Fast fourier transform recursive filtering for bilateral mammography comparison

Purpose

In this paper we describe a method to compare left and right mammographic views of the same patient as in CC and as MLO projection. The proposed solution uses the symmetry properties of the breast and compute a geometric transformation that permits to represent the two images in comparable coordinates systems. Through this method, potential pathological ROIs detected in one of the projections are compared both with the same region internally randomized as the symmetric region in the second view. The method is applied on a dataset composed of 200 couples of pathological images and experimental results show that this method enables a reduction by up to 95 % of the FP/imm number detected after the classification step.

Methods and Materials

Breast cancer is the most common cancer affecting women world-wide, with an estimated 1.050.000 new cases in 2000 [i] on page   .

Early detection is the most effective way to reduce its incidence. The regular mammographic screening of asymptomatic patients is the best way to detect this pathology accurately in its early stages.

A couple of mammograms is usually produced for both right and left breasts: the Cranio-Caudal (CC) and the Middle-Lateral Oblique (MLO) views; also, these mammograms can be analysed either individually or as couple for temporal or bilateral comparison.

Comparison of couples of mammographic images belonging to a same patient is an important technique used in clinical practice by radiologists for an early and correct diagnosis: massive lesions should be visible in both CC and MLO views of the same breast, so that, if no correspondence is found between the two mammograms, the potential lesion is usually considered as a thrue positive.

Recently, CAD (Computer Aided Detection) systems [ii] on page   have been successfully used in pathology detection, being essentially effective in screening if used as "second reader", reducing both costs and time. CAD algorithms are considered performing if they exhibit both high sensitivity and high specificity [iii] on page   .

All patient images (CC Right/Left - MLO Right/Left), including those acquired at different dates, can be analyzed in couples for temporal or bilateral comparison **Fig 1**. The temporal comparative analysis uses mammograms acquired at different dates for the study of the breast tissues evolution; the bilateral comparative analysis input consists usually of the right and left mammogram views of a same patient and it's aimed to detect possible asymmetries. Both techniques are particular kinds of intra-modal fusion which

consists in fusing together two mammograms in order to get overall information [iv] on page   .

Image registration

Mammograms comparison can be carried on applying a suitable deformation on the two images. In medical image processing many deformations are computed through the establishing of suitable landmarks.

Vujovic & Brzakovic [v] on page   deal with the problem of finding these correspondences in the case of temporal comparative analysis. Landmarks are automatically chosen in the neighbourhood of the blood vessels, because of their easy detection on mammograms. Then, a suitable matching algorithm finds possible correspondences among landmarks in the same views of the breast. Among these correspondences, the best matches are those maximizing the similarity between neighbouring regions of the chosen landmark points.

Some methods for bilateral comparative analysis use suitable algorithms to register the two views. Some of these [vi] on page   [vii] on page   use rigid transformations to produce a rough alignment of the two images, while others apply a non-rigid transformation that deforms one of the images, increasing its similarity with the other one.

These parameters are computed through N correspondences between equally spaced landmarks chosen on the breast contour starting from the nipples. This method use N=12 points and has been applied tto compare the two images of the same view.

Algorithm description

In this method a geometric and elastic transformation is used to superimpose the two CC or MLO projections left and right breast, making comparable the two images.

The pathologic ROI extraction from an image through an iso-contour segmentation process allows the selection of a small area that has both the signal (pathology) that the noise (parenchyma).
In the case of massive lesions the signal can be highlighted by a higher brightness of a ROI compared to the surrounding parenchyma, either by a "spatial coherence" between neighboring pixels that show a higher brightness at the center of ROI, sloping down versus the edge.

To evaluate the signal and noise contribution it was performed a simulation process in three steps.

Step 1 - Since, generally, a ROI extracted has an asymmetric shape, it is possible to find a minimum rectangle that contains it entirely; for easy of description of the method let us assume that, at the first approximation, this rectangle is a square and the ROI extracted is the projection of a two-dimensional Gaussian shape along the rows and columns, with the intensity decreasing from the maximum of the central pixel (of the square) to zero at the edges (3 sigma away from the center of the square).

The corresponding image is shown in **Fig 2**.

The image normalization, zero mean and unit standard deviation, will allow the comparability of results with those obtained from other ROIs shape.

Applying the 2D Fourier transform to the ROI, we obtain the plot of **Fig 3**.

The regions at the corner of the square are clearly visible, corresponding to low spatial frequency components, while the higher frequency components are in the central part.

Since the pitch resolution is fixed, regardless of the pixel number used to include the ROI, the Nyquist frequency is always the same, but the step in frequency channel in the spectrum is inversely to the rows and columns number used by the matrix.

It should be noted that the intensity of each pixel is shown in logarithmic scale for the visual compensation.

Step 2 - In the same area, circular, where it was "injected" a Gaussian, now it was injected a white noise with arbitrary amplitude. Once again, the same area normalization assures us the data comparability.

By applying again the 2D Fourier transform to this new ROI, we obtain the plot in **Fig 4**.

Step 3 - Inside the rim area injected with Gaussian, the signal was randomized by exchanging random pairs of pixels. Once again the injected power was the same as in the case of the Gaussian, but the signal "spatial coherence" has been completely lost.

Since the "signal" injected, randomized or not, and the noise are normalized, the total power spectrum is constant; the shift of the main spectrum component, from low to high spatial frequencies, show a decay of the signal in the ROI. The correct F_{cutoff} choice allow to find the better signal/noise ratio R (**total power spectrum "DC - F_{cutoff} "/total power "F_{cutoff} - $F_{Nyquist}$"**).
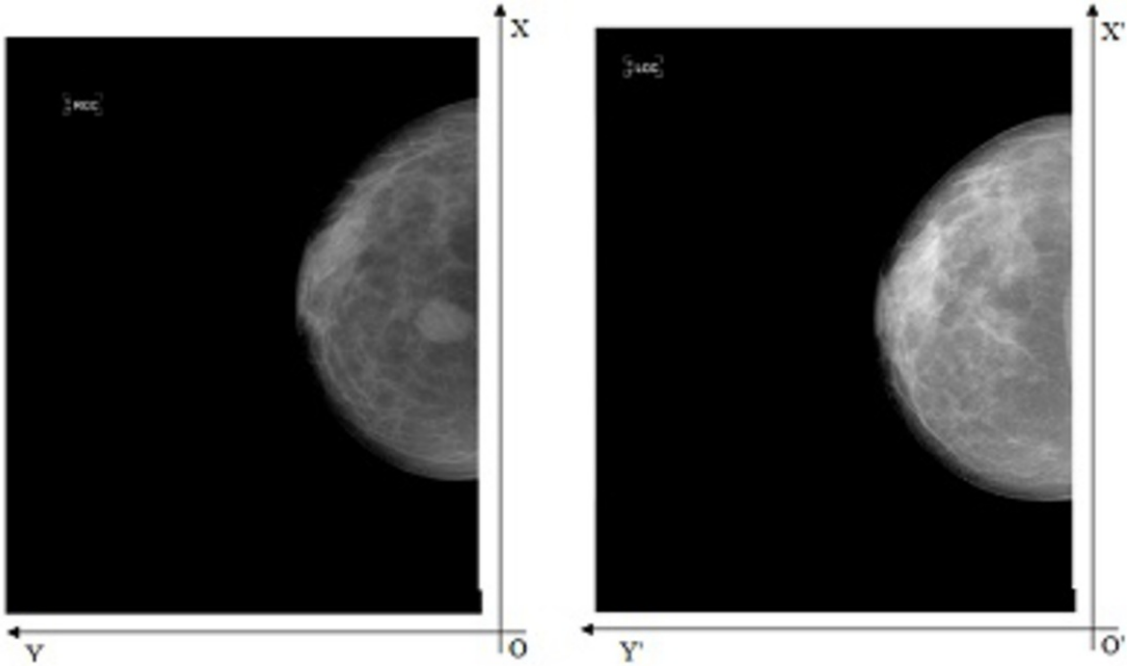
Images for this section:

Fig. 1: Bilateral Original Images (RCC - LCC).
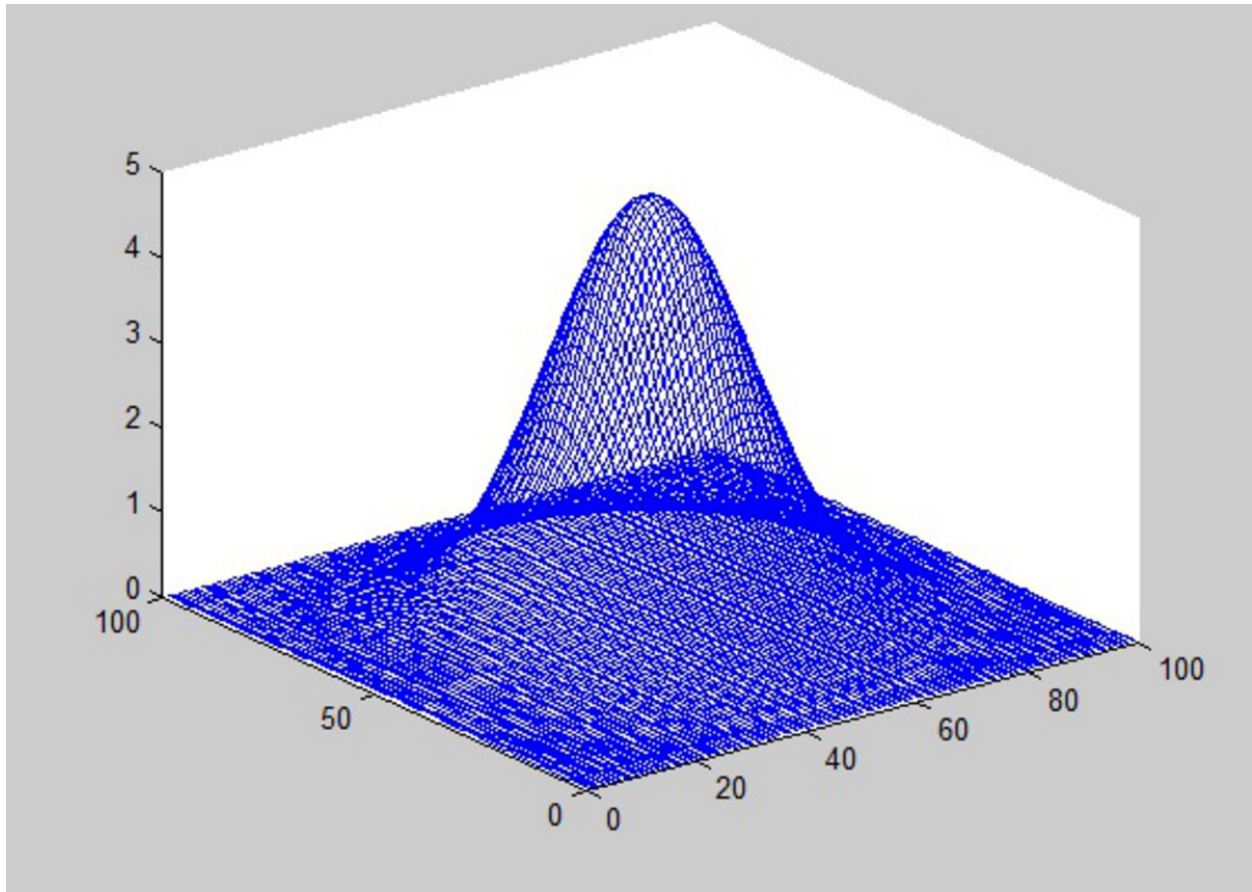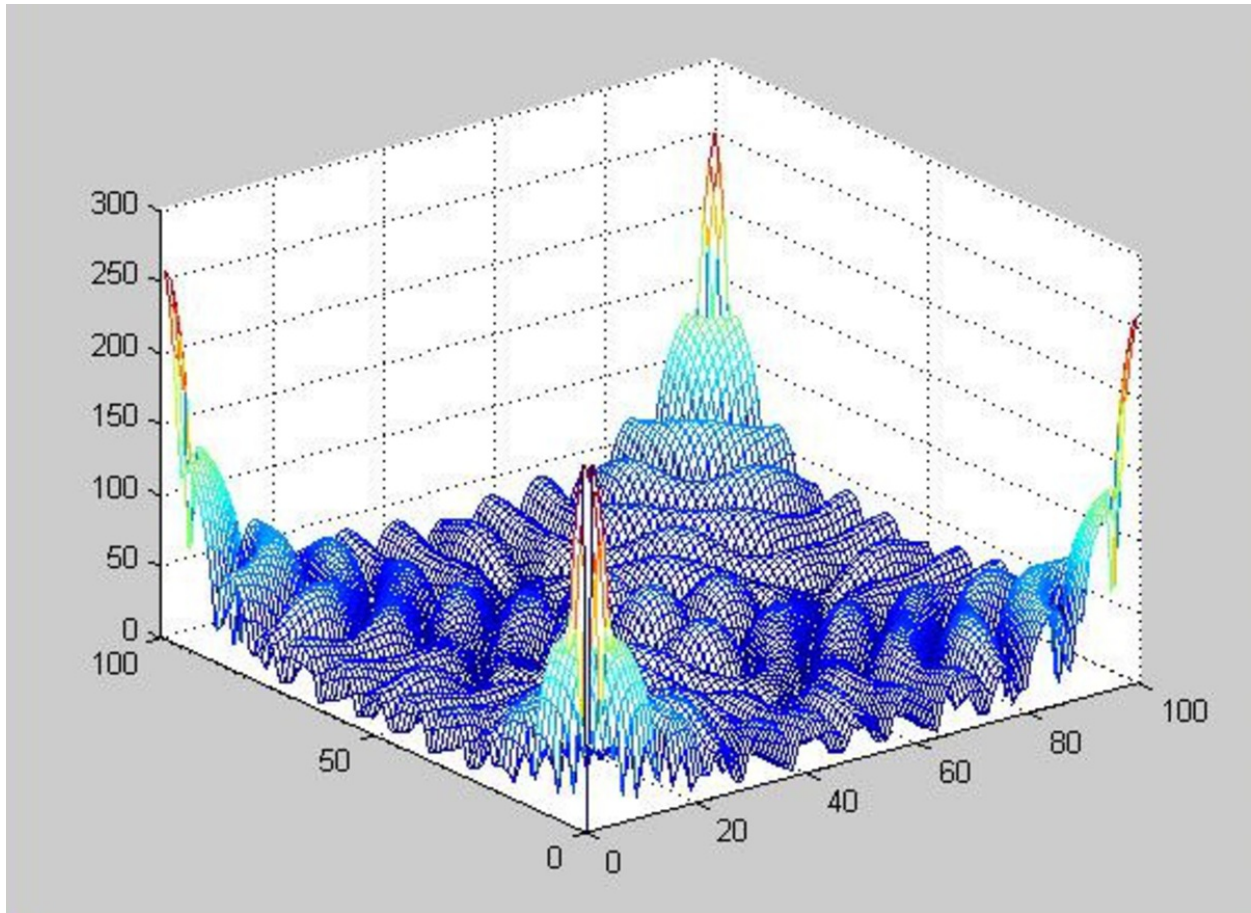
Fig. 2: Gaussian shape for simulation

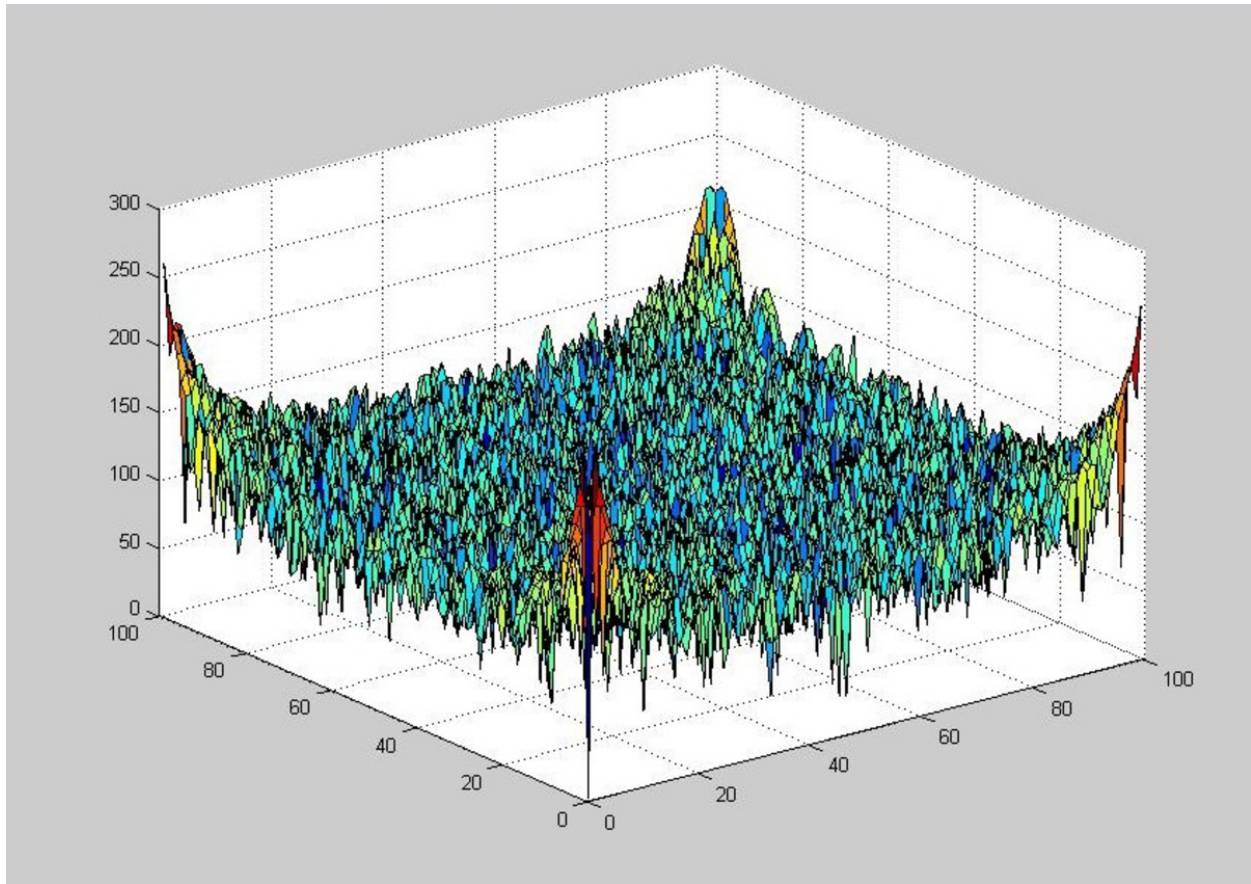**Fig. 3:** Power spectrum of a gaussian shape.

Fig. 4: Power spectrum of the noise.

Results

The acquired informations by the simulation process have been used to extract data by the mammographic images. In particular, a selected ROI_p (p=potentially pathological) in one of the pair projections (RCC/LCC, RMLO/LMLO) have been compared with the exactly symmetrical areas in the other projection of the same pair, obtained after an scale elastic transformation, resulting in projections overlapping of the same pair.

Through the choice of a correct F_{cutoff}, determined in the simulation process, it is possible a comparison between ROI_{pr} (pr=pathological randomized) and ROI_s (s=symmetrical) spectra, in order to eliminate false positives maintaining only the ROI visible in one pair's projection. This is sufficient to ensure the presence of pathology (**Fig 1**).

In particular, the method evaluates the ROI_p elimination when the R value in ROI_{pr} is less than the R value in the ROI_s.

The correspondences detection is the most delicate step of the whole process and is determinant to the success of the whole method; it is a subjective activity whose results are liable of errors. This implies the necessity to consider tolerances when identifying a correspondence among the CC and the MLO views is requested. It is reasonable to consider that one or more columns of the MLO view (i.e. left) corresponds to more columns of the other MLO (i.e. right) image.

The method was applied on a dataset composed of 200 couples of pathological images.

In particular, experimental evidence shows that when the patient has pathological mass lesions in only one of the view (i.e. left), the symmetrical view (i.e. right) include only noise, so the signal disappear. Comparing the correlated ROIs with the radiologist diagnosis, we have observed a full matching up to 95% of the cases.
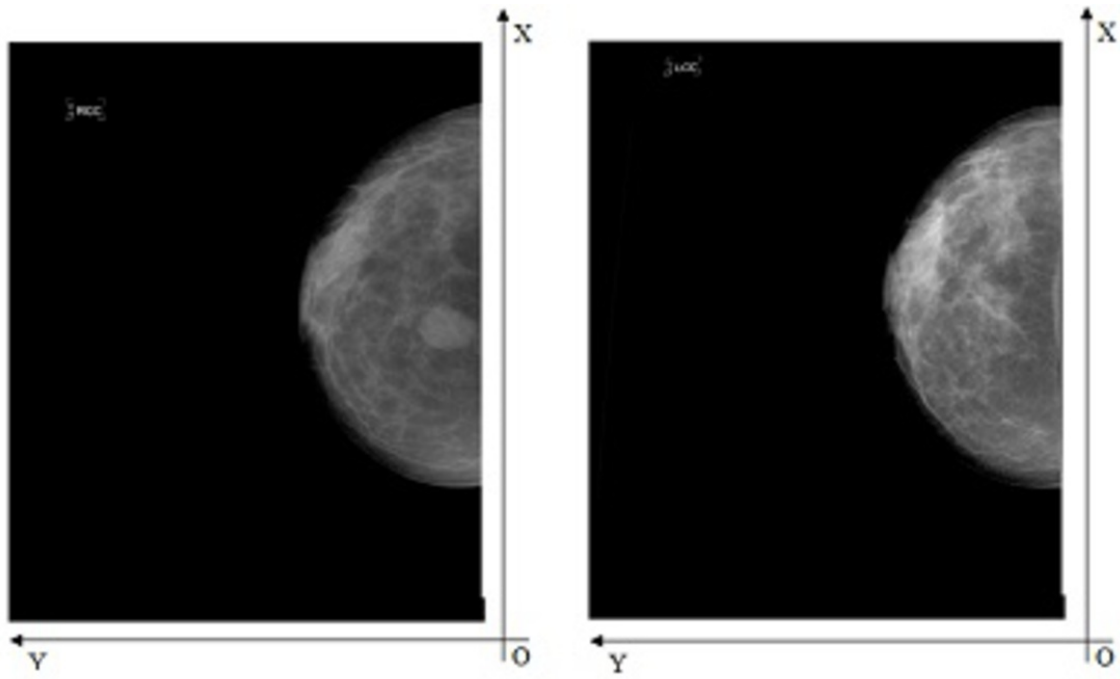
Images for this section:

Fig. 1: Bilateral Images (RCC original - LCC Rotate)

Conclusion

In this paper, we described a method to compare CC or MLO, left and right, breast images of the same patient for false positive reduction. Particularly, the developed method computes a geometric transformation bringing the symmetry axis of the two mammogram to overlap; then, through suitable user defined landmarks it computes a scale transformation that takes into account the breast deformation of one of the view with respect the other.

The geometrical transformations returned by this method have been used to operate a false positives number reduction. Indeed, applying the same transformations to the ROI images, it is possible to compare them and then select only those that are not correlated.

In this paper are reported the results of the method by using CyclopusCAD® powered by Medicad S.r.l. (EXPO E - 572).

References

[i] on page   P. Boyle, ME Leon, P. Maisonneuve and P. Autier, "Cancer control in Women. Update 2003", International Journal of Gynecology & Obstetrics, 83, Supplement 1, 179-202, (October 2002).

[ii] on page   R. Bellotti, F. De Carlo, S. Tangaro, G. Gargano, G. Maggipinto, M. Castellano, R.Massafra, D. Cascio, F. Fauci, R. Magro, G. Raso, A. Lauria, G. Forni, S. Bagnasco, P.Cerello, E. Zanon, S.C.Cheran, E. Lopez Torres, U. Bottigli, G.L. Masala, P. Oliva, A.Retico, M.E. Fantacci, R. Cataldo, I. De Mitri, G. De Nunzio "A Completely Automated Cad System for Mass Detection in a large mammographic Database" Medical Physics, **33** (8), 3066 - 3075, ISSN: 0094 -2405 (2006).

[iii] on page   J. A. Hanley and B. McNeil, "A method of comparing the areas under receiver operating characteristic curves derived from the same cases", Radiology, 148, 839-843, (1983).

[iv] on page   Wirth, Choi, Jennings "A Nonrigid-Body Approach to Mammogram Registration for Comparative Analysis", Image and Vision Computing, Auckland, New Zeland, 169-173, (1998).

[v] on page   Nened Vujovic and Dragana Brzakovic, "Establishing the Corrispondence Between Control Points in Pairs of Mammographic Images", IEEE Transactions on Image Processing, 6, 10, 1388-1398, October (1997).

[vi] on page   E.A. Stamatakis, A.Y. Cairns, I.W. Ricketts, C. Walker, P.E. Preece and A.J. Thompson, "A Novel Approach to Aligning Mammograms," presented at 2nd International Workshop on Digital Mammography, York, England, 355-364, (1994).

[vii] on page   F.F. Yin, M.L. Giger, K. Doi, C.J. Vyborny, and R.A. Schmidt, "Computerized Detection of Masses in Digital Mammograms: Automated Alignment of Breast Images and its Effect on Bilateral Subtraction Technique," Medical Physics, 21, 3, 445-452, (1994).

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