

Efficient Presentation of DICOM Mammography Images using Matlab

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Abstract – DICOM has become a standard for medical imaging. Its purpose is to standardize digital medical imaging and data for easy access and sharing. There are many commercial viewers that support DICOM image format and can read metadata, but image displaying is not always optimal. Since mammography images are mostly 12-bit grayscale images, image viewer has to be adapted for correct displaying when different number of bits has to be allocated. Another problem occurs when only a small portion of amplitudes is of interest to display. In this paper a method for efficient presentation of DICOM mammography images in Matlab is introduced. Algorithm that is developed does automatic contrast and brightness adjustments, regardless of bit depth of an image, number of amplitudes higher than zero and the number of allocated bits.

1. INTRODUCTION

As digital technologies are incorporated in every aspect of our lives, they are also the key part of medical diagnosis. DICOM (*Digital Imaging and Communications in Medicine*) standard was developed to make sharing of medical information safe and above all standardized. Having a standard in digital medical imaging improves flexibility and speed in detection and getting a fast diagnose. DICOM version 3.0 is used today and has become a standard in medical imaging and file exchange [1]. DICOM supports grayscale and color images of different formats. Besides image data, DICOM includes image-related data that are stored in the header of an image file. Some of the information included in the header is image resolution, image type, number of stored bits, patient's name, etc. Software for viewing mammography images in most cases is provided by the manufacturer of medical imaging hardware. Other programs for image viewing have difficulties with correct displaying of images, mostly because the number of amplitudes that are different from zero is not the same as the bit depth of an image. Because of that they have to do automatic adjusting of the displayed amplitude range [2]. In this paper histogram manipulation for a better DICOM image displaying in Matlab is described. The method described in this paper automatically calculates the amplitude range of a mammography image and uses Matlab's function which linearly stretches that range to achieve good image displaying. Sub-range image displaying which makes presentation of mammography images more efficient, as another extension of this approach, has been added [5].

The paper is organized as follows: in Section 2 image representation and bit allocation in Matlab is explained. In Section 3 global and local histogram equalization is described. In Section 4 the method for efficient DICOM mammography image displaying in Matlab is introduced and the results are shown. Section 5 draws the conclusion.

2. IMAGE REPRESENTATION IN MATLAB

Matlab can use different numeric formats to represent image matrices. It uses 16 bits (65536 levels) to display a grayscale image that has bit depth between 8 and 16 bits. Since mammography images that are considered in this paper are 12-bit grayscale images, it is necessary to make certain adjustments to display those images correctly. To read a 12-bit grayscale image from a file Matlab allocates a 16-bit $m \times n$ matrix, where m and n are defined by resolution of the image. 12-bit image (4096 levels of gray) displayed with 16 allocated bits appears dark. This happens because the maximal possible amplitude of 12-bit image for each pixel is 4095 and the maximal amplitude that can be displayed is 65535 (16 allocated bits). Therefore, 4096 levels need to be linearly scaled to 65536 levels to achieve good image displaying. Displayed image will then be a 16-bit image but with only 4096 discrete amplitudes. Fig. 1(a) shows an 8-bit image displayed on a 10-bit system and Fig. 1(b) shows the same image displayed on an 8-bit system.



Fig. 1. Test image Lena: (a) an 8-bit image displayed on a system that allocates 10 bits per pixel, (b) the same image displayed on a system that allocates 8 bits per pixel

3. HISTOGRAM

Image histogram shows the distribution of intensity levels in the image. Histograms of underexposed, normal and overexposed image (Lena 256×256, 8-bit grayscale) are shown in Fig. 2(a)-(c), respectively.

Histogram manipulation is used to improve the contrast of an image. Contrast can be improved by stretching the dynamic range of an image. When stretching the dynamic range, or just some part of the range, brightness of the image changes. Histogram equalization can be divided in two general approaches: global and local histogram equalization. Global histogram equalization takes information from the whole image and manipulates histogram components in a desired way to make contrast enhancement. Contrast enhancement can be made on the whole image or just on the desired range of amplitudes that are of special interest. Transformation function is used to make histogram adjustment. It has to be monolithically increasing function but it can be linear or non-linear [3]. Non-linear transformation function stretches certain range of amplitudes more and can help to make some important details more visible. In medical imaging, non-linear contrast enhancement can help in a faster detection of abnormalities, because on a post-processed image details are more visible and therefore features of interest are easier to spot.

Transformation function $T(r)$ shown in Fig. 3 linearly stretches amplitude range $[a, b]$ to the entire range defined by the number of allocated bits n .

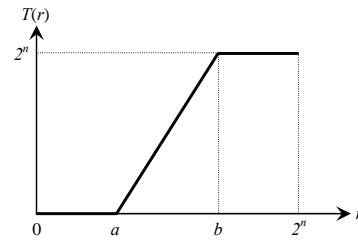


Fig. 3. Transforming function $T(r)$ linearly stretches amplitude range $[a, b]$ to $[0, 2^n]$

3.1. Global histogram equalization

Global histogram equalization is often used to make contrast adjustments of the image using the desired transformation function [3, 4]. Transforming function shows how output pixels are represented considering input pixels. Adjusting histogram using transforming function does not affect the certain part of the image, but only the desired range of pixel amplitudes. It is also possible to apply transforming function on two or more amplitude ranges. That approach gives good results if it is important to preserve brightness of the image.

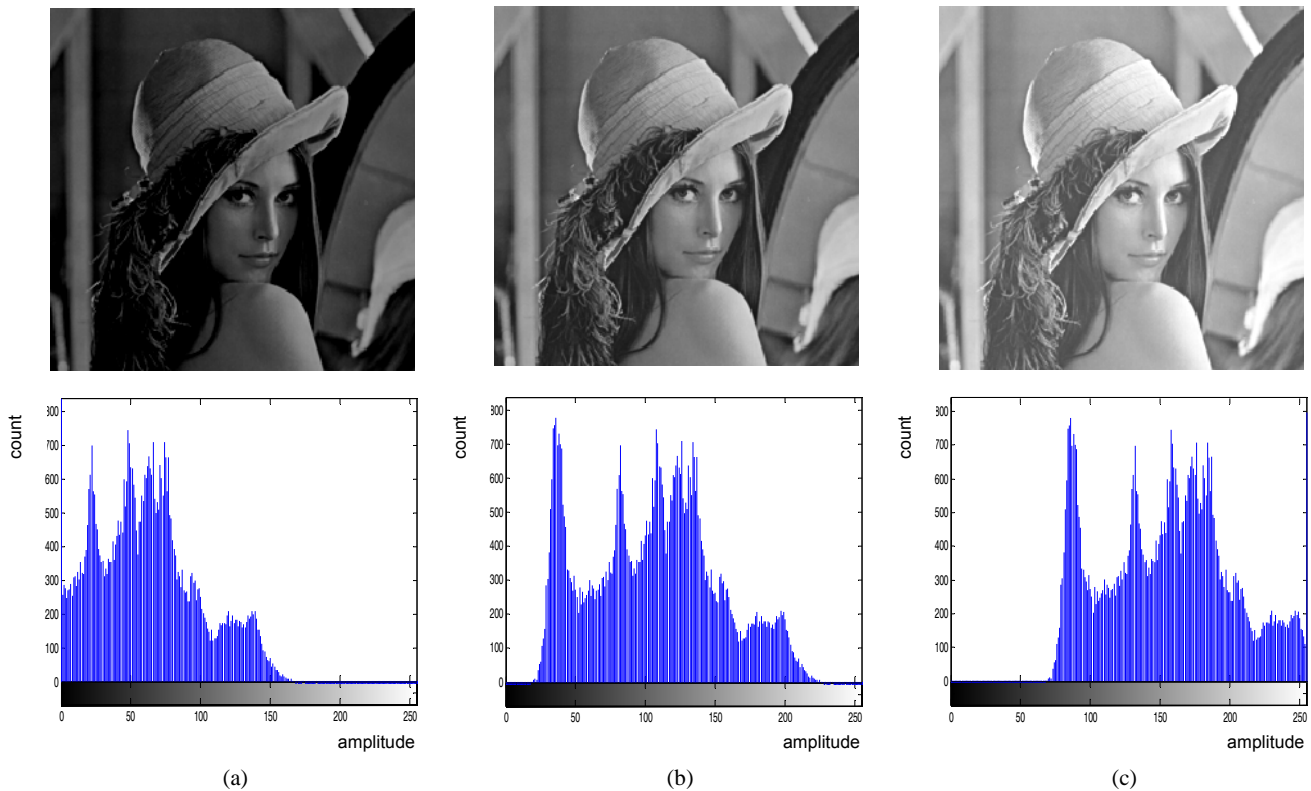


Fig. 2. Test image Lena: (a) histogram of underexposed, (b) normally exposed and (c) overexposed image

3.2. Local histogram equalization

Local histogram equalization does not use the transforming function in a true sense. It makes contrast adjustments on a small part of the image. Local histogram equalization is in fact a method of spatial filtering [4]. There are many methods for local histogram equalization and the general idea is to make local adjustments so some objects will become more visible. The biggest problem of this approach is that it makes processed image visually very different from the original. This happens because contrast is not uniformly changed throughout the whole image, but adaptively on small areas of the image.

4. OPTIMAL DICOM IMAGE DISPLAYING

If we want to display, for example, an 8-bit image and we have 10 allocated bits, it is possible to make an algorithm that takes only first 256 levels and linearly stretches them to 1024 levels. Linear stretching will not affect contrast or brightness of the image and there will not be any improvement in picture quality because only every fourth pixel amplitude value (of possible 1024) will be displayed. This method works fine if the bit depth of an image is known, but it fails if we do not know the bit depth, because then it is impossible to make correct linear stretching. One way to make automatic adjustment for displaying images with unknown bit depth is to find the highest amplitude, x_m , present in the image and linearly stretch amplitude range $[0, x_m]$ to $[0, 2^n]$, where n is the number of allocated bits. This method will give bad results if applied to images that have low overall brightness, because contrast and brightness will significantly increase, resulting in low fidelity displaying results.

DICOM mammography images are usually 12-bit images (4096 levels). To display a 12-bit image in Matlab, 16 bits have to be allocated and optimal range of amplitudes for displaying should be set. This approach gives poor contrast image displaying. That happens because a typical mammography image uses only about 800 pixel amplitudes instead of 4096 that are being displayed. To solve this problem a simple method has been introduced. This method uses histogram of the image to assign correct amplitude range inside which important information are stored. Defining an optimal threshold is the only major problem of this method. Optimal threshold for mammography images is defined by analyzing the pixels with amplitude higher than zero. To get the number of pixels satisfying this criterion, number of pixels with zero amplitude should be subtracted from total number of pixels. After calculating number of pixels that have non-zero amplitude, a threshold for defining boundaries of displaying range should be set. Optimal image displaying is achieved when lower boundary is set in a way that 99.9% of the pixels with non-zero amplitude have higher amplitude than the lower boundary. Upper boundary is set in a way that 99.99% of the pixels with non-zero amplitude have lower amplitude than the upper boundary. The reason why upper boundary has stricter limitation is because objects of interest (tumors, calcifications, etc.) are displayed as brighter, so it is desired to display them with

better amplitude resolution. Fig 4 shows graphic representation of setting lower and upper displaying range boundaries by proposed threshold.



Fig. 4. Defining lower and upper boundary of amplitude range that will be displayed

Fig. 5 (a)-(d) shows the same image under different displaying environments. In Fig. 5(d) results of an automatic system adjustments for mammography image displaying is shown.

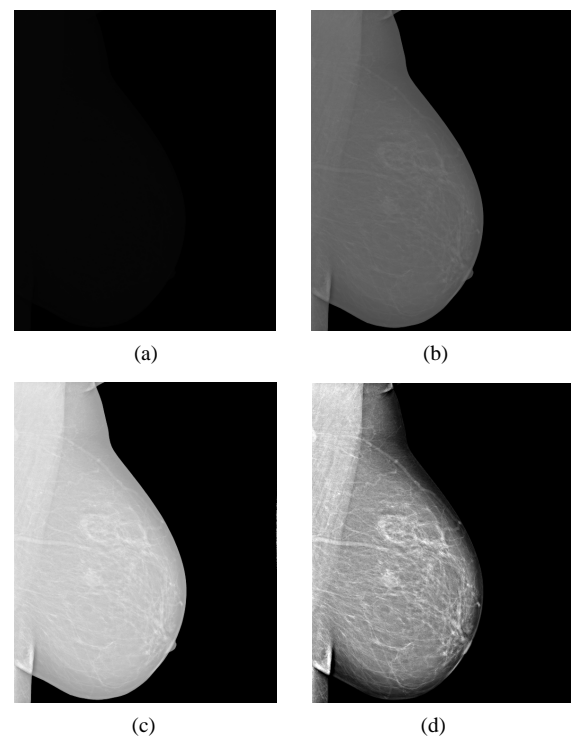


Fig. 5. (a) 12-bit mammography image with 16-bit display range, (b) same image on a 12-bit system, (c) same image with automatic Matlab's display range, (d) our method for optimal displaying with automatic contrast and brightness adjustment

4.1. Histogram stretching and thresholding

To achieve a good mammography image representation in Matlab we have chosen the following methods: linear histogram stretching with adaptive amplitude range detection and sub-range image displaying. Linear histogram stretching with adaptive amplitude range linearly stretches the range of amplitudes that contain important information to entire displaying range defined by the number of allocated bits. In our case stretching has been done automatically by a Matlab's standard function for image displaying. Image information is contained in pixels with amplitude higher than zero. Easy method to set

displaying range boundaries would be finding histogram component with the lowest value higher than zero and highest value that is lower than 2^n-1 , where n is the bit depth of an image. This approach will result in higher than optimal displaying range, because of the noise that image contains. That is the reason why thresholding should be applied. In our case good results are achieved when 99.89% of pixels with amplitude above zero are inside displaying range. Finding an optimal threshold can be a problem when dealing with images from different sources, because of the different amount of noise.

4.2. Sub-range image displaying

To make details of higher amplitude more visible, an extension of the presented approach has been introduced. Image is divided in two sub-ranges in a way that all pixels with amplitudes higher than zero satisfy the following condition [5]:

$$\int_1^{x_s} p_r(r_i) dr = 0.5 \quad (1)$$

The separating point (x_s) of the two amplitude ranges is selected as the median gray level, where $p_r(r_i)$ is the probability of appearance of a pixel with an amplitude in the range $[1, x_s]$. Since mammography images have large black areas, making calculations with pixels that have non-zero amplitudes gives better results, because the mean intensity will not be too low. That result in the higher separating point, and consequently the contrast of the image will also be higher. This is matched to the general idea, and that is making only a small amplitude range visible. The separating point in this method can easily be changed, allowing the viewer to see more or less detail of higher amplitude at the same time. In medical image viewing this method is helpful because global histogram equalization will give low contrast results. Fig. 6(a) shows mammography image with full amplitude range displayed, and Fig. 6(b) shows the same image where only amplitudes above median gray level are displayed. In a sub-range image, some details are more visible because of the higher contrast. This is helpful for easier finding of calcifications and unhealthy tissue.

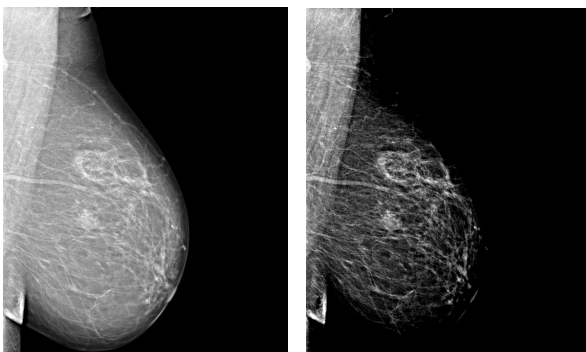


Fig. 6. (a) Mammography image with full amplitude range, (b) the same image where only amplitudes above median gray level are displayed

5. CONCLUSION

Displaying images in Matlab leads to problems when images have different bit depth from the number of automatically allocated bits. Since DICOM mammography images are grayscale images with 12-bit depth, some adjusting is needed for correct displaying. Another problem occurs if the histogram of the image is narrow, which means the number of "important" amplitudes is low. In this paper an approach for good a DICOM image presentation in Matlab has been introduced: linear histogram stretching with adaptive amplitude range detection and sub-range image displaying. Linear histogram stretching ensures that an image will be correctly displayed for quality viewing regardless of histogram shape (number of amplitudes that carry information). Sub-range image displaying helps to distinct objects that have similar gray level amplitudes. In this case only sub-range images with amplitudes above median gray level are considered because objects that need to be detected in case of mammography have higher intensity. Further research will be based on local histogram equalization that should be helpful in making neighbor objects with similar amplitudes easier to spot.

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