag{5}$$

In Equation (5) the values $w0$ and $w1$ are the number of 0 and 1 of digital EPR data, respectively. Data embedding in the image is expressed by the following relations.

$$I_W=I\oplus W\tag{6}$$

In Equation (6) the sign indicates the hidden EPR data operator W in the cover image I. In Equation (7) Iw the medical cover image of the patient's EPR information. To ensure transparency, the coverage phenomenon including spatial coverage and frequency cover is used in the mathematical model of the human visual system in the embedding algorithm. Where V(I) indicates the level of vision of the observer with normal visual acuity when viewing image I.

$$V(I_W)=V(I)\tag{7}$$

The final image quality assessment is performed using a Multi-Scale Structural Similarity measure. Based on the assumption that human visual perception is very suitable for extracting structural information. This criterion performs better in many cases than PSNR and MSE, which have been criticized for not paying attention to the human visual system. The SSIM criteria the comprehensibility of image details depends on the sampling density of the image signal, the distance of the image screen to the viewer, and the perceptual ability of the observer's visual system [18,19,20]. The human visual system pays attention to different components of different frequencies and regions in an image. In line with this feature, we propose HVS-based multiscale structural similarity as shown in Figure 4.

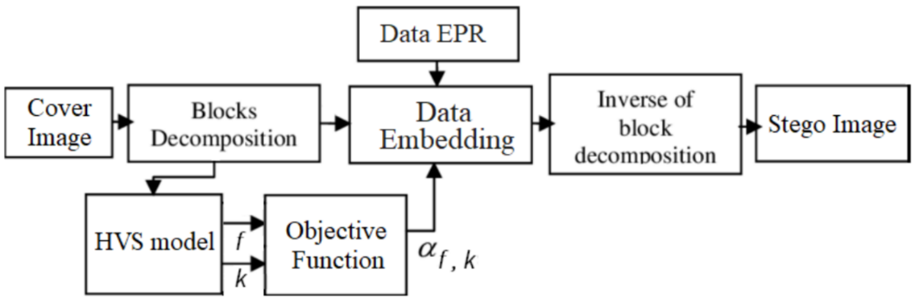

Figure 4. Block diagram of the proposed SSIM with the HVS model

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The frequency components of f the image can effectively reflect the texture features of the image. According to the study of the characteristics of the human visual system, the attention of the human eye to the components of frequency f is different. According to HVS, we can assign different weights to different frequency components. Therefore, the result of objective judgment can be more compatible with subjective judgment [21]. When the human eye sees an image, the central part of the image attracts the primary human attention. The focus area will then gradually expand from the center to remote areas. This means that the importance of different parts of an image usually decreases from the center to the edge. In fact, it is like the habit of the human eye that we usually place the main target at the center of the viewfinder. The stimulation of the retina is shown in Figure 5. Considering the spatial sensitivity of k, each block is assigned an effective spatial weight [22]. Light-sensitive cells are mostly located in the macula lutea region of the retina. Hence, the resolution is higher in the center of the macula lutea while it is lower in the peripheral parts of the retina. As a result, the human eye can only be extremely sensitive to a limited area while ignoring many details in other areas [23].

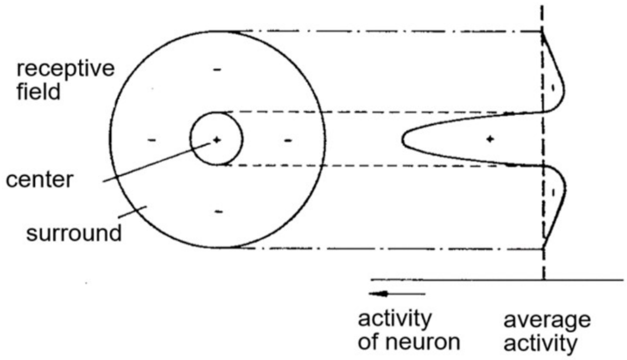

Figure 5. Comparison of stimulation curves in the human retina

Considering the spatial focal sensitivity, each cover image block is assigned a spatially effective weight. The effective spatial weights can be calculated as follows from Equation (8). For a block whose center is (x, y).

$$k_{spatial}(x,y)=1-C\times\frac{\sqrt{(x-x_c)^2+(y-y_c)^2}}{d_{max}} \quad (8)$$

Where xc, yc indicate the center of the image. $dmax$ is the maximum pixel distance from the center. Parameter C, which is in the range of 0 ~ 1 and determines the effect of spatial focal sensitivity. The effective spatial weight is assigned to each block by Equation (9). Here h (x, y) is a function of a multi-scale structural similarity measure.

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$$h(x,y)=k_{spatial}(x,y)\cdot freq(x,y) \quad (9)$$

The purpose of the optimization function block is to find an acceptable solution, given the limitations and needs of the problem. However, choosing the right objective function is one of the most important optimization steps [24]. In the above optimization f, k simultaneously contains several different objective functions. In such cases, the formation of a new objective function is a linear combination of the main objective functions, in which the effectiveness of each function is determined by the weight assigned to it [16]. Equations (10) and (11) $S_w(I_w)$ show the process of detecting the embedded EPR data W in Cover Image I. The value of TL is the threshold that is selected following the desired level of certainty and indicates the process of extracting the presence of patient medical records in the cover image [25].

$$S_W(I_W)\geq T_L \quad (10)$$

$$S_W(I_{w^*})\langle T_L \quad (11)$$

In Eq. (12), the robustness condition expresses the method of data embedding versus the post-processing method and the ε value shows the amount of variation in the effect of the post-processing effect on the cover image.

$$S_W(I_W+\varepsilon)\geq T_L \quad (12)$$

$$I_W=\{y_{nm},n\in\{0,1,\ldots,N\text{-}1\},m\in\{0,1,\ldots,M\text{-}1\} \quad (13)$$

$$y_{nm}\in\{0,1,\ldots,G\text{-}1\} \quad (14)$$

In methods in which the discrete cosine conversion function and the wavelet conversion function are used as the transfer function from the spatial domain to the frequency domain, the average square root of the error results in lower embedding rates than in other methods.

3. SIMULATION RESULTS

With the help of embedding digital images of medical images, It can be goals such as improving security, and the confidentiality of the patient's private information he obtained the unified saved image file with the table EPR data file. The results of the experiment on database images indicate the effectiveness of the method on sample medical images. To evaluate the performance of the final response of the system designed to include data EPR in the cover image of the criterion (15). It

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indicates the number of changes made to the cover image, which provides a level of certainty for EPR data detection and retrieval.

$$S=\frac{|I(x,y)-I_w(x,y)|-Mean}{Max-Min}\times 255 \quad (15)$$

The main cover image $I(x,y)$and embedded image $IW(x,y)$. Mean is the average value of the gray levels of the cover image. Max is the maximum gray level of the cover image and Min is the minimum gray level of the cover image. The cover image will be added after EPR data embedding during transmission on telecommunication networks and Internet channels Noise effects. This simulation is shown using a 5% random pseudo-noise in the cover image according to Equation (16).

$$nI_w(x,y)=I(x,y)+k^{*}W(x,y) \quad (16)$$

Figure 6 shows some of the selected MRI cover images for embedding EPR data, and Figure 7 shows the hidden EPR data to share.

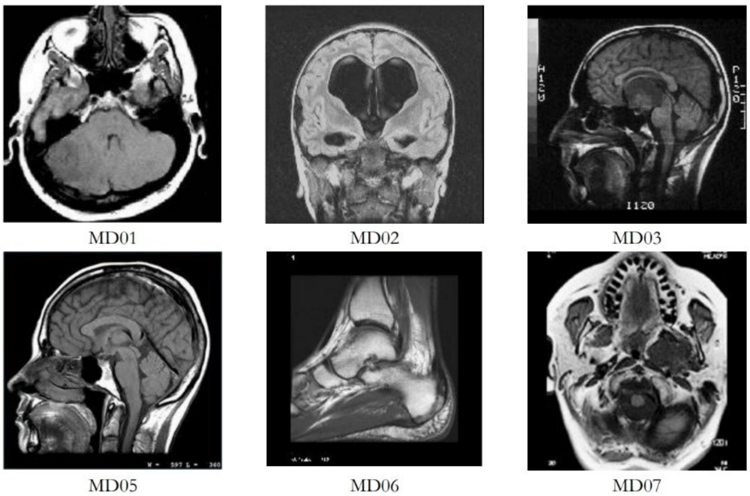

Figure 6. MRI overlay images for EPR dataset embedding.

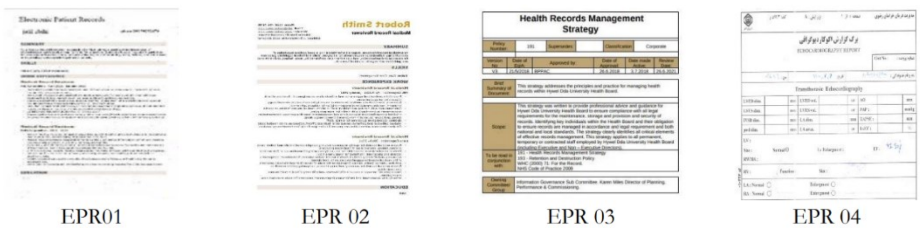

Figure 7. EPRs dataset to share.

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The visual first-class hidden images mentioned in figure 8 examine the excessive performance, the imperceptibility, of our approach. The figures show each true image and its hidden model as well as the secret EPRs preceding and after extraction from the hidden image.

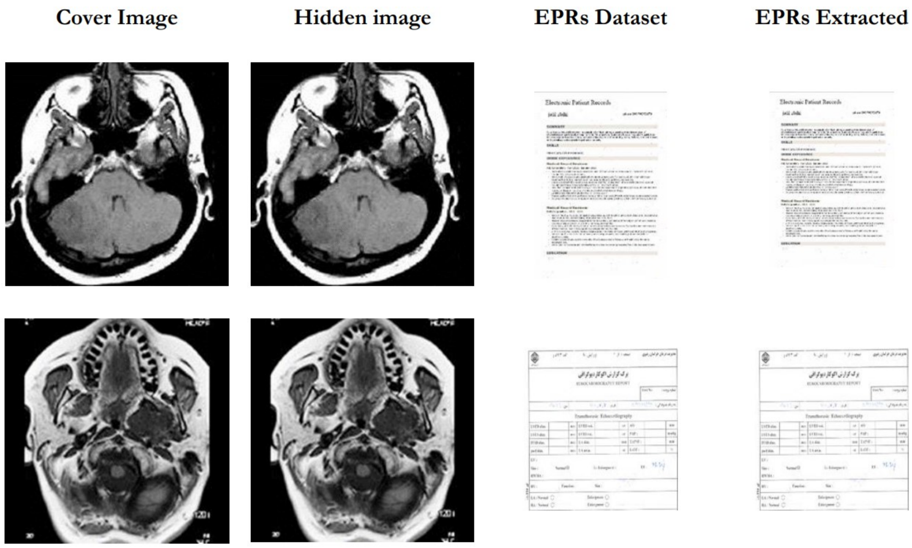

Figure 8. Visual quality for EPRs embedding approach of greyscale images

The method also has good resistance against some other processes such as median filter, Gaussian filter, increasing the light intensity, and adding Gaussian noise and uniform noise, figure 9 and figure 10 show the effects of obstruction attacks. In methods in which the combined cosine and wavelet functions are used as the image transfer function from the spatial to the frequency domain, the mean square error is less, It has created an equal embedding rate compared to other methods. The simulation results were performed on the MRI image database using MSE analysis in the spatial domain with the LSB method and the transform domain with DWT, DCT, and DCT + DWT methods. There are two data sets, one with 20 and the other with 18 topics, known as the first IBSR20 data set and the second IBSR18 data set. Figure 9 shows the reduction of MSE in the above method by other methods.

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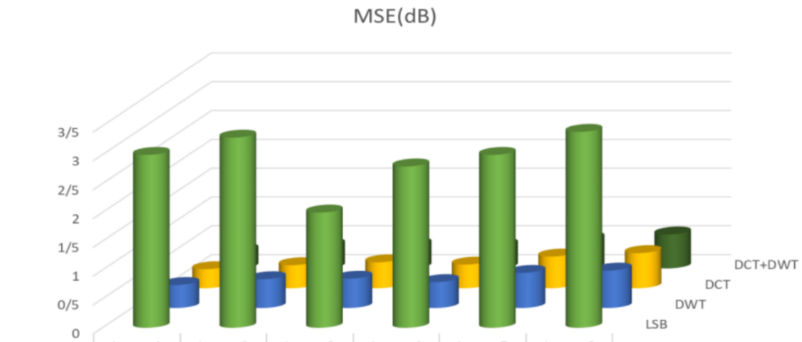

	Image 1	Image 2	Image 3	Image 4	Image 5	Image 6
LSB	3	3/3	2	2/8	3	3/4
DWT	0/4	0/5	0/51	0/45	0/61	0/65
DCT	0/33	0/4	0/45	0/41	0/55	0/61
DCT+DWT	0/3	0/39	0/4	0/39	0/5	0/59

Figure 9. Comparison of MSE, LSB, DWT, and DCT methods with the DCT + DWT method

The simulation results were performed by analyzing the signal-to-noise ratio in the spatial domain by the LSB method and the transform domain by DWT, DCT methods, and the combined DCT + DWT method. The MRI image database, one with 20 subjects and the other with 18 subjects, is the first IBSR20 data set and the second IBSR18 data set. The results of the combined DCT + DWT method on the database images performed in Figure 10 show the higher quality of PSNR than other methods and the high level of security of digital medical MRI images.

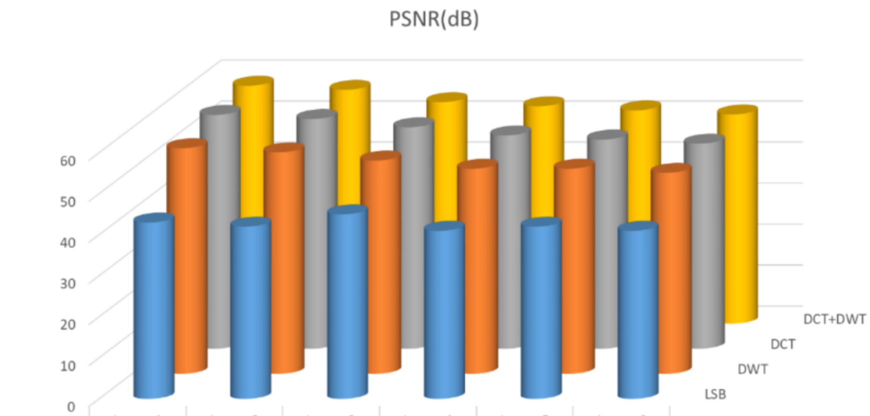

	Image 1	Image 2	Image 3	Image 4	Image 5	Image 6
LSB	43	42	45	41	42	41
DWT	55	54	52	50	50	49
DCT	57	56	54	52	51	50
DCT+DWT	58	57	54	53	52	51

Figure 10. Comparison of PSNR, LSB, DWT, and DCT methods with the DCT + DWT method

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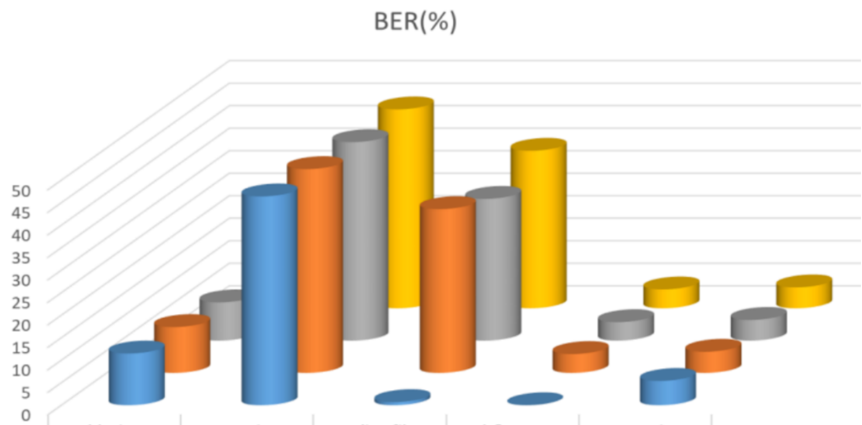
One of the main parameters in estimating the EPR data embedding error is the BER cover image or bit error rate, which is expressed in Equation (17).

$$BER=\frac{\sum_{i=1}^{n} |w_i-w_i^*|}{n} \quad (17)$$

In this equation, $w*$ is the extracted EPR data of the patient and w is the amount of EPR data embedded and n is the total number of EPR data bits. Therefore, studying the BER parameter is used to evaluate the robustness performance of the embedding method. The results are shown in Figure 11 to evaluate the efficiency of the embedding method from the bit error rate criterion for comparing LSB, DCT, DWT, and DCT + DWT methods.



	bluring	gaussian noise	madian filter	salt&pepper	averaging filter
LSB	11/5	46/4	0/7	0	5/4
DWT	10/2	45/3	36/4	4/2	4/7
DCT	8/5	44/1	31/5	4/1	4/6
DCT+DWT	8/6	44/2	35	4/2	4/65

Figure 11. The results of comparing the bit error rate of LSB, DWT, DCT, and DCT+DWT methods

Figure 12 and figure 13 show the effects of obstruction attacks, wherein the EPRs extracted from hidden images have admissible visible quality and there may be no loss of the visible information in the part of the attacks.

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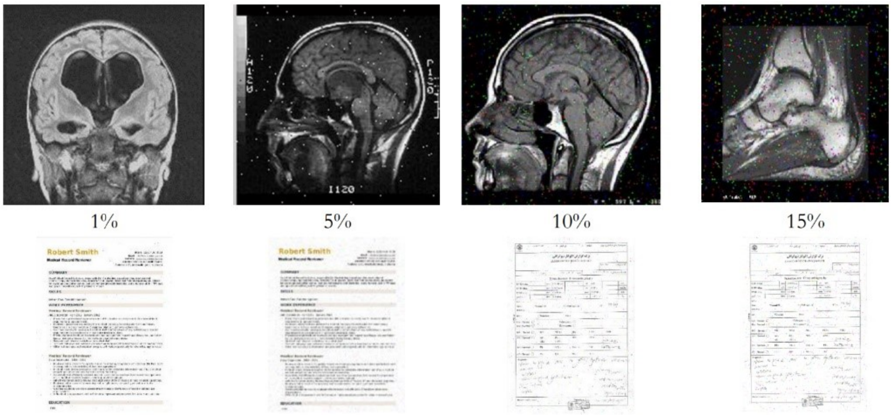

Figure 12. Hidden and extracted images under the noise of various densities. The first row shows the hidden images with added Salt and Pepper noise and their corresponding extracted versions in the second row

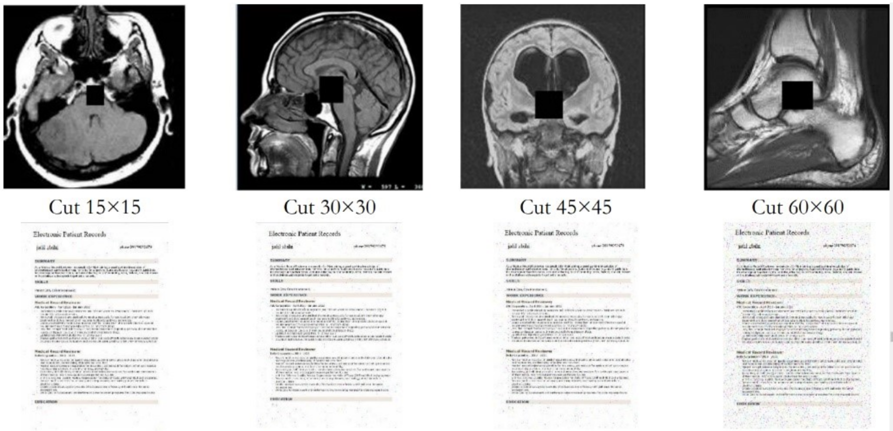

Figure 13. Hidden and extracted EPRs under various data loss by cutting different blocks. The first row shows the hidden images with a block of data loss and their corresponding extracted versions in the second row

Table 1 shows the performance comparison of image quality assessment models in brain MRI images with MAE, NCC, and RMS criteria.

Tabel 1. Performance comparison of image quality assessment models in brain MRI images

	NCC	MAE	RMS
PSNR	0.8089	7.318	9.4847
SIMM	0.9171	5.0173	6.4296
HVS-SSIM	0.9312	4.5217	5.8812

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4. CONCLUSION

The use of Telemedicine technology for the transmission of information and awareness for the purpose of medical diagnosis, treatment, and patient care and distance education related to health is one of the basic needs in the field of health. With the advancement of information technology in medical sciences and computer networks, the use of communication and video archiving systems or PACS has made it possible to transfer, store, retrieve and display medical images in different places. the security situation in PACS systems that allows for transmission, storage, retrieval, and display of medical images at different points of health care systems has weak points. Planning to develop the necessary laws regarding the security of access to patient data and its observance by system support companies, control of access to this data, and risk management, is essential. Bilateral authentication is important to meet the security requirements of the e-health network, which is the subject of privacy, confidentiality, and data integrity, and on the other hand, considering different users in the network, the presence of a reference for registration and initial verification of users. The proposed model can run in different e-health networks.

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