DETECTION OF MICROCALCIFICATIONS IN MAMMOGRAMS USING CONTINUOUS WAVELET TRANSFORM AND MULTISCALE PRODUCT

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Abstract

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Early detection of breast cancer relies heavily on the accurate identification of microcalcifications in mammograms. These small, low-contrast structures are often difficult to detect visually. In this paper, we propose a method based on the Continuous Wavelet Transform (CWT) combined with the multiscale product of wavelet coefficients to enhance spatial discontinuities associated with microcalcifications. After applying a pre-processing pipeline involving three combined techniques, the method is evaluated on images from the MIAS database and from the Mother and Child Hospital of N'Djamena. The results demonstrate a significant enhancement of microcalcifications, including those embedded within adipose tissue, thereby facilitating detection. The performances obtained outperform several approaches previously reported in the literature for similar image types.

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Introduction:-

The detection of microcalcifications in digital mammography is a key challenge in the early diagnosis of breast cancer. Microcalcifications are typically small, scattered, and low-contrast structures compared to surrounding tissues, making their visual identification difficult.

To improve automatic detection, several families of approaches have been explored:

- **Multiscale wavelet analysis:** Microcalcifications correspond to local discontinuities, visible in high-frequency components of the image. Wavelet-based multiscale analysis separates these components, enhancing subtle details (Chen & Lee, 1997; Bagci&Çetin, 2002).
- **Morphological filtering methods:** These techniques use morphological operators to isolate bright microstructures. They are effective in noise reduction but less adapted to highly heterogeneous tissues where microcalcifications may be obscured (Shaji et al., 2013).
- **Hybrid approaches:** Combinations of wavelets with statistical methods, classifiers, or neural networks have improved sensitivity and reduced false positives (Alarcon-Aquino et al., 2020; Mishra & Ranganathan, 2013).

Within this context, we propose a method combining the Continuous Wavelet Transform (CWT) with the multiscale product of coefficients, aimed at efficiently amplifying discontinuities corresponding to microcalcifications.

2. Methodology

2.1 Image Pre-processing

Three pre-processing combinations were evaluated, each designed to enhance contrast, reduce acquisition-related artifacts, and better prepare the images for multi-scale analysis.

Combination 1 relies on a sequence of morphological operations (opening and closing), followed by unsharp masking and dynamic range adjustment. Although effective in suppressing certain artifacts, it sometimes insufficiently preserves fine details. Combination 3 is similar to Combination 1 but replaces dynamic range adjustment with adaptive histogram equalization. While this method enhances overall contrast, it may simultaneously amplify noise.

Combination 2, which was selected for the remainder of the study, is distinguished by the optimized ordering of its operations. Unsharp masking is applied first, directly amplifying the high-frequency components associated with microcalcifications. Morphological operations (closing followed by opening) then remove artifacts without attenuating the amplified details. Finally, dynamic range adjustment (soft double-thresholding and intensity remapping) homogenizes the distribution of gray levels and significantly improves global contrast (Figure 1).

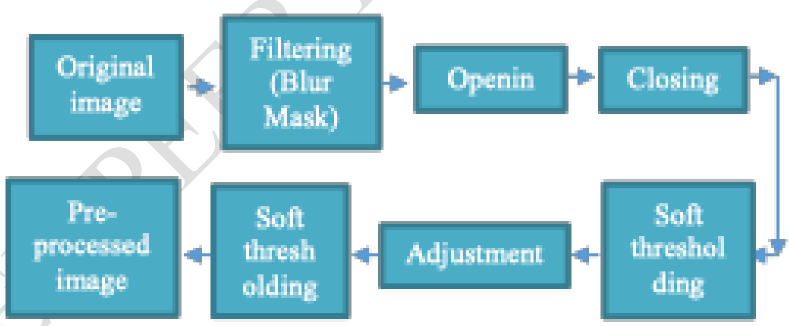


Figure 1 : Steps of combination 2

2.2 Continuous Wavelet Transform and Multiscale Product

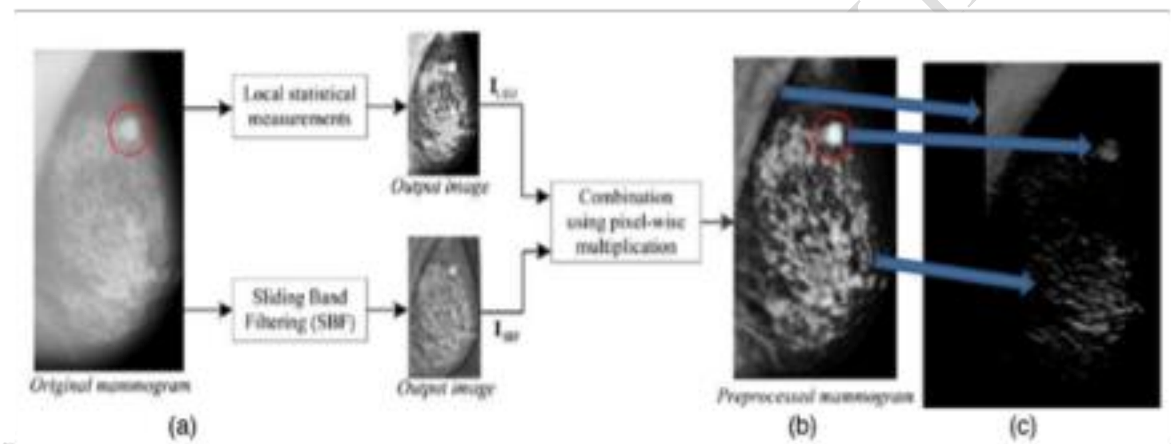
- **Choice of wavelet and decomposition levels:** A wavelet particularly adapted to spatial discontinuities is selected. The analysis is performed over five decomposition scales, balancing the preservation of fine details with the concentration of energy in the approximation (Mbainaibeye, 2000).
- **Multiscale product:** Wavelet coefficients at different scales are multiplied to amplify discontinuities (microcalcifications) while attenuating homogeneous regions.

3. Results

To illustrate the performance of the method, results are provided for images from the MIAS database and the Mother and Child Hospital of N'Djamena. Figures **2–5** highlight both the effects of pre-processing and the multiscale product, showing:

1. Precise delimitation of the region of interest (ROI).
2. Increased dynamic range for intensity variations corresponding to discontinuities.
3. Significant enhancement of microcalcifications, including those embedded within adipose tissues.

Figure 2 compares the proposed pre-processing with that of Jae (2014). The original image (Fig. 2a) contains extensive fatty tissue and dense adipose structures that may obscure important details. Jae's method (Fig. 2b) yields only modest improvement, with insufficient reduction of fatty components, consistent with the observations in Jae (2014) and Ilhame (2017). In contrast, our proposed method (Fig. 2c) effectively reduces both fatty mass and dense tissues, resulting in a much clearer ROI and reducing the risk of false positives.



<u>Figure 2:</u> Comparative pre-processing results: (a) original image, (b) preprocessed image (Jae, 2014), (c) image preprocessed using our method.

Figure 3 shows that the pre-processing approach proposed by Ilhame (2017) (Fig. 3b) fails to sufficiently eliminate fatty components, leaving an overcrowded ROI prone to false detections. Conversely, the proposed method (Fig. 3c) removes these undesirable components far more effectively, producing a clearer and more usable ROI. These findings reinforce the conclusions drawn from Figure 2.

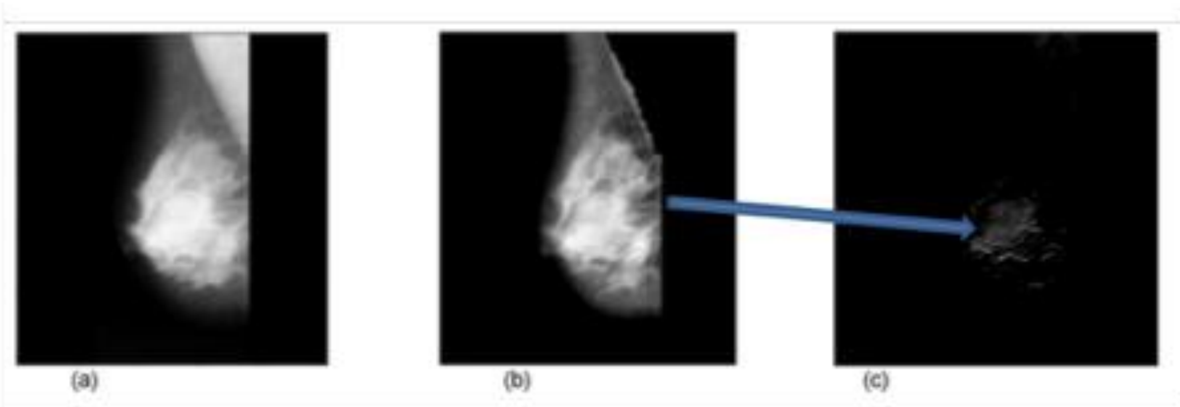


Figure 3: Comparative pre-processing results: (a) original image, (b) preprocessed image (Ilhame, 2017), (c) image preprocessed using our method.

Figures 4 and 5 demonstrate the performance of the Continuous Wavelet Transform using the Morlet wavelet and five decomposition levels. For both databases—MIAS (Fig. 4) and the N'Djamena Hospital dataset (Fig. 5)—the multiscale product extracts fine details more clearly than the original images (Figs. 4a and 5a). The resulting images (Figs. 4b and 5b) reveal microcalcifications distinctly while suppressing noise through Donoho soft thresholding and multiscale fusion. The method thus consistently highlights relevant structures across different image sources.

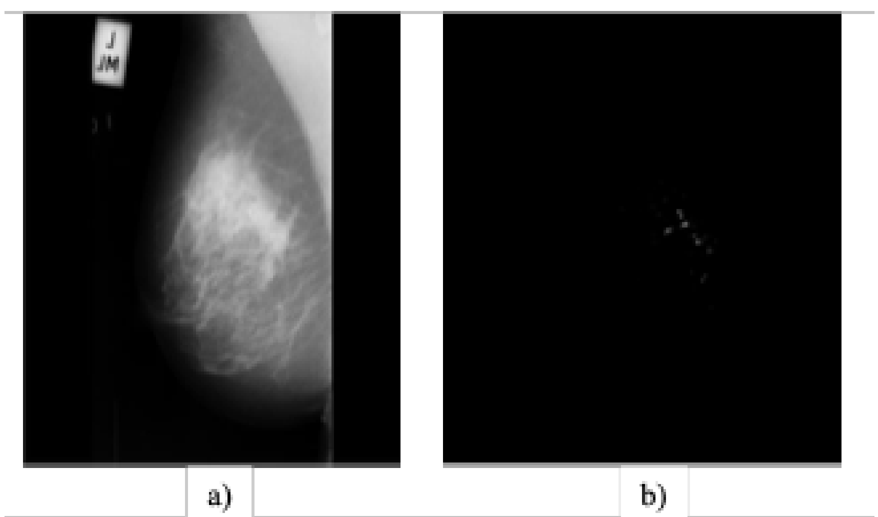


Figure 4: Results obtained from the multi-scale product: (a) original image, (b) multi-scale product

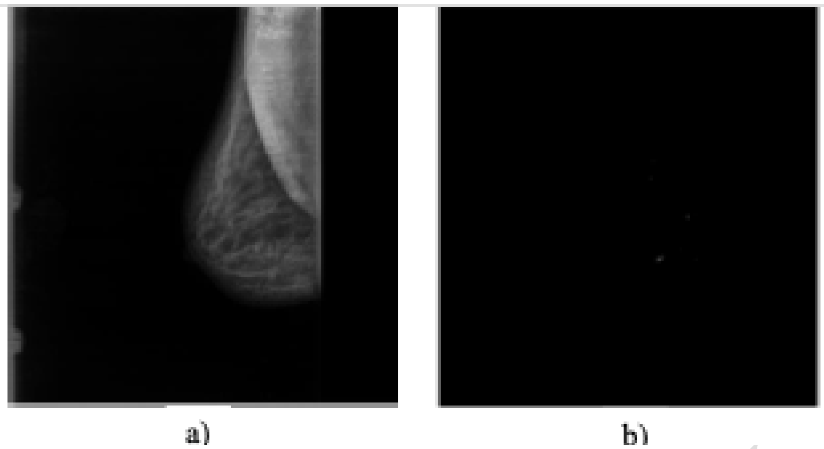


Figure 4: Results obtained from the multi-scale product: (a) original image, (b) multi-scale product

4. Discussion

The results obtained from MIAS and N'Djamena images confirm the effectiveness of the multiscale product in emphasizing microcalcifications. After ROI extraction, the proposed procedure significantly enhances intensity dynamics, revealing discontinuities associated with fine mammographic structures.

The multiscale product multiplies corresponding wavelet coefficients across five scales, amplifying high-value coefficients (non-homogeneous regions) while attenuating low-value ones (homogeneous regions). As a result, bright points—often concealed within fatty tissues—become more visible. Microcalcifications, which behave as isolated singularities, are therefore strongly reinforced, facilitating their localization and improving detection reliability.

5. Conclusion

This study introduced a pre-processing strategy combining three enhancement techniques with the Continuous Wavelet Transform followed by the multiscale product. The results demonstrate the ability of this approach to highlight regions likely to contain microcalcifications, even in challenging tissue environments. The proposed method not only improves visibility and localization but also reduces the risk of false detections, offering a robust foundation for future work on microcalcification characterization and classification.

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