EVALUATION OF CONTRAST ENHANCEMENT BY DIGITAL EQUALIZATION IN DIGITAL MAMMOGRAPHY

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ABSTRACT

Purpose: This study evaluated an algorithm based on a method of contrast enhancement by digital equalization (CEDE).

Method: The algorithm was designed to enhance image contrast by employing digital equalization of digital mammograms. The CEDE algorithm was tested using ten mammograms with cancer (13 lesions) taken the University of South Florida data base, together with eight mammograms which only contained benign lesions. Three readers compared the processed images with the original mammograms for lesion conspicuity. A five point ranking scale was employed where a score of 3 corresponded to equal lesion visibility, ranks > 3 corresponded to superior lesion visibility, whereas ranks < 3 corresponded to markedly inferior lesion visibility.

Results: The mean observer score for all lesions was always at least equal to that of the original digital mammogram (i.e., 3 or greater), and there was no evidence of any image distortion or other image processing artefacts. The mean rank (± standard deviation) for the 13 malignant lesions was 3.52 ± 0.38. The corresponding rank for the eight benign lesions was 3.33 ± 0.26. These differences were statistically significant in terms of standard error.

Conclusion: The CEDE algorithm is capable of significantly enhancing lesion contrast in digital mammograms and our preliminary results indicate that this algorithm merits additional refinement and further (objective) evaluation.

INTRODUCTION

Contrast enhancement is useful in mammography because of the inherent low contrast of subtle lesions. Global mapping techniques, such as histogram equalization and other methods of linear and nonlinear enhancement, often fail to provide sufficient local contrast that is required for feature detection in radiographs. Diagnostic performance on softcopy displays can often remains unsatisfactory as a result of the limited display contrast range.

Visualization of low contrast features is complicated because mammograms often contain regions of glandular and adipose tissues which have different X-ray attenuation characteristics and result in large intensity differences in mammograms. These differences dominate the overall contrast of a mammogram, whereas the contrast between a lesion and its background is often very low due to its smaller varied difference between the background projected tissues. In this study, we propose an algorithm for contrast enhancement based on the analog process of digital equalization, and present preliminary results on the ability of this algorithm to improve visibility of masses and microcalcifications in mammograms.

CONTRAST ENHANCEMENT BY DIGITAL EQUALIZATION (CEDE)

The principle idea of CEDE is to decrease the average intensity in the bright regions and increase the brightness in relatively dark regions. Thus the relatively small variation in gray levels of a malignant lesion and its nearby background can occupy more gray levels (dynamic range) for display, thereby increasing local contrast.

The CEDE algorithm operates by subtracting the average brightness over a set of local regions which are selected to be squares of a specific size. The algorithm takes an initial mammogram (Figure 1), which is then divided into square regions of uniform size. Figure 2 shows the average brightness of each region.

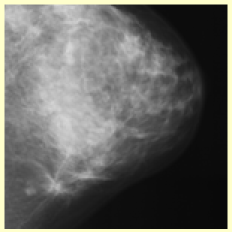
Figure 1

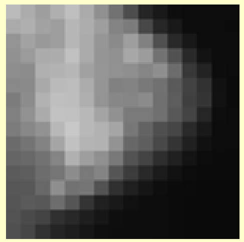
Figure 2

Figure 3 shows the effect of subtracting the local average image from the original image, and which illustrates the resultant "block effects". To eliminate "block effects" on the boundary of these square regions, use was made of a bilinear interpolation algorithm to obtain a modified "average image". Figure 4 shows the effect of the bilinear interpolation (??).

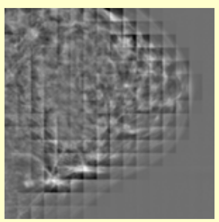
Figure 3

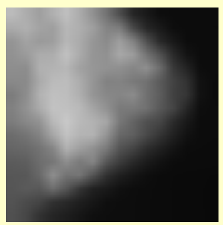
Figure 4

Because the "local average image" is the same size as the original image, we can subtract it from the original image pixel by pixel. The resulting value for the pixels could be negative, so a simple linear histogram stretch was applied before displaying the result image as shown in Figure 5.

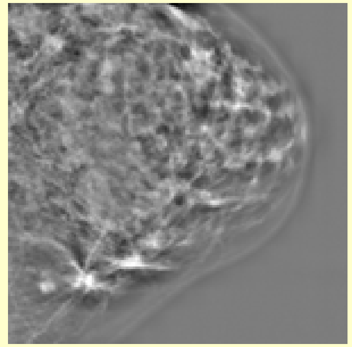
Figure 5

METHOD

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RESULTS

The mean observer score for all lesions was always at least equal to that of the original digital mammogram (i.e., 3 or greater), and there was no evidence of any image distortion or other image processing artefacts. The mean rank (± standard deviation) for the 13 malignant lesions was 3.52 ± 0.38. The corresponding rank for the eight benign lesions was 3.33 ± 0.26. These differences were statistically significant in terms of standard error.

DISCUSSION

The CEDE algorithm effectively provides an enhancem the high frequency component of the image. Lesio mammogram vary in size, the distribution and the clus feature, that gives out information of different s frequency, we definitely need a throughout analysis to a frequency range. From this view, CEDE algorithm provides a possibility of analysis within different freq range.

It is possible to take different block size for the enhance Images obtained using other block size may also provide information, and might be supplement for each Processing with different block size actually pro enhancement of different range of the frequency domain. analysis about the choice of the block size has also been the average process is an equivalent of lowpass filter, in s domain, it is a constant function defined on the block. Fro Fourier analysis, we know that the broader it is in s domain, the narrower it is in frequency domain, in the lo filter, that means it represent a filter of lower cut frequen our case, we subtract the lowpass filtered signal, so we c less low-frequency component.

CONCLUSIONS

The CEDE algorithm is capable of significantly enha lesion contrast in digital mammograms and our prelim results indicate that this algorithm merits additional refin and further (objective) evaluation