

Contrast Enhancement of Radiograph Images Based on Local Heterogeneity Measures

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Abstract: Contrast enhancement of the lateral skull x-ray images is very important in orthodontic practice, cephalometric evaluation and craniofacial landmarking. In this paper we present computational techniques involving contrast enhancement of two-dimensional digitized x-ray images. The algorithm is developed based on the use of local heterogeneity measures of pixel distribution. Image enhancement is accomplished by an adaptive gray scale pixels transformation depending on results of local heterogeneity contribution measures. The proposed approach was tested on different images, and the results prove that the proposed method has better performance the existing conventional methods.

1. Introduction

Contrast enhancement is very important in medical imaging applications such as cephalometric tracing and craniofacial landmarking of x-ray. This is due to the fact that visual inspection of the lateral skull x-ray is an essential step in the process of cephalometric evaluation [1]. The quality of x-ray images made in dental practice is often inadequate [2]. This results in an inaccurate treatment and difficulties to detect anomalies and produce unreliable measurements. Therefore, the motivation exists for a reliable method for enhancing the appearance of the digitized images for better treatments.

Image enhancement is a collection of techniques that seek to improve the visual appearance of digital images or transform the image into a more amenable to human and machine analysis [3].

The most widely used techniques for contrast enhancement are linear contrast stretching and histogram equalization [4]. Although these methods are simple, they prove to be inefficient in enhancing the low frequency details and histogram equalization has the problem of over enhancing noise and ignoring details[3]. In medical image analysis local details are more important than high frequency components.

Adaptive local contrast enhancement is more suitable for such applications. Adaptive local contrast enhancement has been subject of research for many years. Dah-Chung *et.al* [5] used a non-linear function based on the histogram of the local standard deviation to obtain the contrast gain. Sabine *et.al.*[6] have shown that the enhancement of radiographs using Wavelets Transform(WT) leads to undesirable artifacts in the enhancement images. Dhawan *et al.* [7] defined a local contrast function in terms of the relative difference between a central region and a larger surrounding region of a given pixel. The contrast values are then enhanced by some of contrast enhancement functions, such as the square root, the exponential, and the log. functions. This method is more efficient than the global method. However, if a small region is used then the algorithm will enhance noise and if the region is large it could lose details. Cheng *et.al.*[8] employed the fuzzy entropy and fuzzy set to enhance the contrast.

In this paper we present an image enhancement algorithm based on the two local measures of heterogeneity of special region. Experimental results using the proposed method are also presented.

2. Heterogeneity Measurements

Heterogeneity of image region related to the variation of pixels values and reflects how uniform the image region is. We will define the heterogeneity of image pixel between [0, 1]. The higher the heterogeneity, the more nonuniform the region is. To measure the heterogeneity of each pixel with a gray level of $x(i, j)$ relative to the neighboring pixels, we define the three local variables over the window defined by $(2n + 1) \times (2n + 1)$ centered at (i, j) as follows:

The local average as:

$$m(i, j) = \frac{1}{(2n + 1)^2} \sum_{k=i-n}^{i+n} \sum_{l=j-n}^{j+n} x(k, l) \quad (1)$$

the local standard deviation as

$$\sigma(i, j) = \frac{1}{(2n+1)} \sqrt{\sum_{k=i-n}^{i+n} \sum_{l=j-n}^{j+n} [x(k, l) - m(i, j)]^2} \quad (2)$$

where n is an odd number

and local entropy as

$$T(i, j) = -\frac{1}{2 \log(2n+1)} \sum_{k=1}^L p_k \log p_k \quad (3)$$

where p_k is the probability of the k th gray level, which is measured as

$$p_k = \frac{\sum_{i=-n}^{i=n} \sum_{j=-n}^{j=n} L_k(i, j)}{(2n+1)^2} \quad (4)$$

L_k is the pixel with k gray level at location (i, j)

Heterogeneity increases as the entropy and standard deviation increase.

All local variables are normalized by dividing each by the maximum value of the variable in the selected window as follows:

$$T(i, j) = \frac{T(i, j)}{\max(T_w(i, j))} \text{ and } \sigma(i, j) = \frac{\sigma_w(i, j)}{\max(\sigma_w(i, j))}$$

where $\max(T_w(i, j))$ and $\max\{\sigma_w(i, j)\}$ are the maximum values of entropy and standard deviation of the selected window centered at (i, j) , respectively. As in [5], we would like to transform the image based on the following:

$$f(i, j) = m(i, j) + k(i, j)[x(i, j) - m(i, j)] \quad (5)$$

Where $k(i, j)$ is the contrast gain. If $k(i, j)$ is greater than 1 then the high frequency elements are enhanced equally causing the strong high-frequency components to be overenhanced. We would like K to increase when there is high contribution of the pixel

located at (i, j) to the average heterogeneity of the region specified by the window centered at (i, j) .

3. Proposed Method

We define the local heterogeneity for each pixel as follows:

$$\lambda(i, j) = (T(i, j) + \sigma(i, j)) / 2.0 \quad (6)$$

It will increase when the standard deviation and the entropy are increase. Fig.1 and 2 show the standard deviation, entropy and heterogeneity profile taken from region marked 1 and 2 in Fig.3. We would like to enhance the contrast of the image when the heterogeneity is high and decide the contrast gain based on heterogeneity of the region

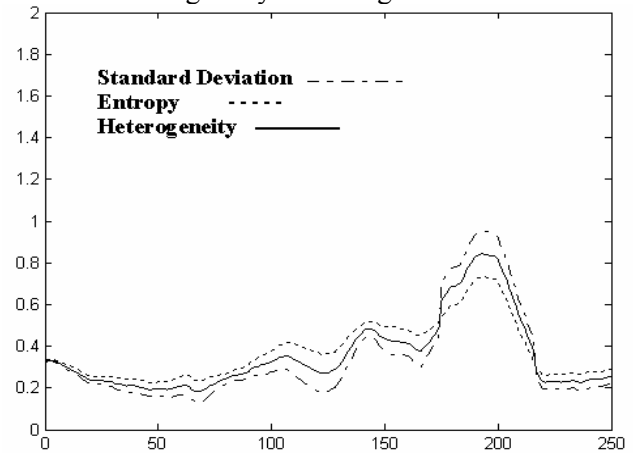


Figure 1 Heterogeneity profile of a uniform image region

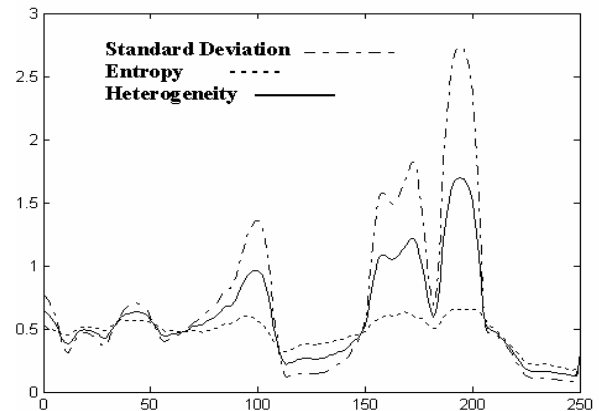


Figure 2 Heterogeneity profile of a nonuniform image region

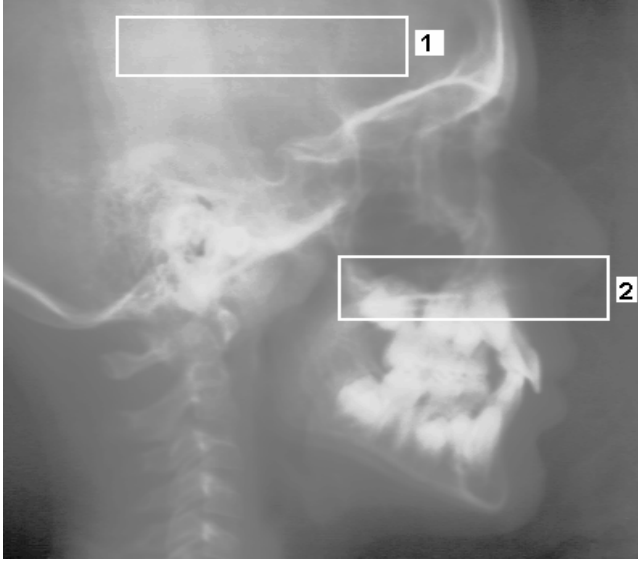


Figure 3. Region 1 marking homogenous region and region 2 represent heterogeneous region

The algorithm

1. Compute the standard deviation and entropy of each pixel (i,j) using a window of size $(2n+1)*(2n+1)$ centered at (i,j)
2. Compute heterogeneity value of each pixel using Eq.(6) and normalize it by dividing it by the maximum heterogeneity of the window centered at (i,j)
3. Compute the contribution of each pixel to the heterogeneity of the region centered at (i,j) as follows:

$$\psi(i,j) = \frac{\sum_{k=i-n}^{i+n} \sum_{l=j-n}^{j+n} x(k,l) * \lambda_x(k,l)}{\sum_{k=i-n}^{i+n} \sum_{l=j-n}^{j+n} \lambda_x(k,l)} \quad (7)$$

4. Compute $G(i,j)$ constant for each pixel as follows:

$$G(i,j) = \frac{|x(i,j) - \psi(i,j)|}{|x(i,j) + \psi(i,j)|} \quad (8)$$

5. Transform the image as using Eq. (5) defining the contrast gain $k(i,j)$ as follows:

$$k(i,j) = \begin{cases} \frac{1 - G(i,j)}{1 + G(i,j)} & \text{if } x(i,j) \geq m_x(i,j) \\ \frac{1 + G(i,j)}{1 - G(i,j)} & \text{otherwise} \end{cases}$$

4. Experimental Results

The algorithm was tested on various x-ray image of different quality. As can be seen from Fig. 4,5,6 the proposed algorithm produces better results than those obtained using histogram equalization and linear mapping methods. The size of the window was empirically decided. The best results were obtained using $n=10$. The CPU time requirement was less than 10 seconds on Pentium 4 with 2.8 GHZ using digitized x-ray images of size 400x400 pixels. From Fig. 5, it is obvious that by using the linear mapping method, elements with high frequency will suffer from over enhancement.

5. Conclusions

Image enhancement using direct mapping method cause over enhancement of high frequency components, while histogram equalization method ignores local details. In medical image details are more important than high frequency components. The proposed method enhances the contrast of the image based on the contribution of each pixel on the local measure of heterogeneity of region. It has been shown that the proposed method outperforms the conventional methods of contrast enhancement. The proposed method enhances the details and does not cause overenhancement of high frequency components.



Figure 4. Image enhanced using histogram equalization



Figure 5. contrast enhancement using linear mapping method.



Figure 6. Contrast enhancement using proposed method.

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