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Mammogram Image Contrast Enhancement by Preserving Radiation Lines based on Adaptive Tuning of the Nonlinear Polynomial Filter Coefficients

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Abstract

This research reviews NPF model and its parameters and then introduces proposed algorithm for contrast enhancement of mammogram images. Investigates proposed algorithms using quantitative and qualitative assessments and finally conclusion of the work is presented. In processing mammogram images, contrast enhancement and preserving the edge are especially important because radiation lines around the lesion specify whether a tissue is cancerous or not. On the other hand, contrast enhancement should not cause the image to be saturated as some breast tissues have tiny calcifications which are not observable by saturation of the image. In this paper, using histogram equalization based on adaptive tuning of the nonlinear polynomial filter coefficients both mammogram image contrast is enhanced and radiation lines around the lesion are observed better and at the same time leads to lower image saturation.

Keywords:

Mammogram Image Contrast, Image Contrast Enhancement, Preserving Radiation Lines, Adaptive Tuning, Polynomial Filter Coefficients

1. Introduction

Mammography is a simple radiography image from the breast and a tool for early discovering of intangible breast cancers (Jain et al., 2013). Cancer breast can be detected by mammography ten years ahead being tangible. All 40 years women and older should do mammography every two years. Women who have a close relative with breast cancer (mother or sister) should do mammography annually after 35. Mammography has vast applications including:

- Screening the women over 40 years old for breast cancer
- Assessment of the patients suppose to have breast mass
- Fallowing up treated breast cancer by removing a part of the breast and radiotherapy
- Assessment of the opposite breast in those whose one breast has been removed due to cancer

Processing mammogram images faces with challenges including:

- Mammogram images have high noise and low contrasts which leads to wrong detection. Then designing an algorithm to remove noise and enhance contrast helps radiologists to analysis and interpret mammogram images better .
- The edges of the radiation lines of the lesion which determine if a lesion is cancerous or not, generally are weaken in common pre-processes (such as noise decrease and so on)

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- Common algorithms for contrast enhancement of the mammogram images make them saturated in such as way that tiny calcifications of the lesions are not seen anymore. Samples of mammogram images are shown in (Fig. 1).

Fig. 1. Samples of mammogram images

There are various approaches for contrast enhancement of the mammogram images which most importantly are morphological filters (Diaz-Huerta et al., 2014), second order filters (Pandey et al., 2013; Zhou et al., 2009) and UM (Gupta and Bhateja et al., 2012). UM which bolds parts contain frequencies above the image such as edges and details is in various types. Although LUMS bolds details very well using high-pass filter but it is very sensitive to noise (Chan et al., 1987). Replacing second order filter with laplace operator (Lee and Park, 1990), second order filter (Ramponi et al., 1996) and cubic operator (Pandey et al., 2013) in UM, various other editions of this filter can be seen. Combination of local histogram equalization and UM leads to local contrast enhancement comparing to laplace operator (Xiao and Xiang, 2010). In another method, named NLUM, logarithmic operators are applied for contrast enhancement of mammogram images. The present study is organized further in three sections: Second section reviews NPF model and its parameters which are provided in (Bhateja et al., 2016) and introduces proposed algorithm for contrast enhancement of mammogram images. Section 3 investigates proposed algorithms using quantitative and qualitative assessments and finally conclusion of the work is presented.

2. Proposed method in this paper

Since the proposed algorithm is based on the paper (Bhateja et al., 2016) to obviate its failures, a short review of the provided algorithm in (Bhateja et al., 2016) is needed.

2.1. A brief glance to NPF

NPF first type structure which is provided in article (Bhateja et al., 2016) is modeled as Eq.1.

$$y_1(n)=y_{linear}(n)+y^1_{quadratic} \tag{1}$$

y_{linear} and $y^1_{quadratic}$ which are acting as high-pass filter and low-pass filter respectively are introduced in Eqs.2 and 3. Low-pass section of the filter decreases noise and high- pass section leads to enhancement of contrast and better representation of the details.

$$y_{linear}=ϴ_0 x_5^{2a}+ϴ_1(x_1^{2b}+x_3^{2b}+x_7^{2b}+x_9^{2b}) \tag{2}$$

$$y^1_{quadratic} = \phi_3(x_1^b x_2^c + x_1^b x_4^c + x_2^b x_3^c + x_3^b x_6^c + x_4^b x_7^c + x_6^b x_9^c + x_5^b x_6^c + x_5^b x_8^c) + \phi_4(x_1^b x_5^a + x_3^b x_5^a + x_5^b x_7^a + x_5^b x_9^a) + \phi_5(x_2^c x_5^a + x_4^c x_5^c + x_5^c x_6^a + x_5^c x_8^a) + \phi_6(x_2^c x_4^c + x_2^c x_6^c + x_4^c x_8^a + x_6^c x_8^c) \tag{3}$$

In Eq. (2) and (3), Xi specifies grey area of available pixels in a 3x3 window for every pixel of input image. a, b and c are power, Øi and Øj are polynomial coefficients of Eq. (2) and (3) which are arranged in article

(Bhateja et al., 2016) as constant values a=b= μ , c=8μ, θ0=0.2, θ1=0.1 as well as ϕ=8e, ϕ3=0.5e, ϕ4=ϕ5=e, , ϕ6=-e which e=0.15 has a value between 0.5 and 0.7. (Fig. 2) represents a sample of mammogram image as well as correspondent image with applied NPF model on it.

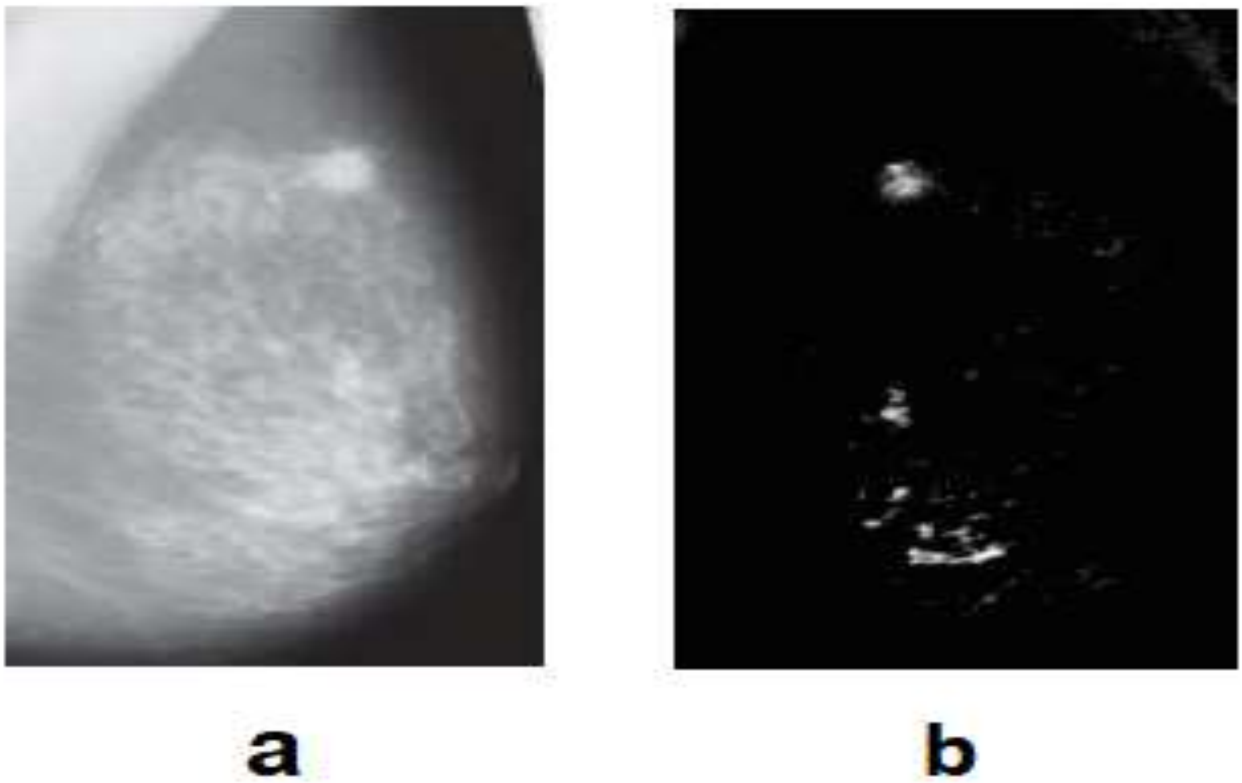

Fig. 2. (a) Input mammogram image (mdb202) and (b) Applying NPF provided in (Bhateja et al., 2016) on input image

2.2. Proposed algorithm

Article (Bhateja et al., 2016) has been used NPF and HVS models for contrast enhancement of the mammogram images. Contrast enhancement with this method has some weaknesses:

Spoiling marginal radiation of the lesion which from specialist point of view this image leads to wrong detection. It used NPF constant coefficients for enhancement of every mammogram image. Clearly, various images of mammogram need application of NPF algorithm with different coefficients due to diversity of the contrasts to prevent saturation. (Fig. 3) indicated a sample of using nonlinear filter to enhance contrast mammogram images. As it is seen in (Fig. 3), applying constant coefficients for contrast enhancement can leads to saturation of the grey areas and fading radiation lines around the lesion.

2.2.1. Extraction of NPF parameters based on the image

For every mammogram image with N pixel its specific NPF coefficients can be obtained. Given to Eq. (2) and (3), Eq. (1) can be written against all pixels of the image as Eq.4:

$$\begin{pmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{pmatrix} = \begin{pmatrix} X_5^{2a} \ldots X_2^c X_4^c + X_2^c X_6^c + X_4^c X_8^a + X_6^c X_8^c \\ . \\ . \\ . \\ X_5^{2a} \ldots . X_2^c X_4^c + X_2^c X_6^c + X_4^c X_8^a + X_6^c X_8^c \end{pmatrix} \begin{pmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \varphi_1 \\ \varphi_2 \\ \varphi_3 \end{pmatrix} \tag{4}$$

If we name coefficient matrix in Eq. (4) as A then NPF coefficients for every mammogram image can be obtained according to (Zhou et al., 2009).

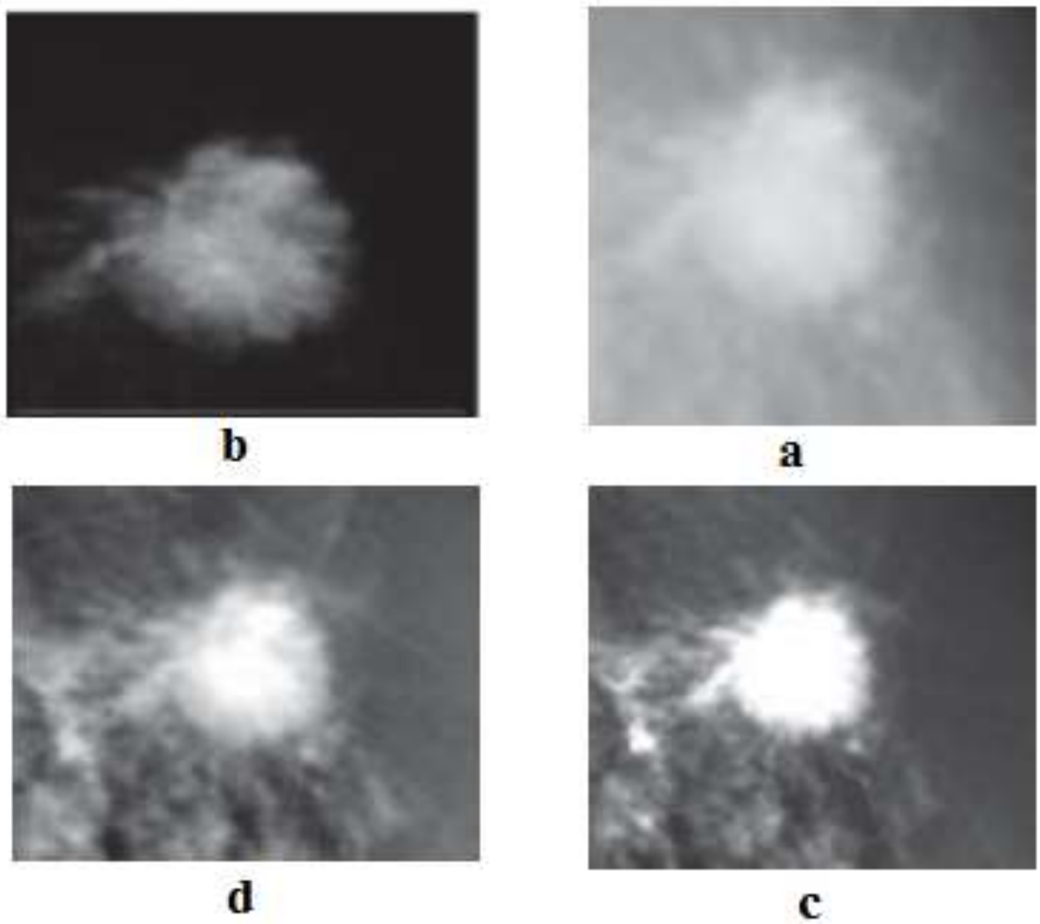

Fig. 3. A sample of NPF component application in contrast enhancement of mdb202 mammogram image a) input image b) enhanced image using provided method in (Bhateja et al., 2016) c) output image with proposed method with constant coefficients of the paper (Bhateja et al, 2016b) and d) by specific parameters of the input image

Flowchart of the proposed algorithm is shown in (Fig. 4). This algorithm is made of two parts: 1- Edge preserving algorithm 2- contrast enhancement algorithm. In this method image is normalized first (negative parts of the image is removed from initial image and divided to interval length of the grey area). Then CLAHE (15) algorithm is applied. The resulted image is deducted from input image and according to (Pandey et al., 2013) and (Zhou et al., 2009) image specified NFP coefficients are obtained. Having NFP coefficient and Eq. (1), (2) and (3) sharpened mammogram image is obtained. Finally, CLAHE algorithm is applied to enhance contrast. The output image will have a high contrast by maintain the edge.

3. Assessment of the proposed algorithm

Evaluation of the contrast enhancement algorithm is not a simple task and usually qualitative assessment is done along with quantitative assessment simultaneously to gain better results. In this paper some available images in MIAS (16) database is used. This database includes 322 grey images in 1024x1024 sizes.

3.1. Qualitative assessment

The result of the applying the proposed method and its comparison with other methods on mammogram image are indicated in (Fig.4) and (Fig.5). The results of the applying the proposed method in in (Fig.4(d)) and

(Fig.5(d)) indicated that enhanced images have high quality in such a way that image contrast enhanced well and at the same time radial radiation is preserved and saturation state does not occur.

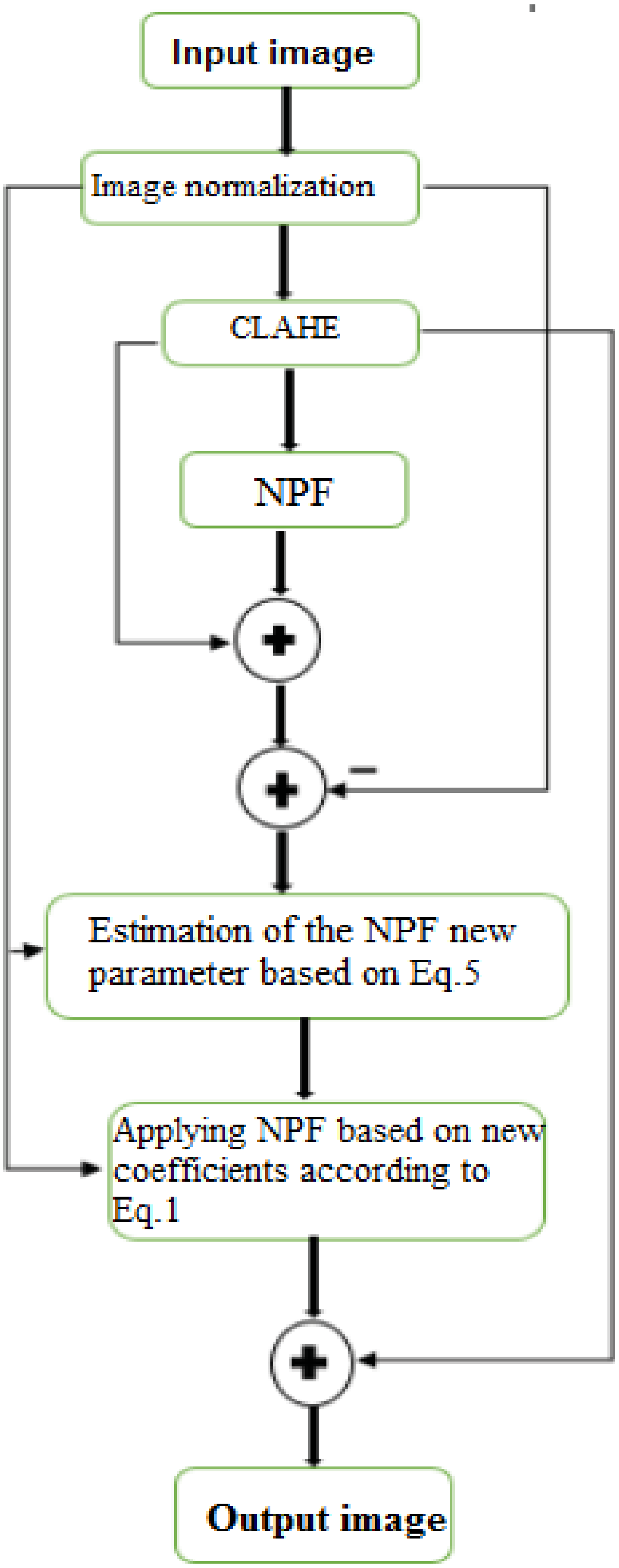

Fig. 4. Flowchart of the proposed algorithm

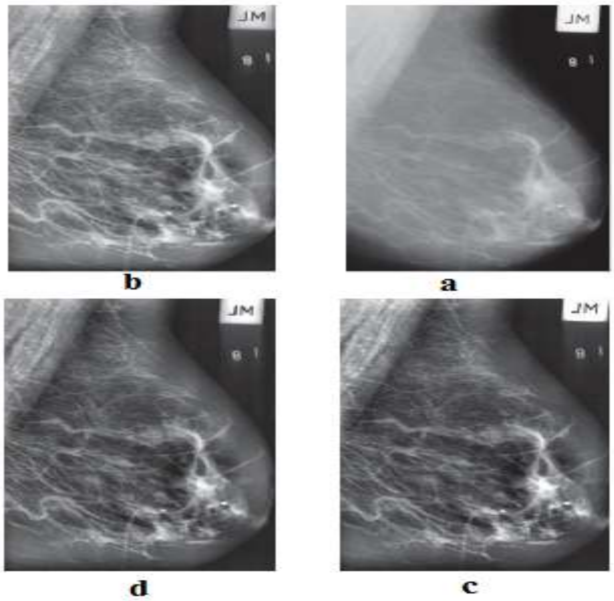

Fig. 4. contrast enhancement of the mammogram images a- input image b- applying CLSHE algorithm c- applying proposed algorithm with constant NPF parameters of paper (Bhateja et al., 2016b) d- applying proposed algorithm with input specific NPF parameters

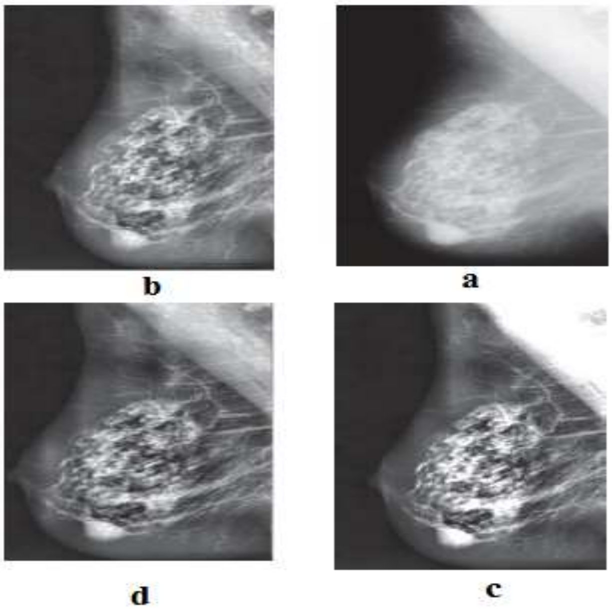

Fig. 5. contrast enhancement of the mammogram image a- input image and applying algorithm b- CLASHE c- proposed by constant NPF coefficients of paper (Bhateja et al., 2016b) d- proposed by input specified NPF coefficients

3.2. Quantitative assessment

To evaluate efficiency of the proposed method in this paper, EMEG (1) and NIQE (Mittal et al., 2013) measures are used on more images from image database of (16) then the results are indicated in Tables (1) and (2). EMEG measure: this measure specifies the mount of enhancement and have a value in an interval of [0,1]. The closer this value is to 1, the greater the enhancement. If we divide the image to k1k2 blocs of 8x8, EMEG is obtained as Eq. (6).

$$\text{EMEG}(x) = \sum_{i=1}^{k1} \sum_{j=1}^{k2} \frac{1}{\beta} \max \left(\frac{X_{i,j}^{dx,h}}{X_{i,j+\epsilon}^{dx,L}}, \frac{X_{i,j}^{dy,h}}{X_{i,j+\epsilon}^{dy,h}} \right) \quad (6)$$

In which $X_{i,j}^{dx,h}$ and $X_{i,j}^{dx,I}$ are maximum and minimum absolute value of Xi,j bloc's derivative in x direction respectively and $X_{i,j}^{dy,h}$ and $X_{i,j}^{dy,1}$ are maximum and minimum absolute value of Xi,j bloc's derivative in y direction respectively. Weightening coefficient β as 255 and ϵ as constant none zero value are selected for preventing dominator to be zero.

Table 1. Quantitative assessment and Comparison using NIQE measure

Mammogram image No.	Input image	CLAHE method	Using NPF with constant coefficients	Proposed method
mdb021	0.0972	0.2548	0.2860	0.2677
mdb184	0.0792	0.2604	0.3018	0.2616
mdb202	0.1734	0.2856	0.3301	0.2969
mdb022	0.0624	0.1960	0.2342	0.2114
mdb148	0.1286	0.4399	0.4862	0.4266
mdb209	0.0900	0.2349	0.2677	0.2427
mdb219	0.1076	0.2938	0.3379	0.2974
mdb193	0.0940	0.2650	0.3166	0.2858
mdb006	0.0831	0.2412	0.2691	0.2437
Mdb196	0.0911	0.2853	0.3081	0.2913

Given to (Table 1), although contrast of images are enhanced using NPF by constant coefficient (Bhateja et al., 2016) but based on the results obtained from qualitative assessment in Section 1-3, contrast enhancement with this method leads to image saturation. Based on (Table 1) and the results of the qualitative assessment in Section 1-3, the proposed method both enhances contrast and does not get saturated and information of the image is preserved. NIQE measure: To assess this measure MATLAB library command has been used. The quality of the initial image does not have any influence on the amount of this measure. The smaller the value of this measure is, the greater the enhancement. In (Table 2) NIQE measure values is obtained for initial image as well as the images obtained from proposed method and then CLAHE algorithm is brought.

Table 2. Qualitative assessment and Comparison using NIQE measure

Mammogram image No.	Input image	Obtained image by CLAHE	Enhanced image by proposed method
mdb021	4.3737	5.5730	3.8630
mdb184	4.7867	6.0215	3.4067
mdb202	4.6198	6.4440	4.2141
mdb022	6.0949	6.0215	3.8544
mdb148	4.0087	4.3432	4.2723
mdb209	3.6886	4.7834	3.9641
mdb219	4.0047	4.9609	3.6329
mdb006	5.0841	7.2939	3.5445

Considering to (Table 2), in 6 out of 8 input images, NIQE value of the enhanced image by proposed method is smaller than input image and in all images, the proposed method has lower NIQE value compare to CLAHE which reflects good efficiency of the proposed method.

4. Conclusion

In processing mammogram images, contrast enhancement and preserving the edge are especially important because radiation lines around the lesion specify whether a tissue is cancerous or not. On the other hand, contrast enhancement should not cause the image to be saturated as some breast tissues have tiny calcifications which are not observable by saturation of the image. In this paper, using histogram equalization based on adaptive tuning of the nonlinear polynomial filter coefficients both mammogram image contrast is enhanced and radiation lines around the lesion are observed better and at the same time leads to lower image saturation.

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