No Reference Medical Image Quality Measurement Based on Spread Spectrum and Discrete Wavelet Transform using ROI Processing

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ABSTRACT: *In this paper a new No-Reference (NR) objective quality measurement method based on spread spectrum technique and discrete wavelet transform using ROI processing is proposed. In this method we divide the original image into two separate sub-images called ROI and non-ROI. Region of interest (ROI) is the decision area in a medical image which is very important .This area may indicate a disease and must resulted in a right diagnosis. We use the spread spectrum embedding algorithm to embed a binary mark into DCT transform of non-ROI part of image. This method is useful when guaranteeing a certain level of quality which is an important and vital concern.*

At the receiver side we extract ROI part with least degradation. Then the mark is extracted from non-ROI part and a measure of its degradation is used to estimate the quality of the original image. The performance of our proposed method is evaluated by calculating MSE and PSNR (of original and extracted mark) and measuring their correlation with degradation of the whole image. The applications of this work could be compression and storage of images with an acceptable quality level, or compression and transmission over a network for telemedicine applications while preserving an appropriate quality level.

Keywords: Image Quality, Spread spectrum, ROI Processing, No Reference, Objective Quality Measurement

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1. Introduction

Compressing a digital image can facilitate its transmission, storage and processing. As medical imaging become increasingly digital, the quantities of imaging data are forcing consideration of compression in picture archiving and communication systems (PACS) and evolving telemedicine systems. HIS (Hospital Information System) and PACS based on DICOM standard pave the way to store medical images and ease remote medical treatments. It has been reinforced through extensive research that the diagnostically important regions of medical images - the region of interest (ROI) - must be compressed by a lossless or a near lossless algorithm in order to preventing from a wrong diagnosis due to a poor image quality. Most of the quality metrics proposed in the literature are Full Reference (FR) metrics. The major drawback of the FR quality metrics for huge databases is that a large amount of reference information has to be provided at the final comparison point. It is essential to develop No-Reference (NR) quality metrics that blindly estimate the quality of an image. Most of the proposed NR metrics estimate annoyance by detecting and estimating the strength of commonly found artifact signals. In this paper we use a spread spectrum technique in order to data hiding(watermarking) and producing a reliable metric for estimating the quality of image[1].Although there are medical oriented watermarking studies in the literature and it is a valuable tool for copyright protection, patient and examination-related information hiding, data integrity control and source identification remain as major issues. In this work, we use watermarking in order to data hiding into non-ROI part of the image while preserving the quality of ROI part and in a manner which can estimate the quality of original image. Watermarking may be done in the spatial domain or in the transform domains such as DCT or wavelet .We choose to insert the mark in DCT domain because this is the domain still used by many compression algorithms such as JPEG standard.

An embedding system for watermarking purposes has to satisfy three main constraints:

*Invisibility-the mark should not affect the perceptual quality of the image and should not produce noticeable distortions in the received data.

*Robustness-the mark cannot be altered by malicious (an attempt to alter the mark) or unintentional (compression, transmission or filtering) operations.

*Security-the mark may not be removed from the image, even if the embedding scheme is known.

However, the use of the embedding system with the purpose of estimating the quality of the host image changes the priority and importance of these constraints. Invisibility for example, is a very important constraint because our goal is drastically reduced if the mark is visible. Robustness, on the other hand, is not so important. In fact if the mark is too robust, the extracted mark will not be affected unless the host image is severely degraded. If the mark is too fragile, the extracted mark will be lost by small degradations making it difficult to differentiate between medium or highly degraded images. Thus, for our application, the mark has to be semi-fragile and ideally it should degrade at around the same rate as the host image. To address this issue, we should meet some constraints described in [1].

2. Proposed Method

The block diagram of the proposed method is shown in figure 1. This figure shows the embedding procedure. At the receiver side we extract the embedded mark from watermarked image and use it for presenting a No Reference quality measurement metric. In this work, we divide the original image into two sub-images called ROI and non-ROI parts. ROI part is determined by a mask whose precise size is determined by a specialist. So we have:

$$O\,(i,j) = x(i,j) + y(i,j) \tag{1}$$

Where o is the host image, x is the ROI part and y is the non-ROI part. The indices i and j corresponds to the horizontal and vertical positions. This is illustrated in figure 2.

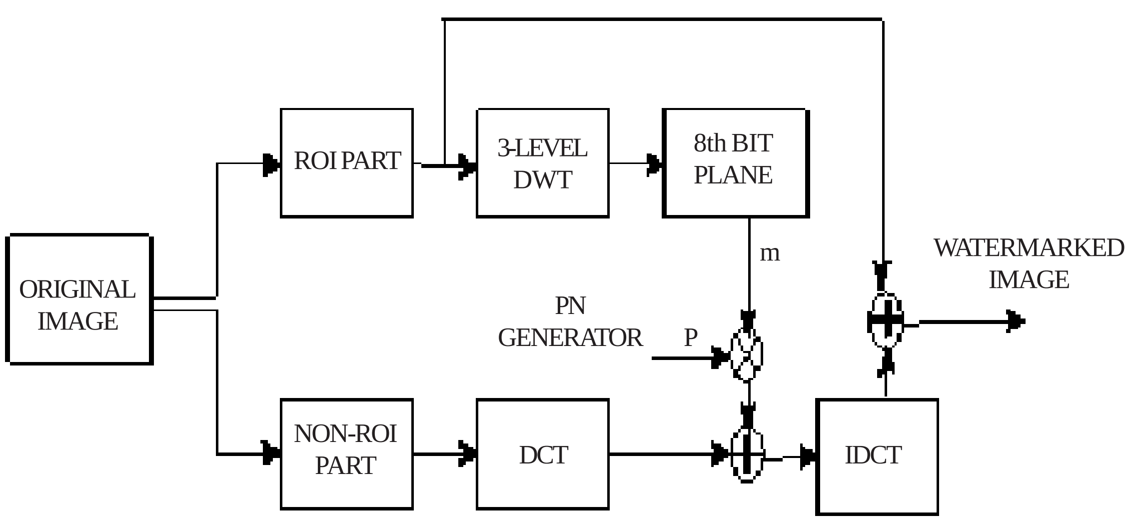

Figure 1. Block Diagram of the Proposed Method

2.1 Embedding procedure

we use 3-level wavelet transform of ROI image and 8^{th} bit plane of resulted image to make an initial binary mark called ***m***. See figure 3.

$$m(i, j) = 8th \text{ bit-plan of } (\text{ 3-level DWT of } (x(i, j))) \qquad (2)$$

In fact 3-level wavelet transform of the image is just to construct an initial mark which has a smaller size than original image. The initial mark could be any binary image because the final mark is a multiplication of initial mark and a pseudo random image.

There are many embedding algorithms such as spiral embedding around ROI part in the spatial domain [2]. Since our final goal is estimating the quality of original image, we embed the constructed mark into special frequencies of DCT domain of non-ROI image with use of spread spectrum technique. This method shows better results for the purpose of quality assessment. As stated before, we should not alter quality of ROI part. It seems that mid frequencies of DCT domain is appropriate for the purpose of assessing the quality of an image. Embedding the mark in low frequencies can change the whole luminance of an image and causes visible impairments; on the other hand embedding the mark in high frequencies produces a very fragile mark which is not robust enough against different types of noise. By dividing the original image into ROI and non-ROI parts and embedding the mark into mid frequencies of non-ROI part we have less variations in low frequency regions of non-ROI part. One of these low frequency regions which is important for us is the place onto which we want later add the ROI image. So by using of this technique in addition to embed the mark in a manner that can estimate the quality of whole image, we do not meaningfully affect the quality of ROI part.

As can be seen in figure 1, a pseudo-noise generator is used to generate a pseudo random image called $\boldsymbol{p} = p(i, j)$ with values -1 and 1,with a zero mean and Gaussian distribution.

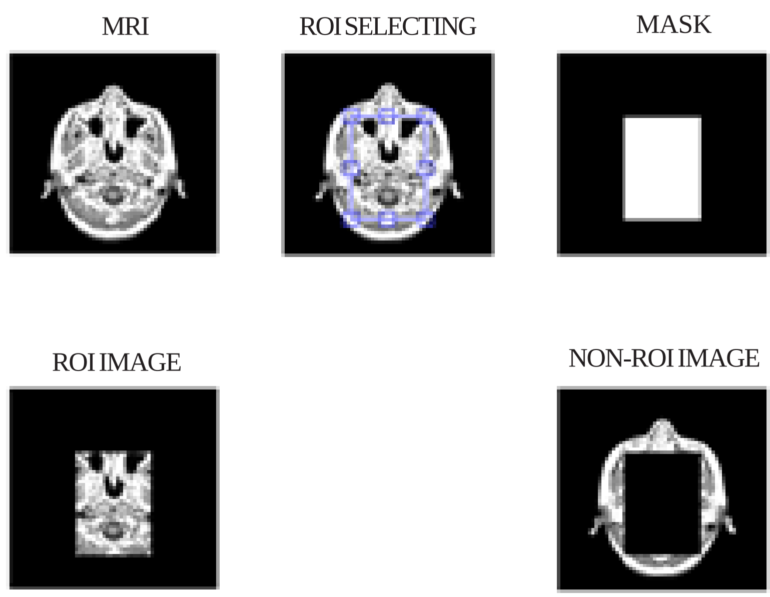

Figure 2. Procedure of Dividing Original Image to ROI and non-ROI Parts

The final mark is obtained by multiplying the binary mark image, ***m***, by the PN image ***p***.

$$w(i, j) = m(i, j).\mathrm{p}(i, j) \qquad (3)$$

Since the final mark which is to be embedded in the original image, has a random nature and it does not contain any information about the image, the proposed method is a No Reference metric. The next stage is embedding the final mark into DCT of non-ROI Part according to following equation:

$$Y' = \begin{cases} Y(i,j) + Q \,.\, w(i,j), & 100 \leq i,j \leq 200 \\ Y(i,j) & elesewhere \end{cases} \quad (4)$$

Where Y is the DCT of non-ROI part and Q is the scaling factor which is used to vary the strength of the mark. An increase of Q increases the robustness of the mark, but also decreases the quality of the image. The design of an embedding system requires that appropriate values of Q be chosen for each image. In this step we estimate the best mark strength based on the visibility threshold of the embedding impairments and the data hiding capacity of the host image [1].

The range of frequencies in which the mark is inserted, strongly depends on the application.

Then we do inverse DCT and due to preserving the quality of ROI part, we calculate an offset matrix which is resulted from watermarking. AT the final stage, we add the ROI part to inverse DCT of watermarked non-ROI part:

$$O'(i,j) = y'(i,j) + x(i,j) \quad (5)$$

Where y' is the inverse DCT of non-ROI watermarked part and o' is the final watermarked image illustrated in figure 4.(a).

Now the image is ready to be compressed in different qualities for storage intentions or to be transmitted over communication channel for telemedicine applications. A compressed image with JPEG quality of 50 is shown in figure 4.(b).

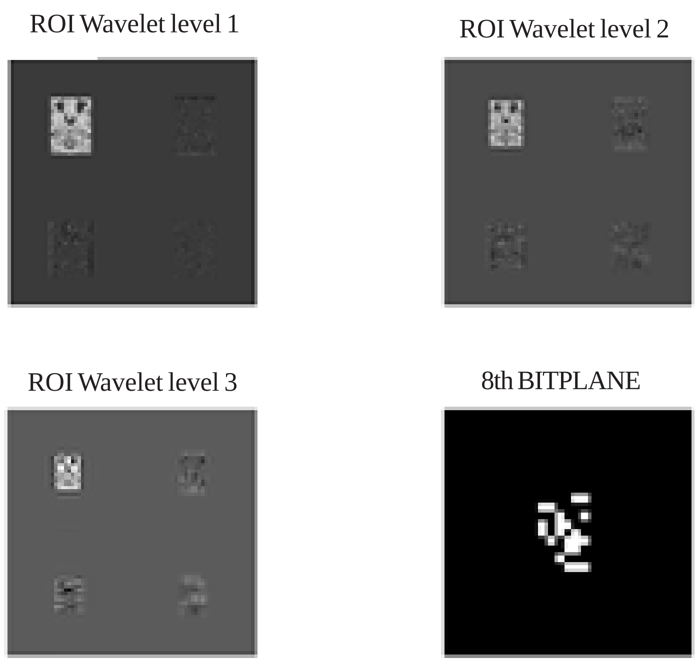

Figure 3. Initial Mark Construction

2.2 Detection procedure

After compression and/or transmission, at the receiver side we separate the received image into ROI and non-ROI parts again and we subtract the calculated offset matrix from that to obtain the important ROI part of the image with least degradation.

At the next stage we extract the embedded mark from non-ROI part. For that reason we do again DCT of non-ROI part and then multiply the same PN image to the same DCT coefficients as follows:

$$\begin{aligned} &for\ 100 < i,j < 200 \\ &Y''(i,j).p(i,j) = Y(i,j).p(i,j) + Qw(i,j).\,p(i,j) \\ &\qquad = Y(i,j).p(i,j) + Q.m(i,j).\,p(i,j).p(i,j) \end{aligned} \quad (6)$$

where Y'' is the DCT of non-ROI part. For the purpose of explaining the extraction of the mark, we assumed that $Y''=Y'$.

Since $p(i, j).p(i, j) = 1$ because $p(i, j)$ is either -1 or +1 ,the above equation becomes:

$$Y''(i, j) \, . \, p(i, j) = Y(i, j) \, . \, p(i, j) + Q.m(i, j) \tag{7}$$

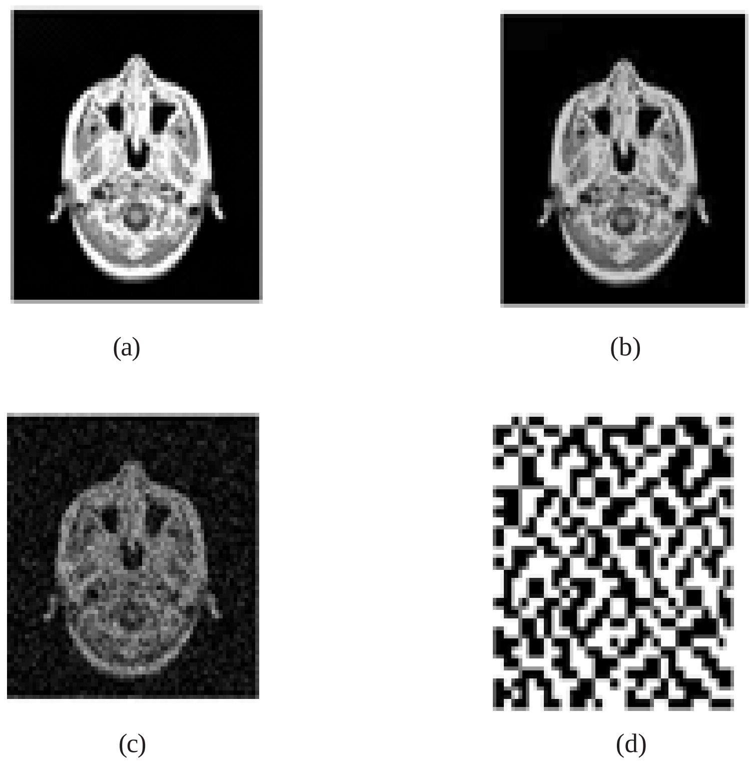

Figure 4. (a) Watermarked image, (b) Compressed image with JPEG quality of 50,(c) Noisy image, (d) Extracted mark

By using sign function we can extract the embedded mark:

$$\begin{aligned} m_r(i, j) &= sgn\,(Y''(i, j) \, . \, p(i, j)) \\ &= sgn\,(Y(i, j) \, . \, p(i, j) + Q. \, m(i, j)) \end{aligned} \tag{8}$$

Since the PN image has zero-mean, if we do an averaging operation we can eliminate the noise(PN signal)which is resulted from the spread spectrum embedding algorithm. Therefore the component $Y(i, j) \, . \, p(i, j)$ in sign function is suppressed.

Now when errors are added while compression or transmission, the extracted mark m_r is an approximation of the original mark m.

A measure of the degradation of the original mark is given by the *MSE* of the extracted mark m_r:

$$MSE = \frac{1}{I.J} \sum_i \sum_j [m(i, j) - m_r(i, j)]^2$$

where $I.J$ is the size of the mark.

The less the amount of errors caused by processing, compression or transmission, the smaller *MSE* is. On the other hand, the more degraded the image, the higher *MSE* is. Therefore, the measure given by *MSE* can be used as an estimation of the degradation of the original image. In fact with considering some constraints such as choosing a semi-fragile mark, we can reach to a same degradation rate for the host image and the mark [1].

3. Results

We examined the performance of our proposed metric with measuring correlation of whole image degradation and *MSE* and *PSNR* of the extracted mark. We considered 100 different images which were compressed by JPEG qualities from 1 to 100 and 100 other images which were degraded by Gaussian noise with zero mean and 0.01 to 0.1 standard deviation. This metric also outperforms the algorithm of spiral embedding in spatial domain [2].The results for spiral embedding is illustrated in figures 5 and 6.

As shown in figures 7 and 8, for the proposed metric the results are strongly correlated and the output dynamic range is higher as well.

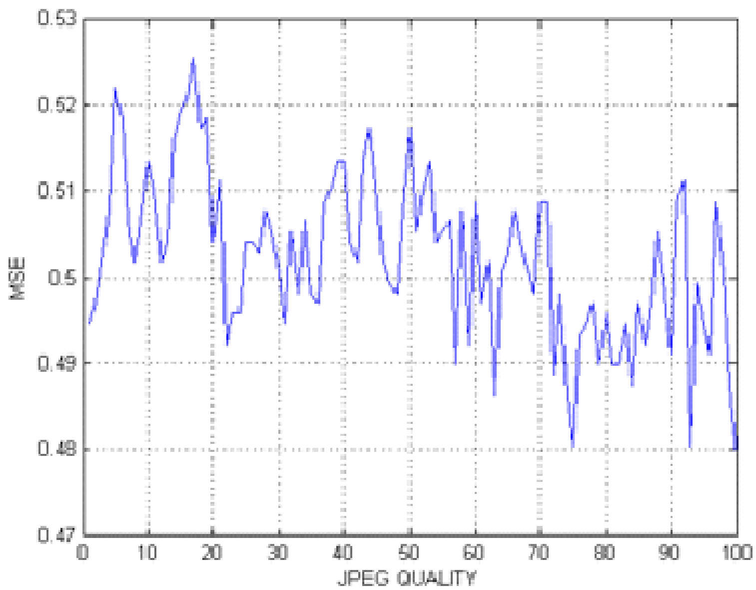

Figure 5. *MSE* in Spiral Embedding Method

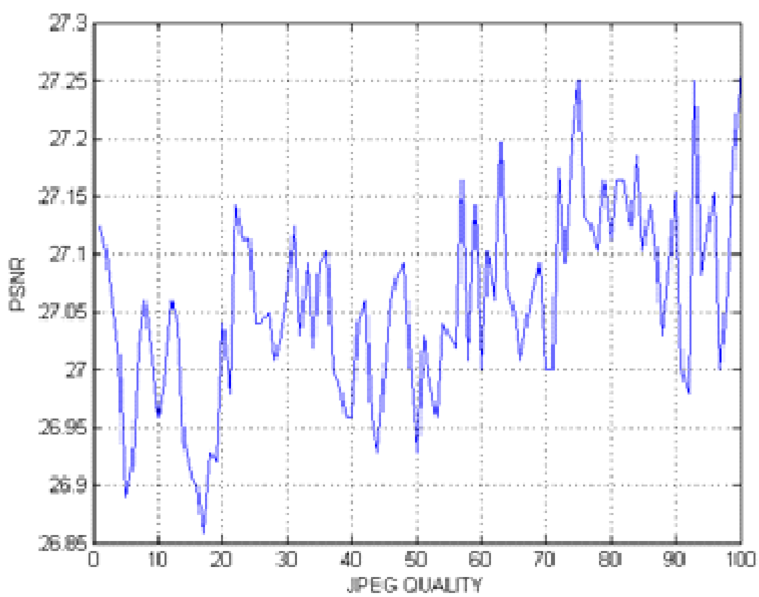

Figure 6. *PSNR* in Spiral Embedding Method

On the other hand, *MSE* and *PSNR* of the extracted mark are a good approximation of degradation of whole image which is done once by JPEG compression and then by adding Gaussian noise. In figure 9, *MSE* of 100 images degraded by Gaussian noise with scaled standard deviation in the range of 0.01 to 0.1 is shown. The results prove that the proposed metric works better than the spiral method.

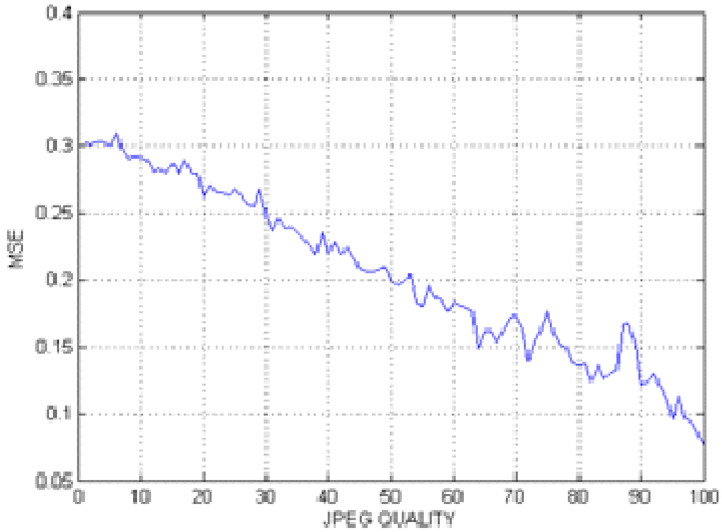

Figure 7. *MSE* in Spread Spectrum Embedding Method

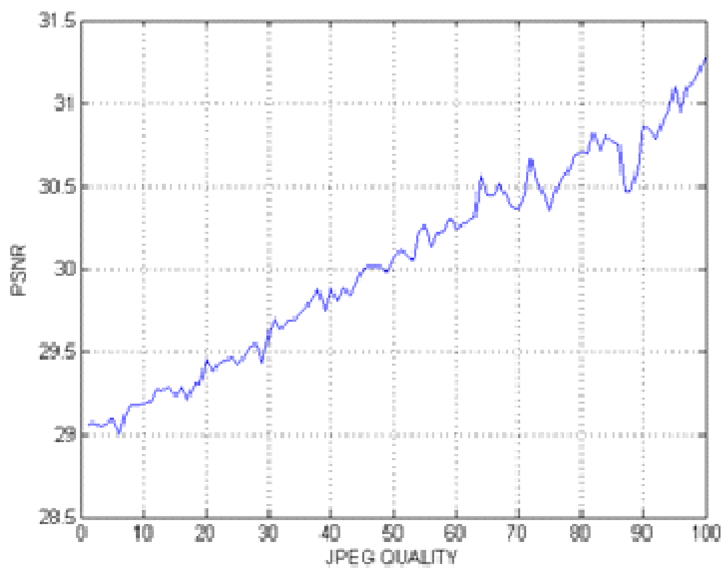

Figure 8. *PSNR* in Spread Spectrum Embedding Method

4. Conclusion

The main idea of this paper is presenting a watermarking method using spread spectrum and discrete wavelet transform based on ROI processing which is appropriate for No Reference quality measurement.

We evaluated the performance of the method by measuring correlation of the degradation of original image with objective metrics such as *PSNR* and *MSE*.

Results show that while preserving the quality of ROI part, there is a reasonable relationship and strong correlation between

MSE and *PSNR* of extracted mark and different compression qualities and Gaussian noise characteristics which were used as distortions for the whole original image. The proposed metric outperforms spiral embedding method as well. For future work, validation of the method with subjective measurements can be done.

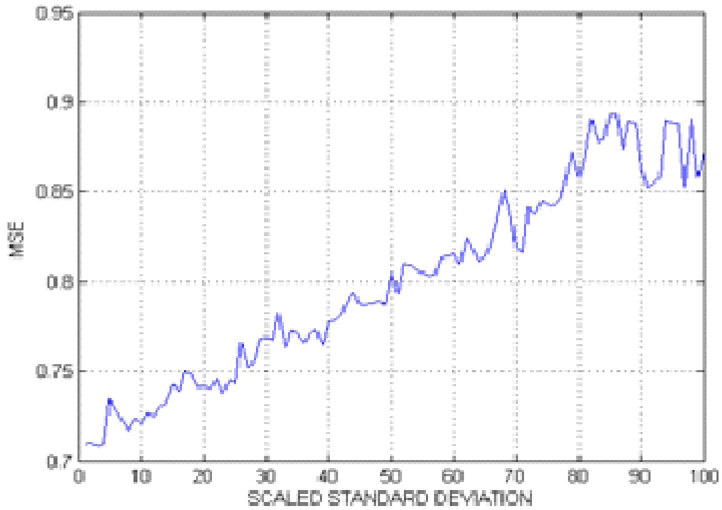

Figure 9. *MSE* in Spread Spectrum Embedding Method

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