QR Steganography for Information Hiding of Patient Record

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Abstract. In recent research studies, biosignals are used to study the behaviour of a human body function which are useful for medical diagnosis. Biosignals such as electrocardiogram (ECG) signals are used to determine the irregularities in heartbeat meanwhile electroencephalogram (EEG) signal is used to record the brain activity of a patient. This paper aims to put together a mechanism to hide patient details with image of patient medical biosignals using steganography. Patient details are stored in the QR Code meanwhile biosignals that are in 1 dimensional are converted into two-dimensional image. In this process of hiding the patient details and its biosignal, fine details may be lost. Thus, image enhancement process is needed. In this paper, methods such as Local Laplacian filter, Successive Mean Quantization Transform (SMQT) algorithm, Non-Local Means filtering, Bilateral filtering with Gaussian Kernel and Anisotropic Diffusion are used to evaluate the medical image quality of the biosignal. Quantitative metrics are used to evaluate the quality of implementation. The proposed method has given out results of Peak Signal-to-Noise Ratio (PSNR), Mean-Squared Error (MSE), Normalized Cross-Correlation (NCC) that are comparatively well with other established methods. Findings from this paper indicates improvement in the overall image quality of biosignals after extraction from its cover image using the proposed methods.

Keywords: Steganography · EEG · ECG · SMQT · QR Code

1 Introduction

Patient information is always tagged with their medical images which are then transmitted to the healthcare service provider over the internet. There is a high possibility that the information of the patient is being exposed over the internet by hackers or any third party with the purpose of knowing specific information about the patient. Steganography is a process of hiding an information in a cover image. Thus, a crucial challenge in steganography is to protect the secret image and achieve full retrieval of the secret image.

Greater attentions have been given on information leakage in the cyber territory but remains neglected in our physical world. Third party is able to acquire sensitive information such as health status, name, address, and National Registration Identity Card (NRIC) number without using any sophisticated technology. Ideally, private information

shall be protected in both cyber and physical worlds. Therefore, QR (Quick Response) Code has been introduced as carrier of patient information. QR Code is a 2D barcode that looks very simple yet able to store more information than 1D barcode.

A considerable number of previous studies has explored the reading of a signal, its processing, and identifying peaks of the signal but the displayed patient information on the signal monitor has not been a primary concern. Electrocardiogram or elektrokardiographie (ECG/EKG) and electroencephalogram (EEG) are among the electrical activity tests that can be used to check the behaviour of the heart and brain in human, which will be the dataset used in our research.

In image steganography of signals, the patient data and the medical image of signal (SMI) are the secret image. Patient data can be name, age, National Registration Identity Card (NRIC) and other medical records that are stored in a QR Code image and merged with a SMI.

The Least Significant Bit (LSB) algorithm is normally used to embed the secret image with a standard cover image such as the well-known *lena* and *baboon* images. However, this method is unable to retrieve the secret image without affecting its quality. In such cases, image enhancement techniques are used on the SMI.

In our proposed method, the Local Laplacian with Successive Mean Quantization Transform (SMQT) algorithms are used to enhance the quality of SMI. We proposed the Bicubic Interpolation Algorithm to interpolate the SMI with a QR Code image, which contains the patient data while the LSB is used for embedding and extracting of the secret image. The metrics such as the MSE (Mean-Squared Error), PSNR (Peak Signal-to-Noise Ratio) and NCC (Normalize Cross-Correlation) are used for performance evaluation.

2   Related Works

In [1], the medical image-based approach used by the researcher created a watermark image using the Dijkstra algorithm to protect the authentication of medical image. The visibility of the watermark depends on the reference value that was set by the researcher. The lower the reference value, the lesser the visibility of the watermark on the medical image.

To avoid unauthorized alteration on medical image, polynomial decomposition was used for image smoothing in [2]. Watermark were inserted and extracted on the smoothen medical image without any distortion on the medical image.

In [3], QR Code was hidden on an X Ray medical image using a steganography technique, which is the Discrete Cosine Transform (DCT). The medical image that acted as a cover image was normalized to be embedded with the QR Code that resulted to become a stego image. The inverse of DCT resulted in extraction of the QR Code from the medical image.

In [4], by using X Ray scans of images from the dataset of COVID-19, patient information was embedded in a medical image using the LSB steganography technique. Initially, the patient information was converted into a ciphertext using Baconian Cipher Generation before embedding with the medical image.

In the ECG steganography by [5], the Arnold Cat Map algorithm was used to scramble the ECG signal. Secret messages were converted into a ciphertext using the RSA Algorithm and embedded in the scrambled ECG signal using Singular Value Decomposition (SVD).

To avoid suspicion from intruders, [6] applied the Local Laplacian of Gaussian on the cover image to improve its quality when embedding with a secret image. Logistic maps were applied on the secret image to scramble and embed with cover image using LSB.

Accuracy of medical image plays main role in detecting symptoms in a patient. [7] used several filters such as the median filter for preserving image details, the Wiener filter for image smoothing and the NLM (Non-Local Means) filter. The filters were responsible in comparing the pixel weight and replacing the lower pixel weight with the heaviest pixel weight to improve medical image quality.

To preserve the edge of a medical image, [8] used bilateral filtering to reduce noise in medical image and apply sinusoidal enhancement to increase brightness of an echocardiogram medical image. Lastly, a piecewise linear transformation was applied on the medical image for improving contrast of the medical image by compressing the pixel value.

In [9], the researcher proposed anisotropic diffusion filter for reconstruction and smoothing a(n) MRI (Magnetic Resonance Imaging) medical image. Unsharp masking was applied after anisotropic diffusion filter on the MRI medical image for enhancing sharpness.

3   Methodology

Figure 1 shows the block diagram of our proposed method. The vital processes in this research starts by converting the 1D (one dimensional) medical signal into a 2D (two dimensional) image, which is the SMI. Then we apply Local Laplacian filter and SMQT algorithms on the SMI and interpolate the SMI with a QR Code image using Bicubic Interpolation Algorithm. After that, we embed and extract the secret image using LSB and finally execute performance evaluation.

3.1   Convert ECG and EEG Signals as 2D

An ECG signal in mat data format carries an average of 10 Kb of data. The dataset is a 1D signal with size of 10 Kb and is converted to 2D image. The dataset is taken from the MIT-BIH arrhythmia database with a frequency of 500 Hz. The signal is converted to 2D image to be a secret image. Meanwhile, another dataset that are used in our research is the raw EEG dataset for sleeping. The EEG data is in edf data format, which carries average of 127,086 KB and is also converted to 2D image. The dataset is taken from Zenodo.

3.2   Generate QR Code

There are up to 40 different versions of QR Code. The largest version, which is 40, is able to hold up to 7089 numeric characters, 4296 alphabetic characters or 2953 of 8-bit binary
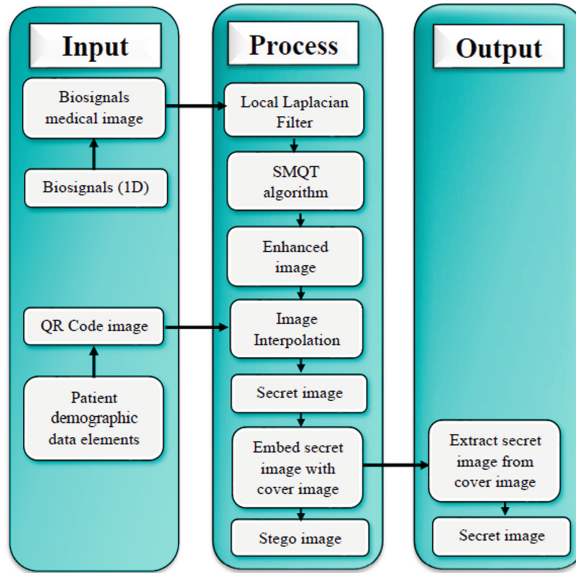
Fig. 1. Block diagram of proposed method using Local Laplacian and Successive Mean Quantization Transform (SMQT) algorithms.

numbers. The highlights of QR Code are the recovery capacity of 30 percent, which gives its strong resistance to damage. The QR Code used in this research is software generated. Patient information such as the name, address, and NRIC number are included in the QR code before generating the QR Code to be interpolated with the SMI.

3.3 Apply Local Laplacian with Successive Mean Quantization Transform (SMQT) Algorithm on Medical Image

3.3.1 Local Laplacian Filter

Local Laplacian filter focuses on changes in image intensity by using the second derivative method. It is particularly good at finding details in an image. Any existence of discontinuity of sharp feature will be enhanced by using the formula. The Laplacian function is defined as follows [12]:

$$\nabla^2 f(x, y) = \frac{\delta^2 f(x, y)}{\delta x^2} + \frac{\delta^2 f(x, y)}{\delta y^2} \tag{1}$$

where the partial 1st order derivative in the x-direction is defined as follows:

$$\frac{\delta^2 f}{\delta x^2} = f(x+1, y) + f(x-1, y) - 2f(x, y) \tag{2}$$

So, the Laplacian can be defined as follows:

$$\nabla^2 f = \left[f(x+1, y) + f(x-1, y) + f(x, y+1) + f(x, y-1)\right] - 4f(x, y) \tag{3}$$

which results to a matrix:

$$\begin{bmatrix} f(x-1,y-1) & f(x-1,y) & f(x-1,y+1) \\ f(x,y-1) & f(x,y) & f(x,y+1) \\ f(x+1,y-1) & f(x+1,y) & f(x,y-1) \end{bmatrix} \qquad (4)$$

Based on Local Laplacian filter algorithm, the results of using the 2nd derivative formula derive a matrix Eq. (5), which then will be mapped on each pixel.

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix} \qquad (5)$$

The 2nd derivatives from Laplacian formula are mapped on the image. Once the pixel values are calculated, the image pixel values will be compared with the image pixel intensity that carries 0–255 pixel. If the calculated pixel carries a negative value, the pixel value will be changed into 0 and if the pixel value exceeds 255, the pixel value remains as 255. Once the declared parameter satisfies the enhancement in the medical image, it has a better pixel intensity which results to a better quality of image.

3.3.2 Successive Mean Quantization Transform (SMQT) Algorithm

The SMQT algorithm involves three main steps, which are calculation of mean from pixels of an image, quantization the image pixel into either a 0 or 1 and splitting the pixel value into groups based on the quantized value [13]. The algorithm is as below:

1. Firstly, mean of image is calculated.

$$\bar{v}(x) = 1/|D| \sum x \varepsilon D \, v(x) \qquad (6)$$

2. Then the pixel is quantized into either 0 or 1.

$$\varepsilon(v(y), v(x)) = \{1, \textit{if } v(y) > \bar{v}(x)$$
$$= \{0, \textit{else} \qquad (7)$$

3. Finally, divide the image into 2 subsets according to Eq. (8).

$$D_0(x) = \{x|v(x) \le \bar{v}(x), \textit{for every } x \, \varepsilon \, D$$

$$D_1(x) = \{x|v(x) > \bar{v}(x), \textit{for every } x \, \varepsilon \, D \qquad (8)$$

Figure 2 represents the SMQT as a binary tree. The abbreviation of MQU in Fig. 2 represents the mean of image block of the calculated RGB value. Output of MQU represents as $U(x)$, which can be either a 0 or 1 value. At the first level, MQU is the output of the first calculated mean. Each level is represented as 2^{L-1} where L ranges
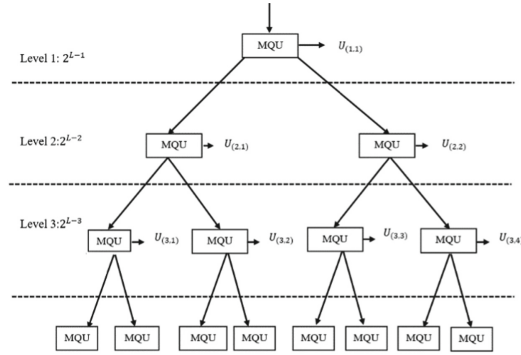
Fig. 2. The binary search tree of Successive Mean Quantization Transform (SMQT) for finding the mean value.

from 1, 2, …, $2^{(1-1)}$. The output of the mean of MQU is represented as $U(n1, n2)$ where $n1$, $n2$ has a range of 1, 2, 3, …, n. The values of U will be used to divide the pixel values into groups in the binary tree. The final results will be obtained when there are no groups of pixel value based on the calculated mean.

When medical image is loaded, the mean of the image pixel is calculated then the total mean is compared with each pixel in the image. If the mean value is greater than a pixel value, the pixel value is replaced with 1 else return a 0. Once the image is changed into all binary values, a binary tree iteration takes places according to its weight.

If the image current value is similar as previous image value, for an example, if previous image value is 0 and current image value is 0 then it returns a 0. If the image current value is not similar as previous image value, then return a 1. Once the binary tree iteration and comparison of values are completed, the process ends.

3.4 Interpolation of Medical Image with QR Code Image

When an image is cropped or enlarged or shrunk, the image quality gets poor. Resizing and increasing the number of pixels contained in an image, are able to preserve the quality of the image.

In a bilinear interpolation method, only four nearest pixels are chosen from the desired pixel. Compared to nearest neighbour interpolation, bilinear are considered well performed. Bilinear uses $k(x,y) = ax + bx + cxy + d$, where $k(x,y)$ is the intensity of the pixel.

Bicubic interpolation method is much more complex than bilinear interpolation method. In bicubic interpolation method, the intensity value of pixel in coordinates of $p(x,y)$ are obtained by interpolating sixteen nearest neighbour pixels by using Eq. 9.

$$p(x, y) = \sum_{i=0}^{3} \sum_{j=0}^{3} a_{ij} x^i y^i \tag{9}$$

During mapping of smaller image (QR Code image) into bigger image (ECG and EEG SMI), the smaller image needs to be resized into small size. Therefore, during

resizing there might be a loss of pixel intensity. Use of Bicubic interpolation allows choosing of closer neighbourhood pixels to provide sharper images. Resolution value is also set to get a better image quality.

3.5   Embedding and Extracting Secret Image Using LSB Steganography

The suitable invisible hiding method that fits this research is LSB steganography. The basic idea of LSB method is to hide a secret image in a cover image based on pixels of the cover image. Once the secret image is embedded with the cover image, now the cover image becomes a stego image. The advantage of using LSB steganography is that there is high possibility of less distortion occurring during embedding. The embedding and extracting concept are demonstrated as follows:

Assume secret image in binary: 110100011.

Assume cover image in binary:

11111111	11001010	11011010
11000011	10001010	10000010
11100000	11001110	11111110

After applying LSB:

| 1111111**1** | 1100101**1** | 1101101**0** |
| 1100001**1** | 1000101**0** | 1000001**0** |
| 1110000**0** | 1100111**1** | 1111111**1** |

The last bit of binary values on the cover image is replaced with each bit of secret image. Stego image is the result from the embedded process of LSB.

3.5.1   Embedding Secret Image in Cover Image Using Least Significant Bit (LSB)

Figure 3 shows a flowchart on embedding a secret image into a cover image. The secret image in this research is the SMI with a QR Code image that carries patient information. The cover image used is *lena*. Both secret image and cover image are initially demarcated into the size of cover image. Then the secret image is converted into binary to be traversed into the cover image. The result of embedding a secret image and a cover image is a stego image.

3.5.2   Extracting Secret Image from Cover Image Using Least Significant Bit (LSB)

Figure 4 shows a flowchart of extracting the secret image from the cover image. Initially the size of the stego image is examined. If the sizes of the cover image and secret image are similar, then the stego image is traversed and pixels are extracted. The pixel that is initially in binary format is converted to pixel intensity values.
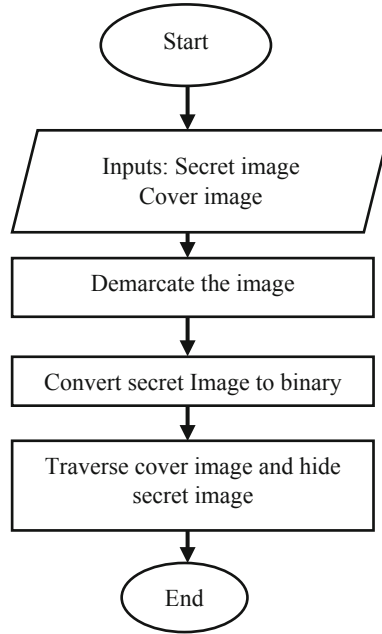
Fig. 3. Flowchart on embedding a secret image into a cover image.

4 Performance Evaluation

The proposed method is tested on both the cover image and secret image. There are three distortion quality measure used for evaluation. These are the PSNR, MSE and NCC.

4.1 Peak Signal-To-Noise Ratio (PSNR)

The PSNR is a distortion measurement between a cover image and a stego image. The higher the PSNR, the greater the quality of the image, which also indicates greater similarity between two images. PSNR is calculated as Eq. 1, where L represents the maximum intensity level of an image.

$$PSNR = 10\log_{10}(\frac{(L-1)^2}{MSE})$$

(10)

4.2 Mean-Squared Error (MSE)

The MSE calculates the error between two images, which is the cover image and stego image. MSE is calculated as in Eq. 2 where O refers to the original image, S refers to the stego image, m is numbers of rows, n represents the number of columns, i is the row
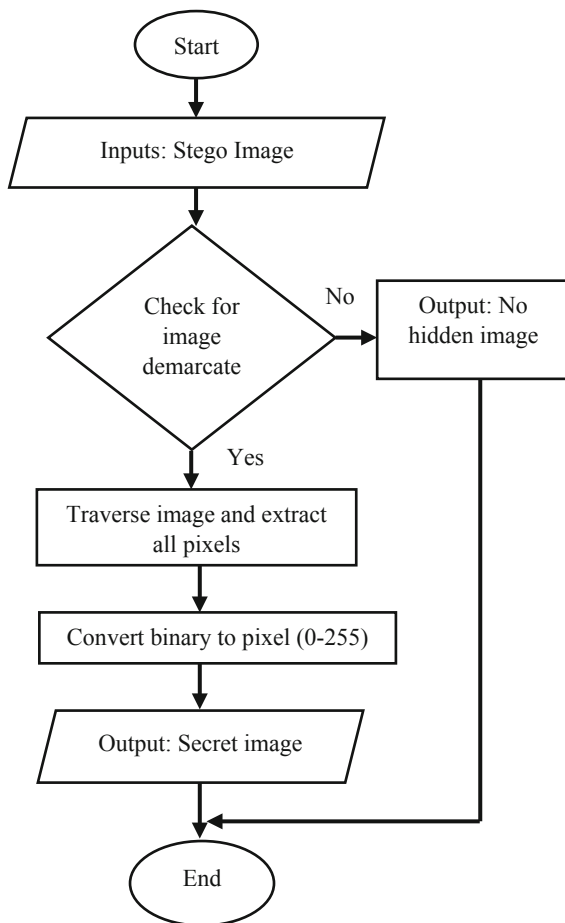
Fig. 4. Flowchart of extracting the secret image from the cover image.

index and j is the column index. When the calculated error between the images is closer to 0, it is assumed to produce a better image quality.

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} (O(i,j) - S(i,j))^2 \tag{11}$$

4.3 Normalized Cross-Correlation (NCC)

The NCC denotes the correlation between the secret image and the extracted secret image. Equation (3) shows the calculation for NCC where Ic denotes as secret image and Is is the extracted secret image. Meanwhile M and N are the number of rows and columns in an image. A calculated correlation that is closed to the value 1 is to be
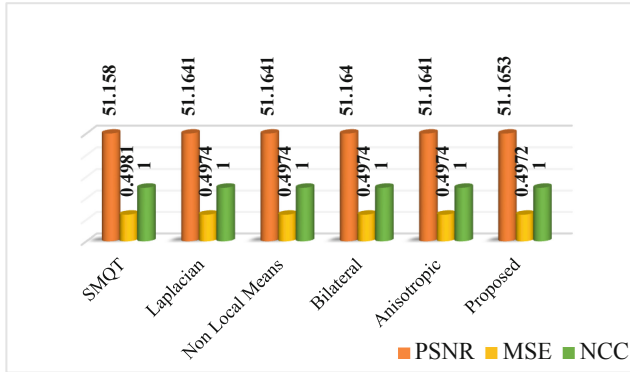
Fig. 5. Comparison five techniques on electrocardiogram (ECG) image.
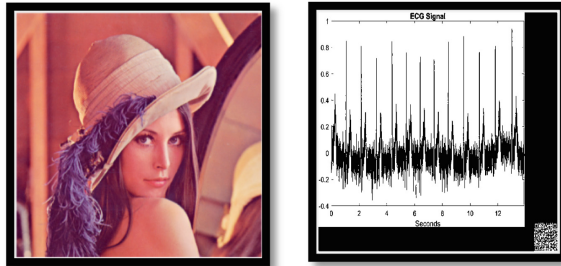
Fig. 6. Results of stego image and extracted secret image (ECG image with QR Code).

indicated as highly correlated. If the value of correlation is exactly 1, the secret image
is very similar.

$$NCC = \frac{\sum_{i=0}^{N-1} \sum_{j=0}^{M-1} I_c(i,j) I_s(i,j)}{\sum_{i=0}^{N-1} \sum_{j=0}^{M-1} I_c^{2}(i,j)} \tag{12}$$

Figure 5 shows the results of ECG image that is used as a secret image. The cover
image *lena* is used for embedding and extraction process with the secret image. Findings
from this result indicates that Local Laplacian filter with SMQT algorithm has given out
results of PSNR (51.1653), MSE (0.4972), and NCC (1.000) that are comparatively well
with other established methods.

Figure 6 shows a stego image and the extraction of the SMI of ECG with QR Code
(secret image). Neither the stego image nor secret image, have big impact of distortion
on both images.

Figure 7 shows the result of EEG image used as a secret image. The cover image *lena*
is used for embedding and extraction process with the secret image. Findings from this
result indicates that Local Laplacian filter with SMQT algorithm has given out results
of PSNR (51.1653), MSE (0.4973), and NCC (1.000) that are considerably well with
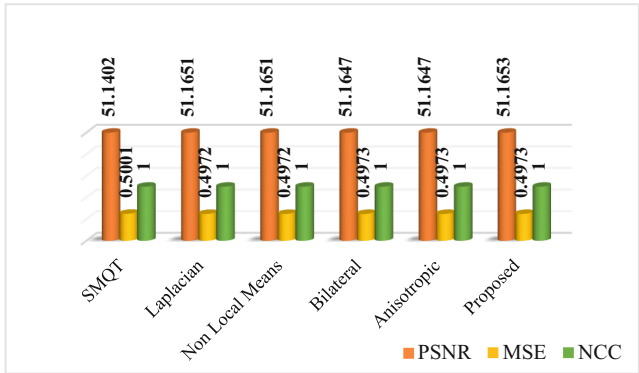other established methods.

Fig. 7. Comparison five techniques on electroencephalogram (EEG) image.
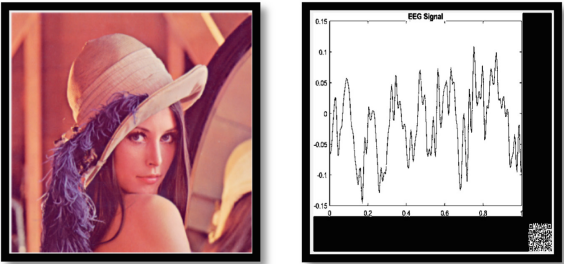

Fig. 8. Results of stego image and extracted secret image (EEG image with QR Code)

Figure 8 shows a stego image and the extraction of the SMI of EEG with QR Code (secret image). The secret image is well extracted using LSB and the proposed techniques.

Table 1 shows the researchers [10] and [11] who used *lena* and *baboon* images as their cover images for comparison with our proposed method. In this research, the SMI is interpolated with QR Code image and embedded in a cover image and used similarly as with [10] and [11]. Researcher [10] used QR Code image as secret image while researcher [11] used medical image to be secret image; both embedded them in the cover image of *lena* and *baboon.* As shown in Table 1, the PSNR values of [10] are about 48dB and 46dB, respectively and [11] are both 51dB and our proposed methods are also both 51dB for *lena* and *baboon* cover images, Thus, we can conclude that our proposed method has performed equally well and improved the image quality with less distortion.

5   Conclusion

Patient information is a crucial information that shall be protected together with a diagnosed SMI. This protection of information can be done through steganography. Healthcare field requires method that helps in protecting and preserve medical information

Table 1. Comparison of PSNR with other researcher methods

Cover Image	[10]	[11]	Proposed Method
lena	48.2092	51.1404	51.1653
baboon	46.8326	51.1407	51.1643

without any alteration of data, which helps them in acquiring the solution of a diagnosed disease. In our proposed method, the SMI and QR Code image, which carries patient information are interpolated together to be embedded into a cover image using the LSB method that gave out a stego image. It is observed that by using the proposed method, our secret image quality improves compared to the secret image without applying any techniques. PSNR is used to evaluate the performance of this method and we compare the results with other researchers that used similar cover image. Converting the SMI with QR Code and implement these in a blockchain will be the future work of this research.

Authors' Contributions. Subramaniam A: Data Curation, Methodology, Investigation, Validation, Writing – Original Draft Preparation; Mohd-Isa W: Conceptualization, Formal Analysis, Supervision, Writing – Review & Editing; Yap T: Project Administration, Supervision.

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