IMAGE SELECTION CRITERIA FOR EMBEDDING DESIRED CAPACITY USING FRBS

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Abstract: Data hiding methods are used to carry information from one place to another. Digital watermarking is one of the data hiding methods. Imperceptibility and capacity are the conflicting parameters in digital watermarking. The more the embedded information, lower the imperceptibility and vice versa. Imperceptibility factor (IF) is measured as peak signal to noise ratio (PSNR) of the image after embedding information. No such schemes exist in the literature in which an image can be chosen that may carry a desired capacity, while keeping imperceptibility as high as possible. In this scheme a two stage fuzzy rule based system (FRBS) is designed to choose the image among the list that is capable of holding desired capacity while achieving high imperceptibility at the same time. Validity of the proposed scheme is checked through simulation results of different types of images like natural and medical. Moreover, the proposed scheme is also robust against JPEG compression attack.

Key words: *Imperceptibility, FRBS, capacity, digital watermarking*

Received: October 5, 2013 **DOI:** 10.14311/NNW.2014.24.030
Revised and accepted: October 17, 2014

1. Introduction

There are two classical methods for protecting documents, encryption and copy-protection. The problem with encryption is that after decrypting the data, it can be copied and distributed easily. However, copy-protection procedures can

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be bypassed. Digital watermarking is considered as a safe method against unauthorized distribution of valuable digital information as an alternative of encryption and copy-protection [15, 5]. Digital information is directly embedded into the cover data in the digital watermarking i.e. the digital information could be the ownership, timestamps, name of legitimate receiver and copyright information. Moreover, illegal copying, tampering and re-distribution of documents could not be prevented by digital watermarking. However, when the copy-protection and encryption methods fail, digital watermarking allows the documents to be tracked back for ownership verification. The effective watermarking system should have the properties of Robustness, imperceptibility and more capacity. Security and more complexity are the issues that may be considered.

There are two domains for watermark embedding, spatial domain and transform domain. Spatial domain embeds the watermark information directly in the pixels of image [3] while spatial domain embeds the watermark information in the transform domain by taking DCT, DWT or some other wavelet transform etc [8,10]. Transform domain watermark embedding scheme is presented by exploiting the properties of human visual system (HVS), which specifies the certain regions in the image for embedding the information [1]. Furthermore, chaos base secure watermarking scheme in transform domain is also proposed which is robust against common image processing attacks [6]. Singular Value Decomposition (SVD) based robust watermarking scheme is also presented by modifying the singular values of the original cover data with the singular values of the watermark information [7]. A new robust watermarking scheme is presented by taking the image into the wavelet transform [9]. Watermark information is embedded where the change between lower bands of the original image and the reference image is minimum. A new transform domain and SVD based reference watermarking scheme is also proposed by calculating the DC coefficient of each sub-band. First wavelet coefficient is set to zero and then the reference image is calculated which has DC coefficient less than a certain threshold [2]. Fuzzy logic based watermarking scheme is also presented with the intent of embedding watermark information which is undetectable to the human visual system (HVS). The scheme targets three of five perceptual properties of HVS [4]. Wavelet transform based medical image watermarking scheme using fuzzy logic is also used by exploiting the properties of HVS. HVS search for the pixels with high texture and luminance and then the watermark is embedded. The scheme is also robust against certain attacks [14]. The schemes discussed so far are imperceptible after embedding the watermark which is true for natural images. The most important requirement for the medical images should be that, the image should not be visible to the naked eye because we do not want to show our image to the others. This can be achieved by utilizing the Residue number system (RNS) which alters the image in such a way that it is not seen to the others. Keeping this requirement in mind, fragility and reversibility for watermarking of medical images using chaotic key has already been done by Naseem et al. in [11] by randomly selecting some of the pixels using chaotic key for embedding chaotic watermark. The rest of the pixels were passed through RNS and then checksum was computed for the whole image using cyclic redundancy check (CRC) which makes an overhead of 4 bits hence, representing each pixel with 12 bits. This overhead also removed by the author by applying some trick on the residues and by choosing different scheme for embedding the watermark information [12].

The schemes discussed so far have certain limitations, that is, if we want to embed with the desired capacity, one should check individually/manually to chose an image which can carry our desired capacity, while keeping imperceptibility factor (IF) high. Moreover, this way of finding the individual is also time consuming. To overcome this limitation, a novel technique is presented which can select an image from the list which can carry our desired capacity.

In this paper, two stage FRBS is proposed to choose the candidate image from the list of images for embedding desired capacity while keeping the imperceptibility factor (IF) high. FRBS proposed here is comprised of two stages. In the first stage, FRBS is used to compute the capacity factor, alpha, from the given features in the image. In the second stage, FRBS is used to select the image embedded with desired capacity. Scheme is tested for natural and medical images both.

Rest of the paper is organized as; Section 2 describes about the features of the image, Section 3 describes about our proposed scheme, Section 4 describes about Simulation and results and finally section 5 concludes the paper.

2. Features of Digital Image

Determining the certain features of the image is an important factor for embedding the useful digital information. Though there are various types of features in the digital image features, but only three features, namely, texture, brightness and edge are determined in the proposed scheme which are defined as below.

2.1 Texture Sensitivity

The stronger is the texture feature of the image , the less it is visible to the naked eye after embedding so in our scheme we search for the pixels with the highest texture since, embedding in such type types of pixels makes the image more imperceptible with embedding more information. Local Binary Pattern (LBP) is used for texture sensitivity calculation which was based on the postulation that texture has locally two paired aspects, strength and the pattern [13]

2.2 Brightness Sensitivity

Brighter background areas are less sensitive than dark ones That is why our proposed scheme searches for those pixels that have high value of brightness, for embedding information. The most common format of the pixel is the byte image that results in a value from 0 to 255 as the numbers in this range are stored in an 8-bit. The pixel value 0 represents the maximum darkness in the image while the value 255 represents the maximum brightness in the image whereas the grey shades represent the values in between.

2.3 Edge Sensitivity

Higher are the edges, lesser is the visibility of embed information so higher edges are chosen for embedding the watermark in our scheme. A gradient analysis has been made to test the model by using different edge detection methods such as sobel prewitt and canny.

3. Proposed Scheme

Our proposed scheme consists of system model, components of fuzzy rule base and designing of fuzzy rules. Detail of each module is given subsequently.

3.1 System Model

Block diagram of the proposed scheme is given in Fig. 1. Different types of cover images of size M $\times$ N are given as input to the feature extraction block. Feature extraction block in return provides three features that are brightness sensitivity S_B, texture sensitivity $S_T$and edge sensitivityS_E. First fuzzy rule based system (FRBS-1) takes the three features of the whole image as input and gives the capacity factor alpha (α). Second fuzzy rule based system (FRBS-2) takes capacity factor alpha and desired capacity (C_d) as input and returns imperceptibility factor (IF) of each image. The details pertaining to the components of proposed model are given in subsequent sections.

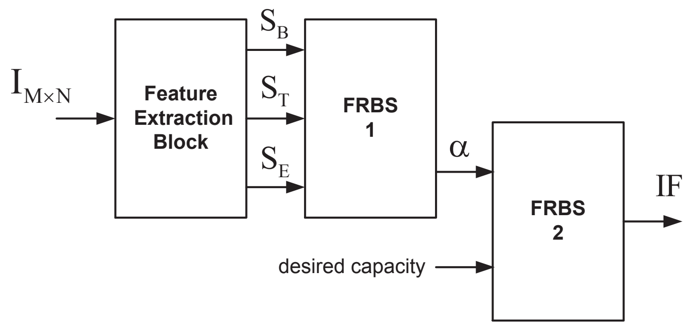


Fig. 1 *Brief diagram of proposed system.*

3.2 Components of Fuzzy Rule Base System

- Fuzzifier: Standard Gaussian fuzzifier is used to transform crisp values of input to corresponding fuzzy values.
- Inference Engine: Mamdani Inference Engine (MIE) is used for inferring that an input vector is mapped on to which corresponding output point by making use of rules in the rule base. In MIE, fuzzy operation AND is chosen as MIN while OR is chosen as MAX.
- De-Fuzzifier: Standard Center Average Defuzzifier (CAD) is used to transform the output fuzzy value to the crisp value.

3.3 Fuzzy Rule Based System

This section focuses on the design of fuzzy rule based system. As already described first FRBS takes the image features as input and finds the capacity factor alpha. Components of the both FRBS are discussed in succession.

3.3.1 Design of FRBS-1

As mentioned earlier, first FRBS has three input variables namely *brightness sensitivity*, *texture sensitivity* and *edge sensitivity* duly defined in previous section. The input range of brightness and edge sensitivity is between 0-255 and edge sensitivity could either be 0 or 1. Five membership functions are used to cover the input space of *brightness sensitivity* (very dark, dark, dim, bright and very bright), two membership functions are used to represent edge sensitivity (low, high) and five membership function for texture sensitivity (very smooth, smooth, average, rough and very rough). These relationships are shown in Fig. 2, 3 and 4 respectively. There is one output variable named capacity factor. Five membership functions (very low, low, medium, high and very high) are used to cover the range which is between 0 and 1.

As cardinality of rule base is the product of number of membership functions in each input variables, there are fifty rules in the rule base. As all three features are somewhat directly proportional to the output, the rules are formulated accordingly. The possible values of variable *edge sensitivity* are 0 or 1, so twenty-five rules are formulated for each case. Rules can be found in Tab. I and Tab. II for edge sensitivity 1 and 0 respectively. Each table contains twenty-five rules. The first row and first column of each table contains IF part while rest of the table contains according value of THEN part. A rule format can be expressed as

$$IF(Texture = Average\, AND\, Brightness = Dim\, AND\, Edge = \\ = 1)\, THEN\, (Alpha = Medium) \tag{1}$$

The rule surfaces according to these tables are given in Fig. 6 and Fig. 7 respectively. Both of these figures narrate that higher the values of brightness and texture sensitivity, image capacity factor is higher. However, this impact is more when edge sensitivity is 1 and less when edge sensitivity is 0, which conforms to the definitions given in previous section.

Edge = 1		**Brightness**				
		V-Low	**Low**	**Dim**	**High**	**V-High**
Texture	**V-Smooth**	VL	L	L	M	M
	Smooth	L	L	M	M	H
	Average	L	M	M	H	H
	Rough	M	M	H	H	VH
	V-Rough	M	H	H	VH	VH

Tab. I *Rulebase with Edge Sensitivity = 1.*

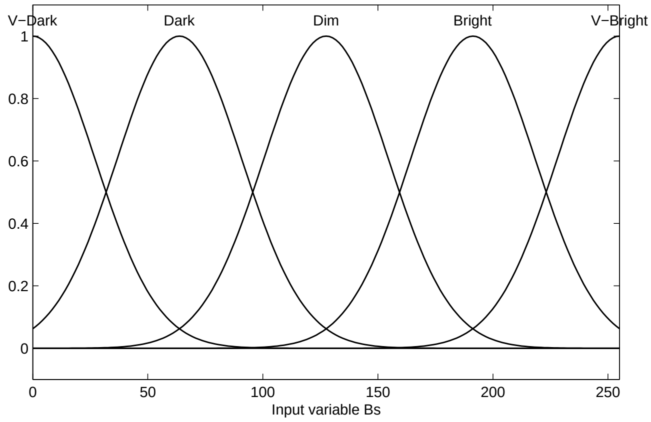


Fig. 2 *Input variable Brightness sensitivity.*

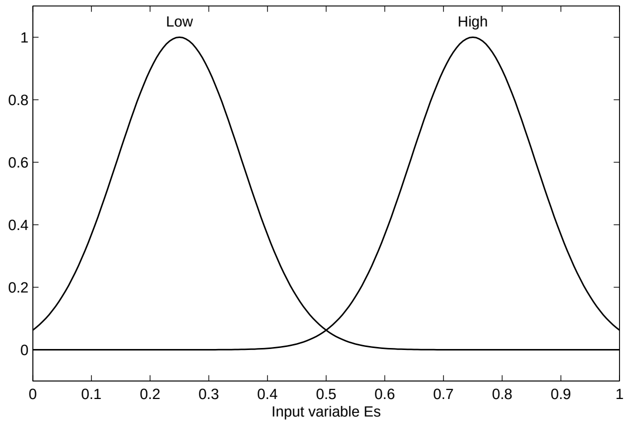


Fig. 3 *Input variable Edge sensitivity.*

Edge = 0		**Brightness**				
		V-Low	**Low**	**Dim**	**High**	**V-High**
Texture	**V-Smooth**	VL	VL	L	L	M
	Smooth	VL	L	L	M	M
	Average	L	L	M	M	H
	Rough	L	M	M	H	H
	V-Rough	M	M	H	H	VH

Tab. II *Rulebase with Edge Sensitivity = 0.*

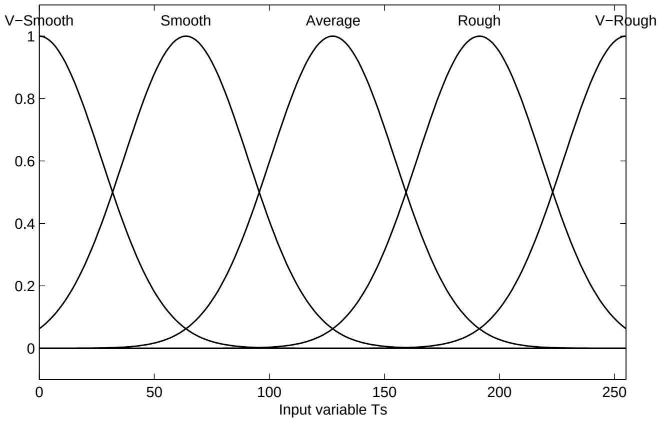


Fig. 4 *Input variable Texture sensitivity.*

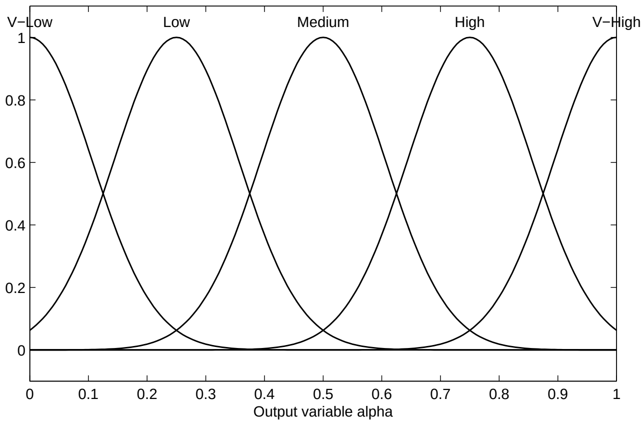


Fig. 5 *Output variable Capacity Factor.*

3.3.2 Design of FRBS-2

In second fuzzy rule based system (FRBS 2), there are two input variables namely capacity factor (alpha) which is outcome of FRBS 1 and second input variable is desired capacity (C_d) and output of FRBS 2 is imperceptibility which is actually desired peak signal to noise ratio (PSNR). As far as the ranges of input variables are concerned, value of first input variable capacity factor is between 0 and 1 and five membership functions (Very low, low, medium, high and very high) are assigned to it. Similarly value of second input variable desired capacity (C_d) is also between 0 and 1and five membership functions (Very low, low, medium, high and very high) are assigned to it. These relationships are shown in Fig. 5 and Fig. 8 respectively.

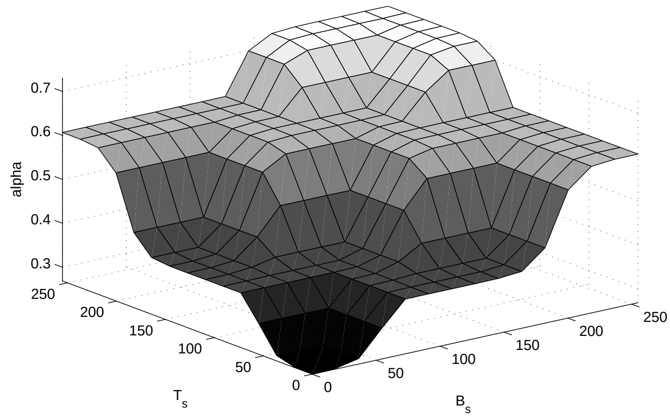


Fig. 6 *Rule surface with edge sensitivity = 1.*

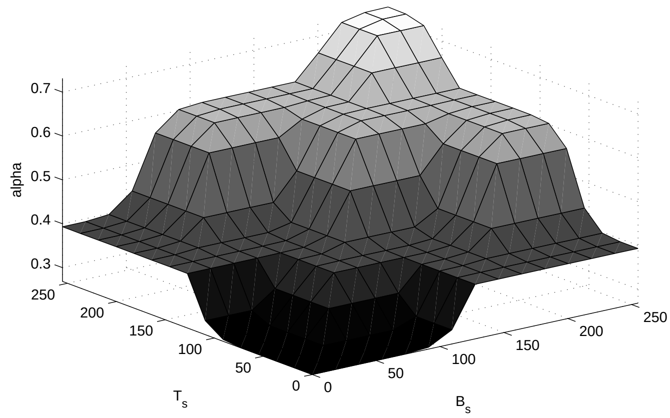


Fig. 7 *Rule Surface with edge sensitivity = 0.*

There is one output variable named imperceptibility factor which is between 30dB to 70dB while there are nine membership functions (Exceedingly very low EVL, Exceedingly low EL, very low VL, low L, medium M, high H, very high VH, Exceedingly high EH and Exceedingly very high EVH). This is shown in Fig. 9. As there are five membership functions in each input variable, there are twenty-five rules in the rule base. These rules are given in Tab. III. Rule surface of FRBS-2 is shown in Fig. 10. Fig. 11 shows the relationship between desired capacity and capacity factor (alpha) at the mean value of 50dB which shows that both are directly proportional to each other. Similarly Fig. 12 shows the relationship between imperceptibility factor (IF) and desired capacity at the mean value of capacity factor (alpha) of 0.5 which shows that both are inversely proportional to each other.

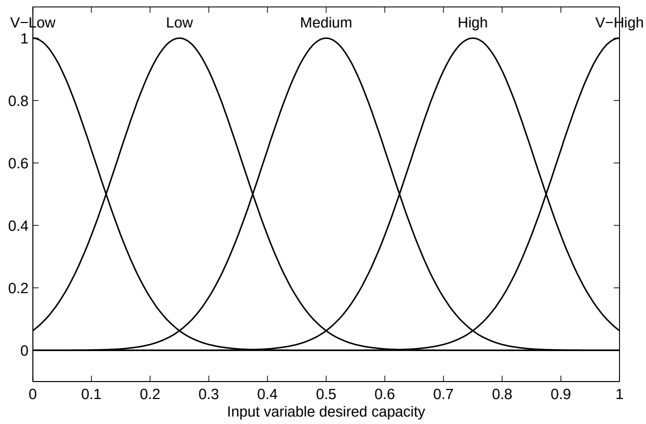


Fig. 8 *Input variable desired capacity.*

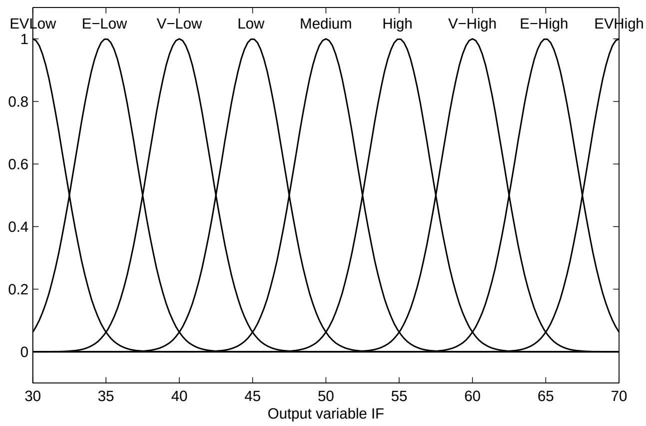


Fig. 9 *Output variable Imperceptible Factor (IF).*

Capacity Factor (alpha)	**desired capacity (C_d)**				
	V-Low	**Low**	**Med**	**High**	**V-High**
V-Low	M	L	VL	EL	EVL
Low	H	M	L	VL	EL
Med	VH	H	M	L	VL
High	EH	VH	H	M	L
V-High	EVH	EH	VH	H	M

Tab. III *Rule base for FRBS-2.*

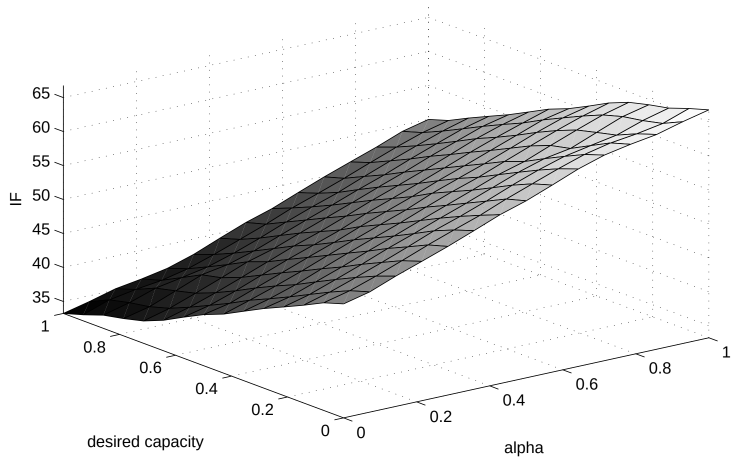


Fig. 10 *Rule Surface of FRBS-2.*

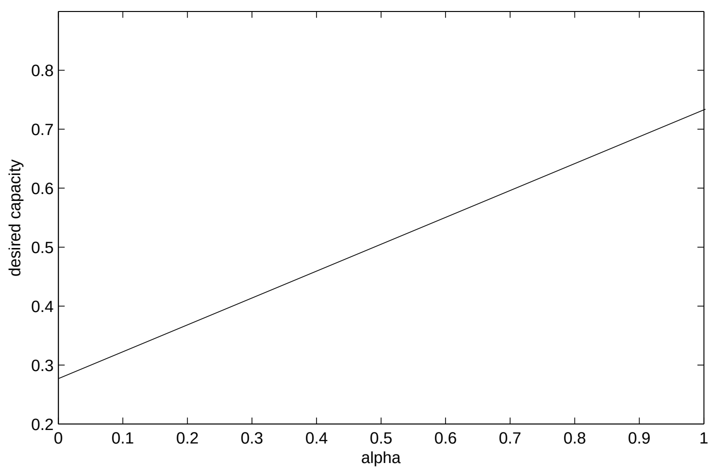


Fig. 11 *Relationship b/w alpha and desired capacity at IF = 50dB.*

3.4 Image Selection Criteria

The steps for selecting the image from the list of images for embedding desired capacity are given as below.

- Input different arbitrary original images to feature extraction block.
- For each input image, image extraction block will compute the features of each image.

- Input the features of each image to FRBS-1.
- FRBS-1 will calculate the capacity factor (alpha) of the image as

$$\alpha = FRBS - 1(S_{\mathrm{B}},\mathrm{S}_{\mathrm{E}},\mathrm{S}_{\mathrm{T}})$$

- Input desired capacity (C_{d}) and alpha to the FRBS-2 to calculate the imperceptible factor (IF) The image with the highest IF is chosen as a candidate image for carrying desired capacity. FRBS-2 will provide the imperceptibility factor (IF) as

$$\mathrm{IF} = \mathrm{FRBS\text{-}2}(\alpha, C_{\mathrm{d}})$$

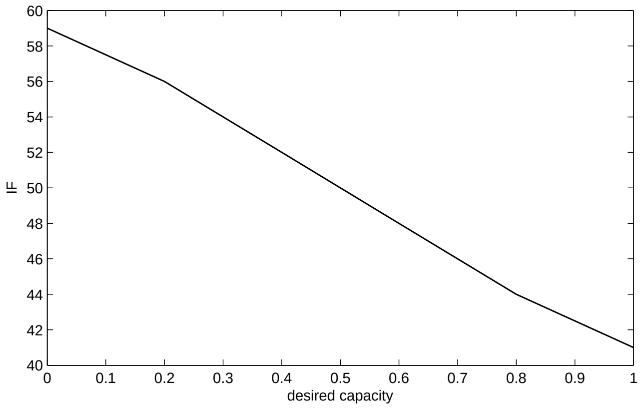


Fig. 12 *Relationship b/w IF and desired capacity at alpha = 0.5.*

4. Simulation & Results

This section contains the objective measures and simulation results to validate the effectiveness of our proposed scheme. To measure the imperceptibility of watermark after embedding, Peak Signal to Noise Ratio (PSNR) is considered as a figure of merit which is given as

$$\mathrm{PSNR} = 10\log_{10}\frac{255^2}{\mathrm{MSE}}$$

where

$$\mathrm{MSE} = \frac{1}{\mathrm{MN}}\sum_{i=0}^{\mathrm{M\text{-}1}}\sum_{j=0}^{\mathrm{N\text{-}1}}[f(x_i,y_j) - f'(x_i,y_j)]^2$$

where M and N denotes the size of image, f(x,y) and f′(x,y) denotes the original image and watermarked image respectively. Higher the value of PSNR, lower is the degradation between original and the watermarked contents.

To measure the degradation between original watermark and extracted watermark normalized correlation (N_c) is used as a figure of merit which is given as

$$N_c(W,W') = \frac{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} W(i,j)W'(i,j)}{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} [W(i,j)]^2}$$

where W and W' represents the original and extracted watermark respectively. M and N is the dimension of watermark. The value of Nc lies between 0 and 1. More it is close to 1, higher is the robustness.

Images from different domains each having size of 256×256 pixels are taken. For desired value of capacity, imperceptible factor (IF) is calculated by our proposed FRBS-2 which is termed as PSNR found.

Fig. 13(a-f) shows the different images used in the experiment. Fig. 14(a-f) shows the images with their PSNR found with desired capacity of 20K bits.

Fig. 14a shows the ultrasound image with PSNR found of 50.64dB for desired capacity of 20K bits. Fig .14b shows the brain image with PSNR found of 51.94dB for desired capacity of 20K bits

Fig. 14c shows the MRI image with PSNR found of 51.82dB for desired capacity of 20K bits. Fig. 14d shows the X-Ray image with PSNR found of 52.56dB for desired capacity of 20K bits. Fig. 14e shows the Lena image with PSNR found of 52.55dB for desired capacity of 20K bits.

Fig. 14f shows the baboon image with PSNR found of 53.50dB for desired capacity of 20K bits. Since the PSNR found of baboon image is greater than rest of the images, so it is the candidate image for carrying our desired capacity.

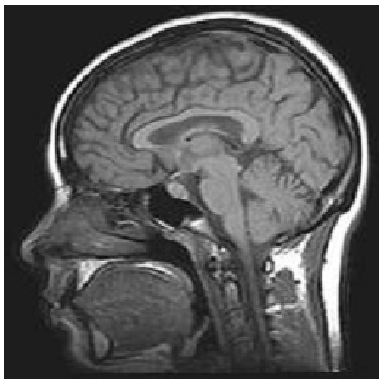
Similarly, when the desired capacity is increased to 26K bits, PSNR found is also computed for the given set of images which is shown in Fig. 15(a-f). Since, again the PSNR found of baboon image is again greater than rest of the images, so it is the candidate image for carrying our desired capacity.

Images	**Capacity factor (alpha)**	**PSNR found(dB)**
Ultrasound	0.3336	50.64
Brain	0.3988	51.94
MRI	0.3928	51.82
X-Ray	0.4408	52.70
Lena	0.4324	52.55
Baboon	0.4790	53.50

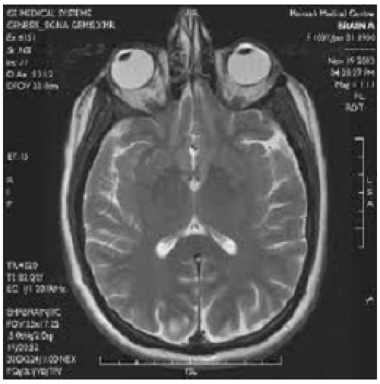
Tab. IV *Shows PSNR found for desired capacity of 20K bits.*

Results are summarized in Tab. IV and Tab. V for desired capacity of 20K bits and 26K bits respectively for different images along with the capacity factor (alpha). From both tables, since, PSNR found of baboon image is greater than the rest of the given images so, baboon image is a candidate image for carrying our desired capacity.

(a) Ultrasound image original.



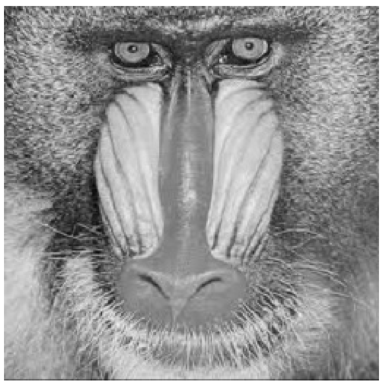
(b) Brain image original.



(c) MRI image original.

(d) X-Ray image original.

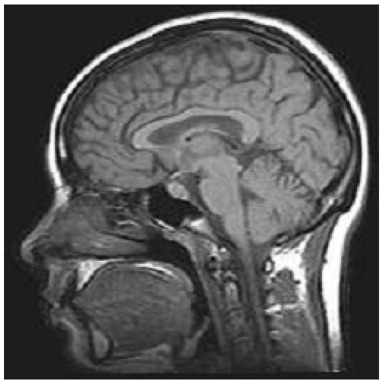
(e) Lena image original.



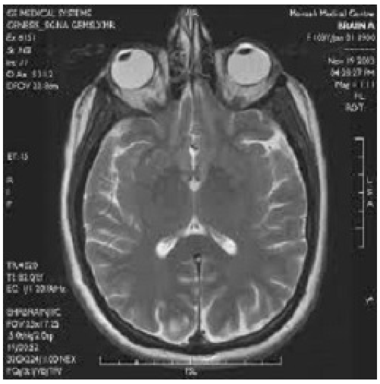
(f) Baboon image original.

Fig. 13 *Shows original images from different domains.*

(a) PSNR found = 50.64dB.



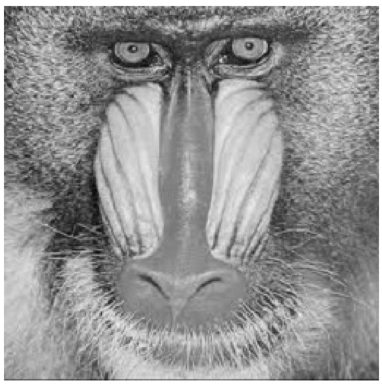
(b) PSNR found = 51.94dB.



(c) PSNR found = 51.82dB.

(d) PSNR found = 52.70 dB.

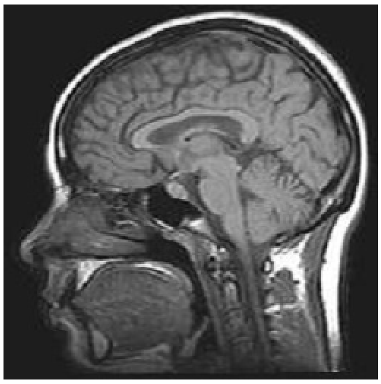
(e) PSNR found = 52.55 dB.



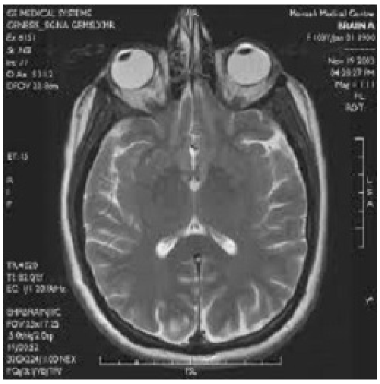
(f) PSNR found = 53.50 dB.

Fig. 14 *Shows PSNR found for different images for desired capacity of 20K bits.*

(a) PSNR found = 48.76 dB.



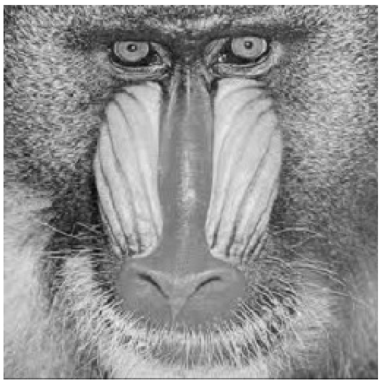
(b) PSNR found = 49.97 dB.



(c) PSNR found = 49.87dB.

(d) PSNR found = 50.77 dB.

(e) PSNR found = 50.61 dB.



(f) PSNR found = 51.53 dB.

Fig. 15 *Shows PSNR found for different images for desired capacity of 26K bits.*

Images	Capacity factor (alpha)	PSNR found(dB)
Ultrasound	0.3336	48.76
Brain	0.3988	49.97
MRI	0.3928	49.87
X-Ray	0.4408	50.77
Lena	0.4324	50.61
Baboon	0.4790	51.53

Tab. V *Shows PSNR found for desired capacity of 26K bits.*

Medical image original of size (256×256)
PSNR found = 40.30dB
PSNR in [14] = 40.12dB.

Fig. 16 *Shows medical original with PSNR found.*

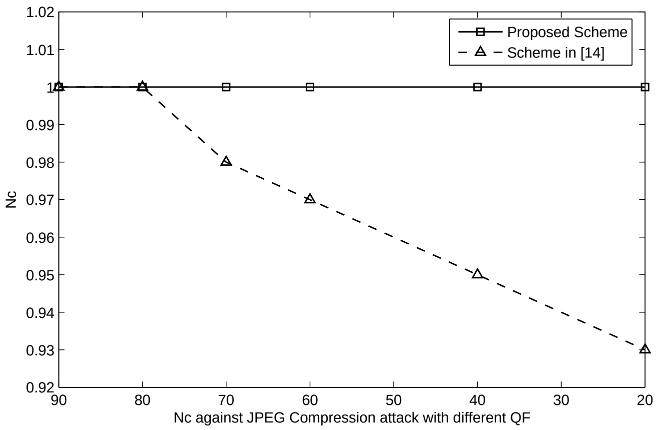


Fig. 17 *Shows Nc of proposed scheme and existing scheme against JPEG compression with different QF.*

Fig. 16 shows the medical image original of size (256×256). The existing scheme as given in [14] embeds 65,536 bits in the medical image, given in Fig. 16 and the PSNR calculated is 40.12dB. When the same capacity is embedded in the same image given in Fig. 16, the PSNR found proposed by our method is 40.30dB which is slightly higher than the existing scheme. Hence, the proposed schemes makes the image more imperceptible than the existing scheme.

Fig. 17 shows the normalized correlation (Nc) of proposed scheme with the scheme in [14] against JPEG compression attack with different quality factors. For QF of 90 and 80, both the existing scheme and the proposed scheme computes the value of Nc = 1. For QF = 70, existing scheme computes the value of Nc = 0.9825 while the proposed scheme computed the value of Nc = 1, When QF is reduced to 60, existing scheme computes the Nc value of 0.9691 while the proposed scheme computes the Nc value of 1. Similarly for QF of 40 and 20, Nc values of the existing scheme are slightly less than 1 but the proposed scheme computes the value of Nc = 1 for same QF. Hence, the proposed scheme is also robust against JPEG compression attack with different QF than the existing scheme given in [14].

5. Conclusion

A two stage fuzzy rule base system (FRBS) is proposed to select an image from the list of images which can carry our desired capacity while keeping imperceptibility as high as possible. Fuzzy rule base designed here consists of two stages. FRBS-1 computes the capacity factor (alpha) from the given features in the image while FRBS-2 computes the imperceptibility factor (IF) for the certain desired capacity. Images from different domains are taken to check the effectiveness of our proposed scheme. Image with the highest PSNR found is chosen as a candidate image from the list of images to carry our desired capacity. The proposed scheme makes the image more imperceptible than the existing scheme. Moreover, the proposed scheme outperforms than the existing scheme in terms of JPEG compression attack with different QF.

Acknowledgement

This research work was supported by Higher Education Commission (HEC) of Pakistan.

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