16-Bit DICOM Medical Images Lossless Hiding Scheme Based on Edge Sensing Prediction Mechanism

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Abstract. Medical imaging is an important part of patient records. The pixel of a 16-depth DICOM image is totally different from the 8-bit depth nature image and is seldom the same as the other pixels in the nearby area. In this paper, we propose a reversible hiding method that expands Feng and Fan's prediction technique and adapts the scheme to match the characteristics of medical image. In the previous work, we determine what prediction method should be applied based on standard deviation thresholds to obtain more accurate prediction results. Finally, our approach includes embedding hidden information based on the histogram-shifting technique. The experimental results demonstrate that our approach achieves high-quality results.

Keywords: Medical imaging, Reversible data hiding, Standard deviation, Histogram shifting technique.

1 Introduction

Medical images are important data. Because Digital Imaging and Communications in Medicine (DICOM) constantly evolves, medical information can now be easily stored and sent via the Internet. Therefore, several data hiding techniques using digital medical images have been developed [1].

Data hiding techniques will induce some permanent destruction of the host image after embedding the hidden information. Therefore, several articles present research on reversible data hiding (RDH) to restore the hidden image to the original image without any loss whatsoever [5]. One approach is to use the differences between image pixels and the expansion prediction value to embed information [6]. One approach is to use the pixel distribution or the difference between prediction values and original pixels to analyze a histogram and embedded information in peak values [7]. In this paper, we use different prediction methods for pixels blocks in which the method used depends on where the standard deviation calculated for a block falls between two different thresholds. To reduce the artificial influence of threshold setting, this research utilizes an adaptive method to set the thresholds.

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2 Related Works

Yang and Tsai proposed partitioning pixels into two sets, such as one resembling a checkerboard pattern, with hidden information determined based on a histogram shift technique [7]. Below are the equations defining the two pixel sets:

$$\begin{cases} \alpha = x_{(i,j)}, & if \quad (i\%2) = (j\%2), \\ \beta = x_{(i,j)}, & if \quad (i\%2) \neq (j\%2), \end{cases} \tag{1}$$

where $x_{(i,j)}$ is the original set of pixels, and i and j represent the pixel position in a two-dimensional image. Let $\alpha = \{x_{(0,0)}, x_{(0,2)}, \ldots, x_{(m\text{-}1,n\text{-}1)}\}$ and $\beta = \{x_{(0,1)}, x_{(0,3)}, \ldots, x_{(m\text{-}1,n\text{-}2)}\}$, where $\alpha \cap \beta = \phi$.

Lukac et al. proposed a prediction approach through neighboring pixels to calculate edge-sensing weight coefficients [4]. They utilized neighboring pixels to calculate weight coefficients through the following formula:

$$p_{(i,j)} = \left\lfloor \sum_{k=1}^{4} w_k r_k \right\rfloor, \tag{2}$$

where $p_{(i,j)}$ is the prediction value, w_k is the weight of neighboring pixels, r_k is the k^{th} neighboring pixel, i and j are the pixel positions in the two-dimensional image, and k is the position set of neighboring pixels where $k = \{(i,j-1), (i-1,j), (i,j+1), (i+1,j)\}$. Through equation (2), we calculate weight w of position set k so that the prediction value $p_{(i,j)}$ is the sum of $w_k r_k$. Edge-sensing coefficients are utilized to calculate weight w_k through the formula below:

$$u_l = \frac{1}{1 + \sum_{k=1}^{4} |r_l - r_k|}, \tag{3}$$

where $l = \{(i,j\text{-}1), (i\text{-}1,j), (i,j+1), (i+1,j)\}$. Using equation (3) to determine the degree of difference among neighboring pixels, if r_l is greater than r_k, u_l will be close to zero. Otherwise, if r_l is smaller than r_k, then u_l will be close to one. Finally, we obtain w_k of the 4-neighbor pixels by calculating the normalized value of u_k with the following formula:

$$w_l = \frac{u_l}{\sum_{k=1}^{4} u_k}. \tag{4}$$

In 2012, Feng and Fan applied Lukac's method to hide data [3]. They assume 4-neighbor pixels $r_{(i,j-1)}$, $r_{(i-1,j)}$, $r_{(i,j+1)}$, and $r_{(i+1,j)}$ have different contribution to prediction value $p_{(i,j)}$. They use some additional pixels to compute the contribution of each