

PERCEPTUAL MODEL BASED DATA EMBEDDING IN MEDICAL IMAGES

S. Dandapat, Opas Chutatape and S. M. Krishnan

Biomedical Engineering Research Centre, Nanyang Technological University, Singapore

ABSTRACT

In this work, we propose a perceptual model based technique for embedding patient information in a medical image. The distortions in the diagnostic information-content, which will arise due to data embedding, can be controlled using a Perceptual Quality Measure (PQM). A Perceptual Quality Distortion Measure (PQDM) has been defined to measure the visible distortions between the original image and the processed image. The PQDM increases with the increase in the quantity of data embedded into the image. However it has been shown that the PQDM has different values when the same quantity of data is embedded into different regions inside the image, whereas the peak signal to noise ratio (PSNR) is only dependent on the quantity of embedded-data and does not show any change when the same quantity of data is embedded at different regions in the image. Quantification of correlation between PQDM and the loss in diagnostic information in medical images could play the key role for further work in this research area.

Index Terms — Data Embedding, Medical Image, Perceptual Quality Measure, PSNR

1. INTRODUCTION

In the recent years, telecommunication and information engineering has seen emergence of many new technologies. Data hiding and data embedding techniques are proposed for efficient use of the limited channel bandwidth [1], [2], [3]. Embedding of medical data has the additional requirements such as retention of diagnostic information and privacy of patient. Embedding patient's information directly into the image through data embedding technology can play an important role. Patient data are normally confidential in nature. Current medical record formats store image data and the textual information in separated fields. If an intruder can access the database, he is able to modify the attached text containing the confidential patient information.

Embedment of data in an image can help the data to remain intact across the varying data file formats.

Acharya *et al* [2] have suggested a least significant bit (LSB) coding method for embedding data on the pixels of a medical image. Though the method shows very small error in the host image due to data embedding, the embedded data does not have any security. Chao *et al* [1] proposed bipolar multiple number-base to hide different patient-data in a marked image. While extending the techniques proposed for use in multimedia applications [4] to the area of medical data embedding, it is required to retain the diagnostic accuracy of the data.

In this paper, we propose a perceptual model based technique for embedding medical data in a fundus image. In section 2, the perceptual model and the spatial domain LSB coding method for data embedding are presented. Results and discussion are presented in section 3. Finally, section 4 presents our conclusion and proposal for the future work on this problem.

2. PERCEPTUAL MODEL BASED DATA EMBEDDING

Figure 1 shows the block diagram of the proposed method. The input RGB color image is converted to a YIQ (luminance and chrominance components) color image. The luminance image is evaluated using a Perceptual Quality Measure (PQM). Using the perceptual quality measure, a subset of pixels is chosen for embedding patient data into them. This will help in avoiding the distortion of the diagnostic information in the image.

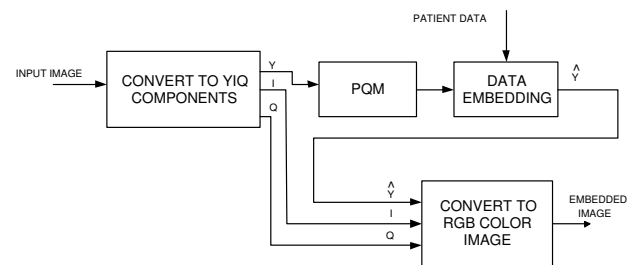


Figure 1: Proposed method for embedding data in a medical image.

2.1. Perceptual Quality Measure (PQM)

Contrast is an invariant perceptual attribute. It is known that perceptual tolerance is high for high contrast regions. Therefore, the contrast of a local region (block) is evaluated to determine the suitability for data embedding. Figure 2 shows the block diagram of the proposed perceptual quality measure. The perceptual quality measure is based on the estimation of the contrast energy [5]. The luminance image ($Y(i,j)$) is divided into blocks of 8x8 pixels. The blocks of pixels are passed through a contrast sensitive function (CSF) filter. The CSF is based on the model of Mannos and Sakrison [6] which is given as

$$A(f) = 2.6(0.0192 + 0.114f)e^{-(0.114f)^{1.1}} \quad (1)$$

where $f = (f_x^2 + f_y^2)$, f_x and f_y are spatial frequencies.

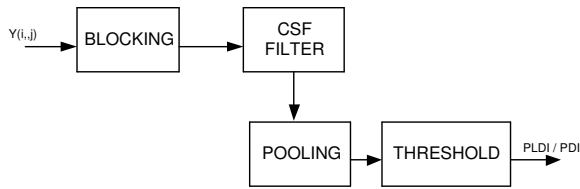


Figure 2: Block diagram of Perceptual Quality Measure (PQM)

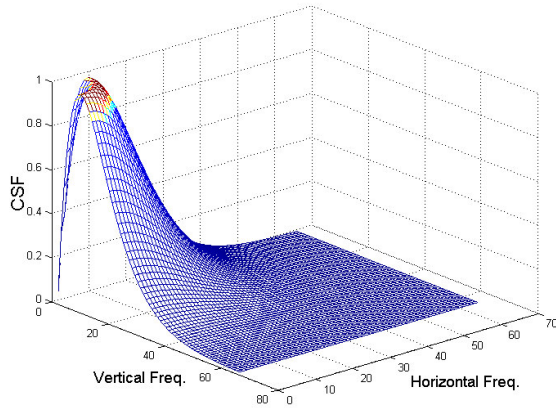


Figure 3: Two dimensional contrast sensitive function.

The CSF for two-dimensional case is shown in Fig. 3. The contrast of each pixel in an image block is estimated as the luminance of the pixel minus the mean luminance in each block. The PQM is implemented in three steps [5]. First, discrete Fourier transform (DFT) of the contrast block is evaluated. Let $X(u,v)$ be the DFT coefficients. A

gain matrix, $a(u,v)$, is computed at these DFT frequencies, assuming that 32 pixels subtend 1 degree visual angle. Then the DFT coefficients are element-wise multiplied by the gain matrix to obtain $a(u,v)X(u,v)$. The last stage is the pooling (probability summation) of all the transform coefficients $a(u,v)X(u,v)$ using a Minkowski metric (β -norm) which is given as

$$CCP = \left(\sum_u \sum_v \{a(u,v)X(u,v)\}^\beta \right)^{\frac{1}{\beta}} \quad (2)$$

where CCP is the contrast characterization parameter. In spatial vision models, probability summation arises from an attempt to combine the separate probabilities that individual channel outputs will be seen. The threshold is a value of CCP or a range of CCP values. This threshold is used to select the blocks of pixels suitable for data embedment. The pixels suitable for data embedment are named as pixels with least diagnostic importance (PLDI) and the other pixels are named as pixels with diagnostic importance (PDI). The central problem lies with the selection of proper threshold (T_{DD}) for data embedment without any diagnostic distortion. The data embedment process can be described as

$$\hat{Y}(x,y) = \begin{cases} Y(x,y) + (P(x',y')), & \text{if } CCP_{x,y} < T_{DD} \\ Y(x,y), & \text{Otherwise} \end{cases} \quad (3)$$

where $Y(x,y)$ are the pixels from the luminous component of the image, $CCP_{x,y}$ is the contrast characterization parameter of the block containing the pixel (x,y) . $P(x',y')$ is the patient data which may be in the form of an image containing patient information. Other type of patient data such as medical signals or textual information can also be considered for embedment into the image in the similar way.

2.2. Data Embedding

A method of inserting data into digital signals in noise-free environments is the least significant bit (LSB) coding [7]. LSB coding has been proposed and used for embedding patient information with medical images [2]. For an 8-bit pixel representation, the intensity error will be 256th part of its original intensity if all the pixels of the host image is affected by embedding data. Figure 4 shows the effect of hiding a patient information on a fundus image. Fundus image has been used for diagnosis of different pathologies of the eye such as microaneurysms, hard exudates and cotton wool spots, hemorrhages and edema [8]. The white patches on this image may be exudates which are diagnostic symptoms for diabetes. This diagnostic

information may be affected if an external data is embedded into this image. Figure 4(a) shows the original fundus image and Fig. 4(b) shows a patient's identity information superimposed on the fundus image. Here, the patient's identity is a binary image. Fig. 4(c) shows the LSB coded image in which the patient's identity has been embedded in the same location as shown in Fig. 4B. Figure 4(d) shows the extracted patient's identity from the coded image. Though the exudates represented by the white patches on the image are observed as unaffected by the embedding of the patient's identity in the same location, it will be useful to quantify the perceptual changes with this type of data embedding.

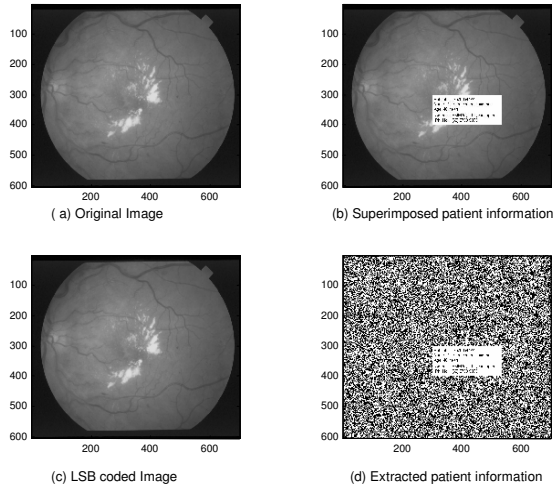


Figure 4: Embedment of patient information using LSB coding

In case of data embedding with medical signals and images, retention of diagnostic information in the host data as well the embedded data is important. DICOM (digital imaging and communications in medicine) standards are suggested for any compression, storing and transmission of medical data [9]. This ensures retention of the diagnostic accuracy of the data. For securing the confidentiality of the embedded data, the pixels of the host image, which are embedded, can be chosen randomly with a key. A particular pixel is chosen from the set of PLDI's using a random key. The LSB of the selected pixel is replaced with a bit from the patient data. For quantifying the distortions in the host image due to data embedding, a perceptual quality distortion measure (PQDM) has been defined as

$$PQDM = \frac{\text{sqrt} \left\{ \sum_{i=1}^{N_b} \sum_{j=1}^{M_b} [CCP_{em}(i, j) - CCP_{or}(i, j)]^2 \right\}}{\left\{ \sum_{i=1}^{N_b} \sum_{j=1}^{M_b} CCP_{or}(i, j) \right\}} \times 100 \quad (4)$$

where CCP_{em} and CCP_{or} are the values of contrast characterization parameters of the embedded image and the original image respectively. N_b and M_b are the number of row and column blocks.

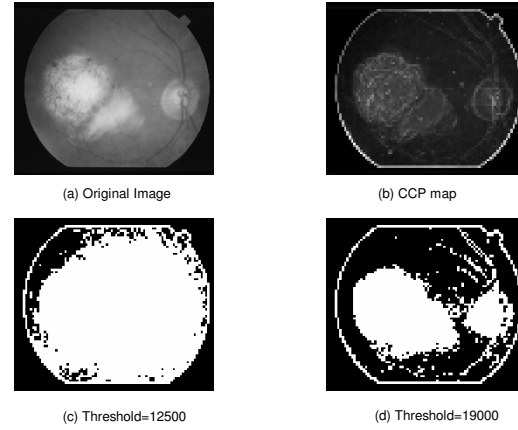


Figure 5: A fundus image, the CCP map and modified CCP maps with different thresholds.

3. RESULTS AND DISCUSSION

Figure 5 shows a fundus image, its contrast characterization parameter (CCP) map and pixel blocks with two threshold values. The CCP map in Fig. 5(b) shows that the values of contrast characterization parameter are different for different regions in the image. The regions having white patches in the image and the blood vessels have higher values of the CCP . The regions correspond to the outside of the circular retinal image have lower values of CCP . Lower values of CCP are also observed at the regions which do not have much diagnostic information. Figure 5(c) and 5(d) shows modified CCP maps with different thresholds. If the CCP value is less than the threshold, it is assigned a value equal to zero. Otherwise a higher constant value is assigned to it. The dark regions in the image are having CCP values below a threshold value. The data embedding can be limited to regions mostly outside the circular retina image if we choose pixel blocks with a threshold of 12500 as shown in Fig. 5(c). Similarly, by choosing a threshold value of 19000, we will have more number of pixel blocks available for data embedding.

It will be of interest to quantify the distortions when data is embedded into the medical image. Table 1 shows the values of PSNR and PQDM (perceptual quality distortion measure) as functions of quantity of data embedded into a fundus image. A random array of bits is

produced using a zero mean normally distributed random number generator. This array of bits is used for embedment into the fundus image. As the number of embedded bits increases, the PSNR value decreases. The percentage value of PQDM increases with the increase in the number of embedded bits. To show that data embedding will have different perceptual effects on different regions in the image, we have chosen two regions for data embedding. It is interesting to observe that for the same number of embedded bits, there is substantial difference in the value of PQDM between the two regions whereas the PSNR value is almost equal for the two regions. This suggests that PQDM can better characterize the perceptual differences when data is embedded into an image.

TABLE 1: EFFECT OF DATA EMBEDDING ON PSNR & PQDM

No. of Bits	Region 1		Region 2	
	PSNR (dB)	PQDM (%)	PSNR (dB)	PQDM (%)
2.5×10^3	36.49	30.27	36.75	14.47
10.0×10^3	33.83	34.24	33.67	16.59
22.5×10^3	31.87	36.82	31.91	18.05
40.0×10^3	30.57	38.30	30.67	18.77
62.5×10^3	29.62	39.02	29.69	19.17
90.0×10^3	28.84	39.51	28.90	19.42
122.5×10^3	28.17	39.89	28.24	19.64
160.0×10^3	27.59	40.18	27.65	19.80
202.5×10^3	27.09	40.41	27.14	19.92
250.0×10^3	26.63	40.59	26.68	20.03

4. CONCLUSION

In this work, a perceptual model based data embedding technique has been proposed. We have shown that embedding data into different regions will have different perceptual effects on the image. This technique can help embed data into regions of least diagnostic importance by choosing a suitable threshold. Quantification of correlation between the diagnostic information in the medical image and the proposed diagnostic distortion threshold will help use of this model for secure and efficient embedding of medical data into a medical image.

5. REFERENCES

- [1] H. Chao, C. Hsu and S. Miaou, "A data hiding technique with authentication, integration and confidentiality for electronic patient records," *IEEE Trans. Information Tech. in Biomedicine*, vol. 6, pp. 46–53, Mar. 2002.
- [2] U. R. Acharya, D. Anand, P. S. Bhat and U. C. Niranjana, "Compact storage of medical images with patient information," *IEEE Trans. Information Tech. in Biomedicine*, vol. 5, pp. 320–323, Dec. 2001.
- [3] S. Dandapat, O. Chutatape and S. M. Krishnan, "Spatial and spectral domain data embedding with medical images", *International Conference on Advances in Pattern Recognition (ICAPR 2003)*, Dec.2003, Kolkata, India, pp. 363-366.
- [4] C. I. Podilchuk and W. Zeng, "Image-adaptive watermarking using visual models", *IEEE Journal on Selected Areas in Communication*, vol. 16, no. 4, pp. 525-539, May 1998.
- [5] N. B. Puhana and A. Makur, "A robust image watermarking scheme based on perceptual contrast energy", *International Conference on Intelligent Sensing and Information Processing (ICISIP 2004)*, January 2004, Chennai, India, pp. 114-118.
- [6] J. L. Mannos, D. J. Sakrison, "The effects of a visual fidelity criterion on the encoding of images", *IEEE Trans. Info. Theory*, 20(4), 1974, pp. 525-535.
- [7] I. J. Cox, J. Killan, T. Leighton and T. Shamoon, "Secured spread spectrum watermarking for multimedia," *IEEE Trans. Image Processing*, vol. 6. no. 12, pp. 1673-1687, 1997.
- [8] Luo Gang, Opas Chutatape and Shankar M. Krishnan, "Detection and measurement of retinal vessels in fundus images using amplitude modified second order Gaussian filter," *IEEE Trans. Biomedical Engineering*, vol. 49, no. 2, pp. 168-172, 2002.
- [9] Digital Imaging and Communications in Medicine (DICOM), Part 5: Data Structures and Encoding. Available:http://www.medical.nema.org/dicom/2003/03_05_PU.PDF.