An Anomaly Detection Method Based on Fuzzy Histogram Hyperbolization and Gray Level Co-occurrence Matrix

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Abstract

A method for an anomaly detection system was developed to automate process of recognizing an anomaly of roentgen image by utilizing fuzzy histogram hyperbolization image enhancement and gray level co-occurrence matrix(GLCM). The system consists of image acquisition, pre-processor, feature extractor, response selector and output. Fuzzy Histogram Hyperbolization is chosen to improve the quality of the roentgen image. The fuzzy histogram hyperbolization steps consist of fuzzyfication, modification of values of membership functions and defuzzyfication. The GLCM is computed from the resulting image and properties are measured from the GLCM. In order to reduce the size of the GLCM, the image intensity is reduced to the range of [0,63]. Experimental results indicate that the fuzzy histogram hyperbolization method can be used to improve the quality of the image. The proposed method is capable to detect the anomaly in the roentgen image.

Keywords:

image processing, anomaly detection, gray level co-occurrence matrix

Introduction

Roentgen image in the form of a film is commonly used in the process of medical diagnosis of disease. But often the quality is so low that body tissue does not clearly visible. Thus, it becomes difficult to determine the anomaly in the image. To overcome this difficulty, it is necessary to convert the roentgen image into digital image. The digital image allows digital image processing techniques be applied to the image to improve the quality of the image and thus the anomaly detection accuracy.

The proposed method consists of a number of steps. First, the digital roentgen image is processed by the preprocessor to improve the image contrast. The pre-processor carries out an image enhancement process in order to enhance the image contrast. It is a useful step when area for the image that is of particular importance has only subtle changes in pixel intensity. In these cases, it may be difficult for the human eye to point out the structures clearly, especially if the image is being displayed on a low quality screen. By exaggerating the changes in pixel intensity the image may become easier to be interpreted [1,2,3,4]. Applying the contrast enhancement filter will improve the readability of areas with subtle changes in contrast but will also destroy areas of the image where the intensity of the pixels is becoming outside the range of intensities being enhanced.

In this research, the improvement to the image contrast was carried out using the fuzzy histogram hyperbolization (FHH) method with the hedges operator [5], since the transformation of the gray level image is logarithmic and it is in accordance with the human vision system. Following the image enhancement, features are extracted from the image. The distance between the reference image and the processed image as represented by their features indicate the existence of an anomaly.

The Proposed Method

Fuzzy image enhancement is based on gray level mapping into a fuzzy plane, using a transformation function. The aim is to generate an image with higher contrast than the original image by giving a larger weight to the gray levels that are closer to the mean gray level of the image rather than to those that are farther from the mean. In recent years, many researchers have applied the fuzzy set theory to develop new techniques for contrast improvement [3, 6]. An image I of size $M \times N$ and L gray levels can be considered as an array of fuzzy singletons, each having a value of membership denoting its degree of brightness relative to some brightness levels. For an image I, the notation of fuzzy sets can be written as:

$$I = \bigcup_{mn} \frac{\mu_{mn}}{g_{mn}} \quad (1)$$

where g_{mn} is the intensity of $(m,n)^{th}$ pixel and μ_{nm} is its membership value. The membership function characterizes a suitable property of image (e.g. edginess, darkness, textural property) and can be defined globally for the whole images or locally for its segments. In recent years, some researchers have applied the concept of fuzziness to develop new algorithms for image enhancement has been applied. The principle of fuzzy enhancement scheme is illustrated in Figure 1.

Figure 1: Fuzzy histogram hyperbolization image enhancement

The idea of histogram hyperbolization, and fuzzy histogram hyperbolization is described in [1,7]. Due to the nonlinearity of human brightness perception, this algorithm modifies the membership values of gray levels by a logarithmic function. The algorithm works in the following sequence: setting the shape of membership function, setting the value of the fuzzifier β, calculation of membership values μ_{nm} , and modification of the membership values by β and finally generation of new gray levels. The choice of the membership function is very important, as the membership function characterize a certain property of the image (edginess, darkness, textual property).

Image Fuzzification

The image fuzzification transforms the gray level of an image, *x*, into values of membership function [0..1]. Two types of transformation functions were used, namely the triangle membership function, and Gaussian membership functions. A triangular membership functions is shown in Figure 2 and it's equation is written equation (2).

$$\text{Triangular}(x,a,b,c)=\begin{cases} 0 & x \le a \\ \dfrac{x-a}{b-a} & a \le x \le b \\ \dfrac{c-x}{c-b} & b \le x \le c \\ 0 & x \ge c \end{cases} \qquad (2)$$

In equation (2), *a* is equal to 0, *c* is equal to 255, and *b* varies. The Gaussian membership function is shown in the Figure 2b, and is characterized by two parameters $\{c,\sigma\}$. The equation for the Gaussian membership function is written in equation (2)

$$Gaussian(x;c,\sigma) = e^{-\frac{1}{2}\left(\frac{x-c}{\sigma}\right)^2} \qquad (2)$$

Modification of membership function

This process is needed to change the values of the membership functions resulted from the fuzzification process above. In this algorithm, the shape of the membership function is set to triangular to characterize the hedges and the value of the fuzzifier β. The fuzzifier β is a linguistic hedge such that β = -0.75 + μ 1.5 [3], so that β has a range of 0.5 to 2. The modification is carried out to the membership values by a hedges operator [8]. The operation is called dilatation if the hedge operator β is equal to 0.5 and is called concentration if β is equal to 2.

If *A* is a fuzzy set and it is represented as a set of ordered pairs of element *x* and its membership value μ , then A^β is the modified version of *A* and is indicated by equation

$$A^\beta = \int_X [\mu_A(x)]^\beta / x \qquad (3)$$

The hedge operator operates on the value of membership function as fuzzy linguistic hedges. Carrying hedge operator may result in reducing image contrast or increasing image contrast, depending on the value of β. The hedge operators can be used to change the quality of the contrast of a digital image.

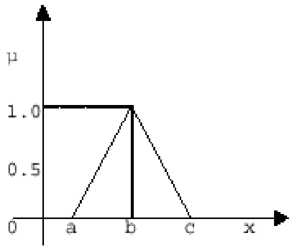

Figure 2a: Triangular membership function

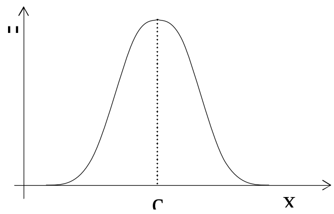

Figure 2b: Gaussian membership function

Image defuzzification

After the values of fuzzy membership function are modified, the next step is to generate new gray level values. This process uses the fuzzy histogram hyperbolization. This is due to the nonlinearity of human brightness perception. This algorithm modifies the membership values of gray levels by a logarithmic function

$$g'_{mn} = \left(\frac{L-1}{e^{-1}-1}\right)\left[e^{-\mu_{mn}(g_{mn})^\beta} - 1\right] \qquad (4)$$

where μ_{mn} (g_{mn}) is the gray level in the fuzzy membership values, β is the hedge operator, and g'_{mn} is the new gray level values.

Feature Extraction

The features to be used for detecting anomaly are computed from the gray level co-occurrence matrix (GLCM) [5]. In this research the roentgen image is divided into overlapping blocks of size 64x64 called region of interest (ROI). In order to reduce the time complexity, the pixel intensity is also reduced to the range of [0, 63]. Four features, which represent the properties of the GLCM, are computed from the GLCM. These are contrast, correlation, energy, and homogeneity. Contrast gives a measure of the intensity contrast between a pixel and its neighbors. Correlation gives a measure of how correlated a pixel is to its neighbors. Energy gives a measure of the energy of the GLCM. Homogeneity gives measure of the closeness of the distribution of elements in the GLCM to the GLCM diagonal. The values of these four properties describes the GLCM, and in turn, the area where the GLCM is computed. The values of contrast, correlation, energy, and homogeneity are each normalized to [0,1] for the anomaly detection.

Anomaly Detection

Following feature extraction, each region of interest (ROI) is described by four values, i.e., contrast, correlation, energy, and homogeneity. Thus each ROI can be considered as a point in a four dimensional space. In this space, the similarity between any two ROI is reflected by the distance between the two points representing the ROIs. The Euclidean distance is used for this purpose.

Results

Results of image enhancement

The system was tested by conducting experiments. The improvement in the contrast of image is observed when the triangular and the Gaussian membership function is applied with different values of β. Figure 4a shows an example of digital roentgen image before enhancement. Figure 4b shows the result of improvement of the contrast digital roentgen image using triangular membership functions with $\beta = 0.5$.

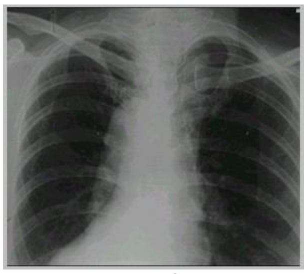

Figure4a: Before image enhancement

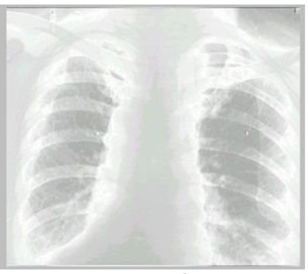

Figure 4b: After image enhancement using triangular fuzzy set and β = 0.5

Table 1 shows the statistical data of the roentgen image before and after image enhancement. This table shows that the fuzzy histogram hyperbolization method can be used to improve the contrast of digital images. For the image with the condition of the gray level located in the vicinity of a particular value (86,374), FHH with the gaussian membership function produces the image with greater contrast than using the triangle membership function. This is due to the spread of gaussian membership function. The spread of the resulted gray level distribution can be seen from the value of the standard deviation which is bigger. With the greater standard deviation of the gray level of image, the contrast of the image will be the better.

Table 1: Statistical data of an image before and after image enhancement

Original image		After image enhancement					
		Triangular			Gaussian		
		hedge (β)operator			hedge (β)operator		
		0.5	1	2	0.5	1	2
Mean of gray level	86.3741	224.310	195.741	149.970	183.569	143.018	101.541
Standard deviation	43.8093	20.5355	37.5721	58.9221	63.0731	81.2258	88.1804

Results of anomaly detection

Once the image features are extracted, the anomaly is detected by calculating the distance between two appropriate regions as represented the set of contrast, energy, correlation and homogeneity. Figure 5 shows the case where anomaly is not found (in Indonesian language, "TIDAK ADA KELAINAN" means "NO ANOMALY"). Figure 6 shows the case where an anomaly is detected. The position of the anomaly of the image is shown in rectangular. Figure 7 shows that the proposed method is translation invariant. This system is able to detect the anomaly, even if the anomaly is shifted in different position.

Figure 5: Results of anomaly detection. Anomaly not found.

Figure 7: Results of anomaly detection. Anomaly found.

Discussion

The level of contrast of the image as a result of contrast improvement depends on the used hedges operator. The experimental results show that using triangular membership functions, with β equals to 0.5, 1, and 2 respectively, results in image with better contrast having an average gray level of 224.31, 149.97 and 195,741.

The Gaussian membership function generated with the value of β equals to 0.5, 1 and 2 results in the average gray level values 183.569, 143.018 and 101.541 respectively. The results show that the greater β the higher the contrast image become. In fuzzy concept, the use of hedges operator is to

change the value of the linguistic variable. If the value of β is 1, the image is considered medium contrast, the results of improvement with β = 0.5 is less contrast, the results of image improvement with β = 2 is more contrast.
The anomaly detection is modeled as measuring the distance between two points in the four dimensional space. The four dimensions are contrast, energy, correlation and homogeneity. This approach allows anomaly detection to be carried out in a simple way.

Conclusion

The results of anomaly detection show that Fuzzy Histogram Hyperbolization (FHH) was successfully used for the improvement of quality of roentgen digital image. The level of contrast image can be arranged with the operator by selecting the hedges value. If most of the gray level values are around a particular value, then the Gaussian membership function provides a better contrast than the triangular membership functions. Anomaly detection is also running well when the anomaly in the test image is shifted relative to the image reference.

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