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Qualitative assessment of image enhancement algorithms for mammograms based on minimum EDV

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ABSTRACT

Breast cancer is one of the leading reason of death among women. Nevertheless, medications for this fatal disease are still away of ambitions. Patients (thought to have breast cancer) should go through several advanced medical diagnostic procedures like mammography, biopsy analysis, ultrasound imaging, etc. Mammography is one of the medical imaging techniques used for detecting breast cancer. However, its resulted images may not be clear enough or helpful for physician to diagnose each case correctly. This fact has pushed researchers towards developing effective ways to enhance images throughout using various enhancement algorithms. In this paper, a comparison amongst these applied algorithms was done to evaluate the optimum enhancement technique. A morphology enhancement, which is resulted from combining top-hat operation and bottom-hat operation, was used as a proposed enhancement algorithm. The proposed enhancement algorithm was compared to three other well-known enhancement algorithms, specifically histogram equalization, logarithmic transform, and gamma correction with different gamma values. Twenty-five mammographic images were taken from the mammography image analysis society (MIAS) database samples. The minimum entropy difference value (EDV) was used as metric to evaluate the best enhancement algorithm. Results has approved that the proposed enhancement algorithm gave the best-enhanced images in comparison to the aforementioned algorithms.

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1. INTRODUCTION

Cancer is an unconfined growth of malignant cells in a certain location of human body [1-3]. It is fatal disease and those suffering cancers most likely facing death [4]. The World Health Organization (WHO) reported in 2014 that cancer is the second cause of deaths in the world [5]. Breast cancer is one of the most health problems in the world. Moreover, it is the main cause of cancer death amongst women especially in developing countries [6]. According to a study conducted by Rajaraman et al. in 2015, the range of women with breast cancer in India was around 36 per 100,000 whilst in Europe and North America was 92 to 112 per 100,000 women [7]. This study also found that the mortality of breast cancer in India is relatively high (12.7 per 100,000 women) which is similar to the rates in developing countries [7]. According to the estimation of the American Cancer Society (ACS) in 2016, women deaths resulted from breast cancer was about 40,290 in the United States [8]. A study conducted by Malvia et al. in 2017 declared that 1,797,900 women suffered from breast cancer in India by 2020 [9]. The last estimation of the American cancer society in 2019 stated that about 268,600 women will be considered to have breast cancer and 41,760 women will face death due to breast growth [10, 11]. The prevention of breast cancer is still impossible due to the unidentified cause of it. Thus, there is no effective way to avoid breast cancer but screening to detect it in early stages [12]. Many organizations in the health sector have raised the awareness to breast cancer by encouraging women to participate in diagnostic investigations such as tissue sampling, clinical breast examination (CBE) and imaging for early detection of breast cancer [13]. Imaging is still the most popular way in breast screening. The X-ray mammography is used for interpreting breast cancer. According to Vikhe and Thool in 2016, mammography is the most effective way for breast screening. This technique has led to decrease breast cancer deaths by 25% [14]. Mammography is the initial step for breast cancer recognition [15, 16]. Calcium depositions create calcifications that usually appear as spots in mammographic images indicating a potential abnormality that is mostly considered as a sign of cancer [1]. In some cases of micro-calcifications in breast tissues, low contrast affects the radiologist's ability in diagnosing breast cancer by digital mammographic images [1]. Gray shade variation in mammograms reduces contrast level due to scattered X-radiation, highly powered X-ray penetration and the film limited capacity which leads to false positive results [17]. Hence, enhancing these images will significantly improve the diagnosing capability. The fuzzy nature of mammographic image and its low differentiability from the background make it too difficult to analyze them. Thus, it is essential to suppress the noise and enhance the region of interest (ROI) [18, 19]. Image enhancement techniques have been used widely for diagnosing aspects. Algorithms such as histogram equalization, median filters, gamma correction, Gaussian filters, logarithmic transformation and morphological filter have been applied to medical images to enhance the region of interest (ROI) [20]. In this paper, four enhancement techniques have been applied on digital mammographic images: Histogram Equalization (HE), Logarithmic transformation (Log Transform), Gamma Correction (GC) and finally Morphology enhancement (the proposed enhancement algorithm).

The rest sections are arranged as follows: next section gives a brief explanation about the used enhancement algorithms. Materials and methods section discusses the research methodology and how the research was performed. Results section clarifies the enhanced mammographic images resulted from all used algorithms. Discussion section explains other aspects that accompany enhancement algorithms. Finally, conclusion section summarizes the used enhancement algorithms and declares the optimum one.

Digital mammographic images are usually accompanied with high noise and low contrast [19]. Several enhancement techniques can be applied to these images to improve their clarity. Thus, enhancing contrast, removing noise, suppressing background and enhancing edges are examples of common image enhancements [20]. In digital images, histogram gives a graphical representation of gray levels distribution in the image. Hence, the frequency of any individual gray level in the image can be estimated and analyzed easily by observing the image histogram. Histogram equalization is a common method used for enhancing image contrast by spreading out the intensity values along the entire range of values. Histogram equalization technique is efficient in contrast enhancement wherever the represented image has closed contrast values. Intensity transformation is another way of image enhancement, it has been considered as the simplest technique used in the field of image processing [21]. Intensity transformations include image negative, logarithmic transformation, gamma correction and piecewise linear stretching. Logarithmic transformation maps the values of low intensity pixels in the input into wider output values and vice versa. This technique is used to expand dark pixels values in the input images and compress the values of bright ones. Similarly, gamma correction maps dark pixels in the input images into brighter ones and vice versa depending on (γ) value.

The morphology enhancement (the proposed Enhancement algorithm) depends on top-hat operation and bottom-hat operation to enhance mammographic image in terms of accentuating high-intensity and low-intensity morphological structures. Opening and closing operations are built from erosion and dilation as follows [22, 23].
Opening operation:

$$OI \circ SI = (OI \ominus SI) \oplus SI \tag{1}$$

Closing operation:

$$OI \bullet SI = (OI \oplus SI) \ominus SI \tag{2}$$

where, *OI is the original image*
SI is the structural element
$\ominus$ *Refers to erosion operation*
$\oplus$ *Refers to dilation operation.*

Then, top-hat (TH) and bottom-hat (BH) filtering are respectively expressed as shown in (3) and (4).

$$TH = OI - OI \circ SI \tag{3}$$

$$BH = OI \bullet SI - OI \tag{4}$$

Finally, morphology enhancement algorithm is obtaind by adding the top-hat operation to the original image, then the bottom-hat operation is subtracted from the result as shown in the following (5).

$$Enhanced\ Image = OI + TH - BH \tag{5}$$

Proposed enhancement algorithm will reduces the noise in addition to enhancing the low and high intensity regions.

2. MATERIALS AND METHOD

MATLAB version R2015b was used to perform all the enhancement algorithms. The mammographic images were taken from the Mammography Image Analysis Society (MIAS) Database samples. MIAS's samples are characterized by 8-bits of grayscale level and size of 1024x1024. The MIAS's samples provide an information about the specific location of the abnormal tissue throughout the mammography [24]. Consequently, MIAS's are considered the most suitable database and has been chosen as the sources of images for testing various images enhancing methods and identifying the optimum one thereafter.

MIAS's mammography samples were labeled by numbers and letters to be different from other samples. Furthermore, MIAS's images have two regions, firstly the background, which forms the whole image except the breast part, secondly the foreground, which represents the breast tissue. Trying to enhance the mammography with their labels and backgrounds has led to distract the effects of the enhancement algorithms on the entire image. Therefore, region of the interest (Breast tissue) was firstly extracted as shown in Figure 1 using algorithm designed for that purpose, then all the enhancement algorithms were applied to region of interest (RoI). In this paper, the qualitative assessment process is done through the following stages:
- Image acquisition.
- Preprocessing (RoI extraction).
- Applying the enhancement algorithms.
- Doing Entropy analysis to the results.
- Declaring the optimum algorithm.

Four enhancement algorithms were applied on 25 mammographic images taken from MIAS's database. The applied enhancement algorithms were histogram equalization, logarithm transformation, and gamma correction for different values specifically (0.3, 0.45, 0.6, 0.75 and 0.9) and morphology enhancement (the proposed one). The optimum enhancement algorithm was chosen depending on the minimum entropy difference value (EDV) [25], looking for entropy near or similar to the original entropy.

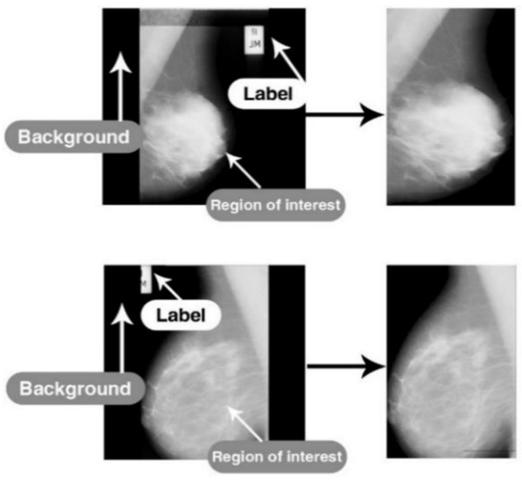


Figure 1. Two original samples from MIAS's database (on the left) were preprocessed to extract the region of interest (RoI) on the right

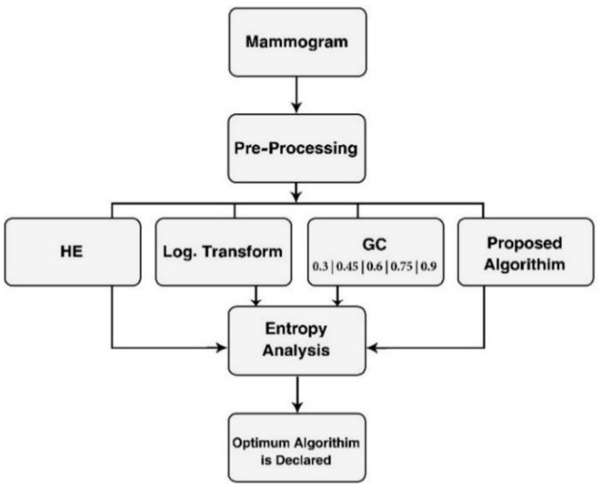


Figure 2. The block diagram of assessment process

3. RESULTS AND DISCUSSION

The entropy of the enhanced images is depending on the used algorithms as shown in Table 1. Table 1 shows that different algorithms modify the original entropy in different ways. Histogram equalization algorithm significantly decreased the original entropy, while the proposed enhancement algorithm have almost the same entropy as the original. The Logarithmic transformation algorithm has slightly modified the original entropy. Whereas the Gamma correction algorithm modified the original entropy according to the used factor, this algorithm (i.e GC) showed that the lowest factor being used gives the highest change in entropy and vice versa (refer to Figure 3 and Figure 4). The differences between the original entropy and the modified entropies that resulted from the used enhancement algorithms have been examined to identify the minimum EDV and eventually the optimum enhancement algorithm is chosen. It is clearly seen that the minimum EDV is obtained when using the proposed enhancement algorithm (morphology enahancement). Gamma correction of 0.9, however, was ranked secondly in producing minimum EDV. Figures (3 and 4) show how the mammography image is enhanced according to used algorithms.

This research has passed through several stages; starting from choosing the right database as a source of the images until the final stage of producing enhanced images. As mentioned in the previous sections, four enhancing algorithms have been used. The proposed enhancement algorithm (morphology enhancement), HE, Log Transform and GC with different values (0.3, 0.45, 0.6, 0.75, 0.9). The reason for using these algorithms in accompanying with the proposed one is to compare their outputs. MIAS was chosen as a source of the mammography images due to the good images' resolution, in addition to the diagnosing information supplied with them. The goal of the proposed enhancement algorithm is to reach the best possible enhancement of the interested area. The labels and the background of the breast are considered as lower importance than the breast itself. Therefore, the region of interest (Breast area) was identified and cropped before applying any of the enhancing algorithms. Approving the best enhancing algorithm has basically based on the statistical factor minimum EDV. The EDV has been used to compare the entropy resulted from each applied algorithm with that of the original images. Thus, the closer resulted entropy to the original one was identified as the best enhancing algorithm. Table (1) showed the entropies resulted from used enhancements algoritms. It is clearly seen that the proposed algorithm has provided the nearest entropy value to the original entropy. The quality of images enhanced by the GC is basically depending on the value of (γ). In this paper, five values of (γ) were used, the maximum used value was (0.9). Exceeding (γ = 0.9) to (γ = 1) will produce an identical image to the original one. In addition, multiplying Log Transform and GC by a factor will modify the brightness of the enhanced image, depending on the value of that factor. Using factor less than one decrease the brightness and vice versa.

Table 1. Comparison amongst the applied enhancement algorithm on mammograms for Entropy analysis

Images sequences	Original Entropy	Proposed Enhancement Entropy	HE Entropy	Log. Transform Entropy	GC 0.3 Entropy	GC 0.45 Entropy	GC 0.6 Entropy	GC 0.75 Entropy	GC 0.9 Entropy
1	6.8974	6.9177	5.3222	6.4244	6.1989	6.4721	6.6368	6.7503	6.846
2	6.9393	6.9688	5.318	6.4318	6.1691	6.4694	6.6497	6.7763	6.881
3	6.607	6.6775	5.4783	6.0771	5.807	6.0958	6.2891	6.4416	6.5594
4	6.529	6.5814	5.1717	6.0034	5.7121	6.0118	6.1972	6.339	6.4601
5	5.6535	5.7205	4.5656	5.2023	4.9535	5.2111	5.3692	5.4912	5.5947
6	6.4031	6.4322	5.1507	5.9051	5.6415	5.9216	6.1044	6.2359	6.3463
7	6.4192	6.4398	5.0577	5.8848	5.5707	5.8837	6.0675	6.2172	6.3468
8	5.4226	5.4507	4.3588	4.9726	4.7036	4.9639	5.1273	5.2535	5.3598
9	6.1838	6.1987	4.8155	5.679	5.3886	5.6813	5.8511	5.9933	6.1117
10	6.7011	6.7298	5.3856	6.1186	5.7722	6.1085	6.3201	6.4835	6.6185
11	6.874	6.91	5.3906	6.3177	6.0029	6.3262	6.5194	6.6675	6.7949
12	6.1148	6.1507	4.9428	5.591	5.2726	5.5831	5.7603	5.9131	6.0407
13	6.9124	6.9429	5.456	6.4246	6.203	6.4756	6.6501	6.774	6.8652
14	7.0354	7.0564	5.6098	6.5593	6.3579	6.6344	6.8056	6.9135	6.9935
15	6.6299	6.6591	5.4398	5.9932	5.5986	5.9751	6.1874	6.3675	6.5279
16	6.6299	6.6591	5.4398	5.9932	5.5986	5.9751	6.1874	6.3675	6.5279
17	6.3156	6.3584	5.1258	5.7748	5.4529	5.7668	5.9625	6.115	6.2387
18	7.0258	7.0407	5.4752	6.4713	6.168	6.4888	6.6809	6.8312	6.9542
19	6.7645	6.7884	5.3806	6.3053	6.1011	6.3615	6.5275	6.6403	6.722
20	6.6236	6.6449	5.0616	6.1413	5.8861	6.1644	6.33	6.4567	6.5651
21	6.0842	6.1467	4.9165	5.5847	5.2929	5.581	5.7632	5.9073	6.0221
22	6.7434	6.7774	5.4621	6.1796	5.8593	6.183	6.3867	6.5374	6.6723
23	6.8611	6.8811	5.3794	6.3376	6.062	6.3556	6.5461	6.6899	6.8002
24	6.7768	6.8079	5.4936	6.1964	5.8702	6.2013	6.4133	6.5697	6.7018
25	6.8256	6.8473	5.3021	6.2644	5.9314	6.2601	6.4543	6.6104	6.7444

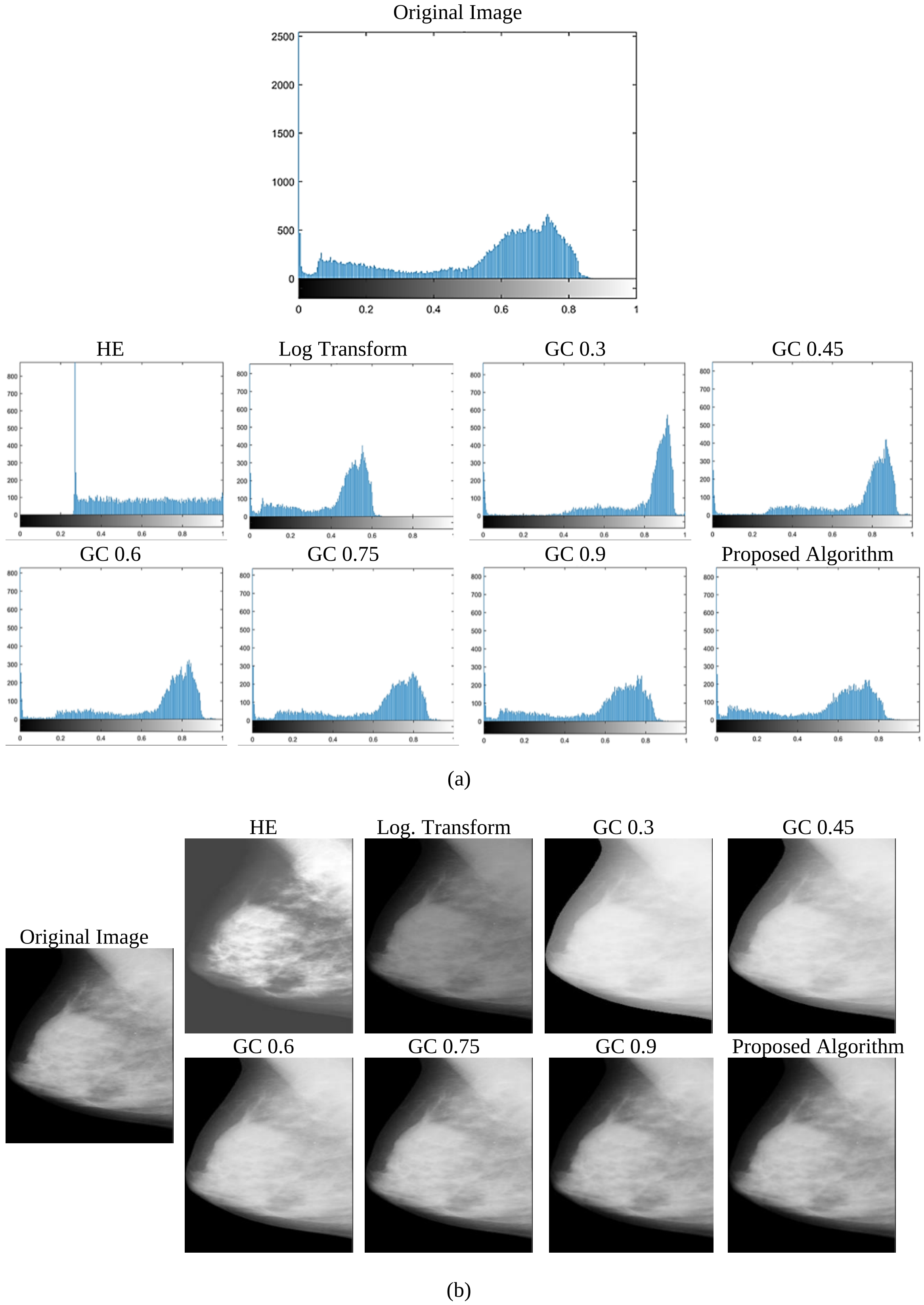
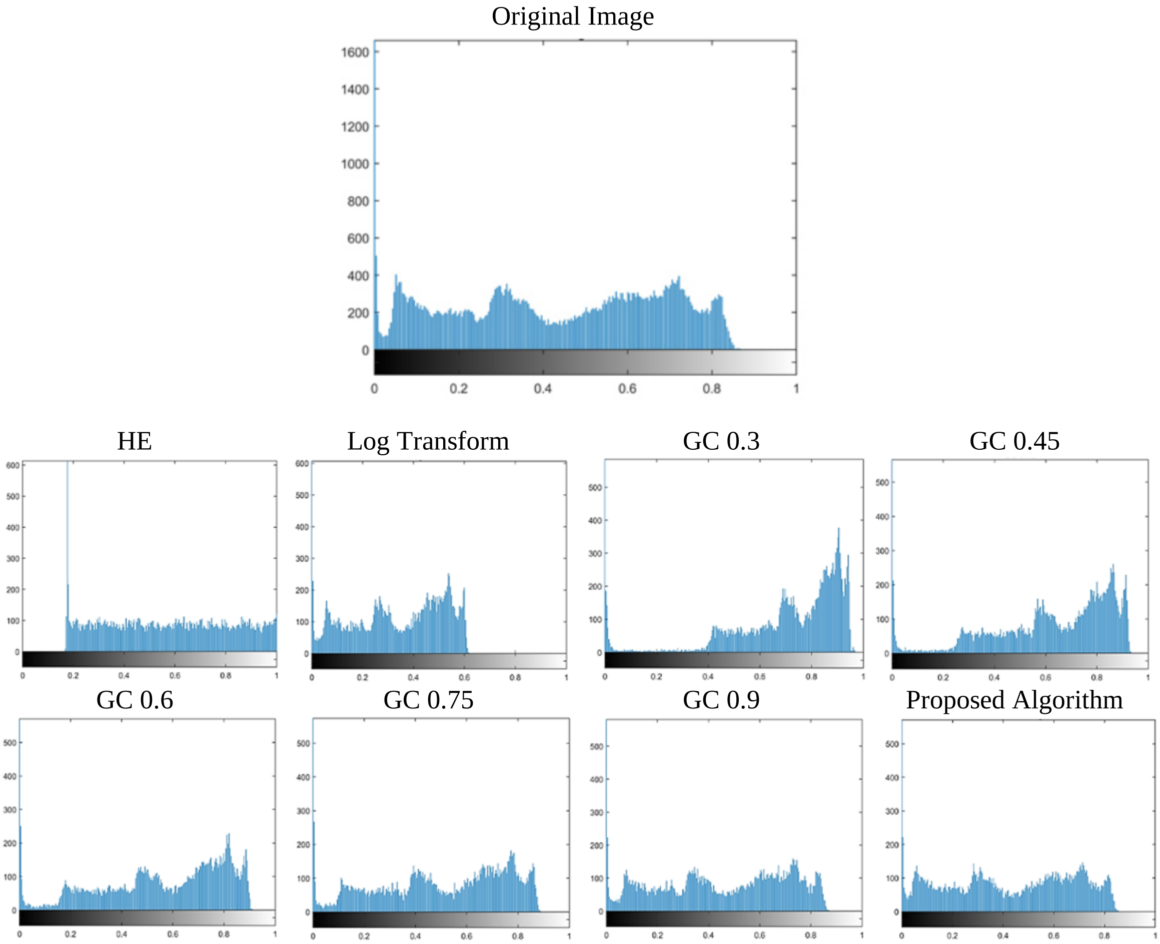
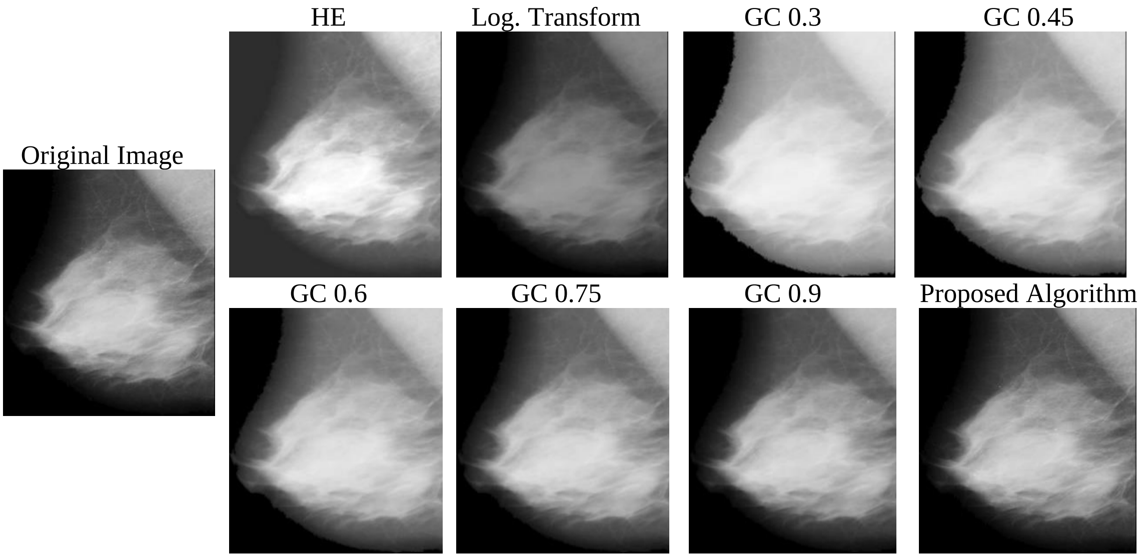


Figure 3. (a) Histograms of the original mammogram with the output of different enhancement algorithms, (b) The effect of applied enhancement algorithms on mammograms



(a)



(b)

Figure 4. (a) Histograms of the original mammogram with the output of different enhancement algorithms, (b) The effect of applied enhancement algorithms on mammograms

4. CONCLUSION

Several popular enhancement techniques including the proposed enhancement algorithm have been applied to the selected mammographic images. Minimum (EDV) was used as a metric to evaluate the efficiency of proposed enhancement algorithm in comparison with other enhancement algorithms. For every selected image, the entropy has been calculated before and after applying the aforementioned algorithms. Then, a brief comparison was done amongst these algorithms according to the resulted entropy differences. Thus, our study declared that the best enhancement was done by the mathematical morphology enhancement (the proposed enhancement algorithm) in comparison with other enhancement algorithms.

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