Improved detection of architectural distortion in digital mammography using distortion-weighted image (DiWI): a new mathematical image-filtering technique by the pinwheel-framelet processing method

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Purpose

The purpose of this study is to investigate the usefulness distortion-weighted image (DiWI) that is processed by the new pinwheel-framelet processing method specific to enhance architectural distortion in digital mammography.

Introduction

Architectural distortion on mammography

- The definition of architectural distortion (AD) in BI-RADS is as follows: “The normal architecture of the breast is distorted with no definite mass visible. This includes spiculations radiating from a point and focal retraction or distortion at the edge of the parenchyma.” [1].
- Architectural distortion is the third most common mammographic appearance of non-palpable breast cancer, representing nearly 6% of abnormalities detected on screening mammography [2, 3].
- Some studies suggest that early detection of architectural distortion may be associated with a more significant improvement in prognosis than earlier detection of calcifications [4].
- Therefore, increasing the sensitivity and accuracy in the detection of architectural distortion will lead to an effective improvement in the prognosis of breast cancer patients.
- However, because the finding is commonly subtle and variable in presentation, architectural distortion is sometimes more difficult to diagnose than calcification or mass formation and is common cause of false-negative findings on screening mammograms [5].
- In addition, some studies have reported poor inter-observer variability in the detection of architectural distortion [6]. The level of experience of reading mammography exerted a greater effect on overall decision accuracy of image interpretation of architectural distortion than that of calcification or mass detection [7].

Overview of CAD in mammography

- Computer-aided detection (CAD) techniques and systems offer the potential for achieving increased sensitivity in the detection of breast cancer.
- Many previous studies regarding CAD systems on screening mammography mainly focused on the detection of microcalcification and breast masses, and has been reported to be as high as 99% and 89% of sensitivity on microcalcifications and malignant breast masses, respectively [8, 9].
• Whereas, a relatively small number of studies have been reported poor sensitivity of detection of architectural distortion as well as high false-positive rate of pseudo-lesions [10].
• One of the reason for the difficulty is that interpretation process of architectural distortion may be under high-level human visual recognition of images that involves integrated assessment of various anatomical factors.
• Different from many previous CAD approach, which tried to establish method to pick up possible abnormal anatomical lesions, we took different approach and focused on the method to generate image-filtering algorithm to enhance architectural distortion on digital mammography so that a reader can easily detect architectural distortion.

Mathematical model of human visual processing

• Currently, some researchers have investigated mathematical model of visual illusion.
• Through understanding of mechanism of visual illusion, they suggested that human visual illusion is a by-product as a result of human visual processing to see things better.
• Arai et al. developed a new mathematical tool to simulate human visual system using "pinwheel framelet" processing method [11, 12]. (Fig 1)
• We applied this "pinwheel framelet" processing method to image filtering process of digital mammography.

The fractal illusion

applied inverted pinwheel framelet filter of human visual process
**Fig. 1**: A: A sample of visual illusion called "the fractal spiral illusion" (A). The figure is consists of various size of circles which are arranged in a concentric pattern, where similar copies of fractal islands are aligned in a circle. Although the real geometry has no spiral configuration, we perceive visual illusion, as if fractal islands arranged in a spiral configuration. B: Applying inverted mathematical filter of human visual processing using the pinwheel framelet processing, illusional spiral components of the figure is removed from the fractal spiral illusion.

**References**: Arai H and Arai S. Graduate School of Mathematical Sciences, University of Tokyo

**Figure 1**

A: A sample of visual illusion called "the fractal spiral illusion" (A).

The figure is consists of various size of circles which are arranged in a concentric pattern, where similar copies of fractal islands are aligned in a circle. Although the real geometry has no spiral configuration, we perceive visual illusion, as if fractal islands arranged in a spiral configuration.

B: Applying inverted mathematical filter of human visual processing using the pinwheel framelet processing, illusional spiral components of the figure is removed from the fractal spiral illusion.

**Images for this section:**

- A: The fractal illusion
- B: Applied inverted pinwheel framelet filter of human visual process
Fig. 1: A sample of visual illusion called "the fractal spiral illusion" (A). The figure consists of various size of circles which are arranged in a concentric pattern, where similar copies of fractal islands are aligned in a circle. Although the real geometry has no spiral configuration, we perceive visual illusion, as if fractal islands arranged in a spiral configuration. B: Applying inverted mathematical filter of human visual processing using the pinwheel framelet processing, illusional spiral components of the figure is removed from the fractal spiral illusion.
Methods and materials

The institutional review board approved this retrospective study and waived the requisite to obtain the informed consent from the patients.

[Patients]

- Using a radiological database of mammography at our institution, we identified 50 consecutive patients (median age of 50 years, ranging 40-75 years) whose digital mammogram showed architectural distortion and, for control, 51 consecutive patients (median age of 47 years ranging 27-80 years) whose digital mammogram showed no associated findings between March 2012 and July 2012.
- For each patient, the mediolateral-oblique (MLO) and cranio-caudal (CC) mammography views of both right and left breast were assessed.

[DiWI processing]

- Original mammograms were processed to DiWI, a digitally-filtered image using the pinwheel-framelet processing method that is newly developed by our group. The pinwheel-framelet processing is an image filtering method based on the mathematical simulation of human visual information processing by simple cells in visual cortex of human brain, which contains several filters with various orientation selectivity. The pinwheel-framelet processing regulate two parameters: degree of multiple-level decomposition of wavelet and degree of orientation selectivity. The detailed methods for pinwheel-framelet processing are described in the previous paper [11, 12].
- For preliminary study, two radiologists (one who has 23 years experience of mammography instructor in Japan, one who has 20 years experience of diagnostic imaging and imaging research) assessed sets of mammograms that applied various filtering with different “degree” parameters in the first 10 cases with architectural distortion and determined optimal setting to assess architectural distortion in this study.

[Image Assessment]

- For the gold standard of the image assessment of architectural distortion, the mammography board-certified radiologist who has 23 years experience of mammography instructor in Japan re-assessed the all mammograms and determined the presence of architectural distortion.
- A board-certified breast radiologist (R1) who has 10-years experience of reading mammography and a radiology resident (R2) who has 1-year experience of mammography assessed original digital mammograms with and without DiWI independently for the presence of architectural distortion.
each in CC and MLO views of right and left breast. To delete memory effect, assessments of original digital mammograms with and without DiWI were performed with 1-month interval.

[Statistical Analysis]

- Diagnostic accuracy was measured by using multireader receiver operating characteristic (ROC) analysis [13]. ROC analysis was performed by using ROCKIT software. The area under curve (AUC) was compared for each imaging method.

Results

The ACUs for the diagnostic accuracy of architectural distortion in original digital mammogram alone were 0.96 and 0.81 by R1 and R2, respectively (Fig 2). The AUCs in digital mammogram with DiWI were increased to 0.98 and 0.88 by R1 and R2, respectively (Fig 2).

The AUC by R1 was significantly lower than that by R2 (p<0.01) but showed no significant difference with DiWI (p=0.25).
Fig. 2: ROC curves for diagnostic accuracy to detect architectural distortion in original digital mammogram (MMG) with and without distortion-weighted image (DiWI) by two readers. R1/R2_MMG: ROC curves for MMG without DiWI by a board-certified breast radiologist (R1) who has 10-years experience of reading mammography and a radiology resident (R2) who has 1-year experience of mammography. R1/R2_DiWI: ROC curves for MMG with DiWI by R1 and R2.

References: Department of Radiology, St. Luke’s International Hospital - Tokyo/JP

**Figure 2**

ROC curves for diagnostic accuracy to detect architectural distortion in original digital mammogram (MMG) with and without distortion-weighted image (DiWI) by two readers.
R1/R2_MMG: ROC curves for MMG without DiWI by A board-certified breast radiologist (R1) who has 10-years experience of reading mammography and a radiology resident (R2) who has 1-year experience of mammography. R1/R2_DiWI: ROC curves for MMG with DiWI by R1 and R2.

**Fig. 3**: Left MLO view of digital mammogram (A) in a 74-year-old woman shows architectural distortion in the upper segment without microcalcification nor mass formation. The original mammography was classified as BI-RADS category 3. DiWI clearly demonstrated architectural distortion (B and C) and the category was upgraded to category 4. R2 missed the architectural distortion at the 1st reading of MMG without DiWI and was aware at the 2nd reading of MMG with DiWI.

**References**: Department of Radiology, St. Luke’s International Hospital - Tokyo/JP

**Figure 3**
Left MLO view of digital mammogram (A) in a 74-year-old woman shows architectural distortion in the upper segment without microcalcification nor mass formation. The original mammography was classified as BI-RADS category 3. DiWI clearly demonstrated architectural distortion (B and C) and the category was upgraded to category 4. R2 missed the architectural distortion at the 1st reading of MMG without DiWI and was aware at the 2nd reading of MMG with DiWI.
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Conclusion

DiWI improved the diagnostic accuracy to assess architectural distortion of digital mammography, especially in less-experienced reader.

Personal information

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Takuya Ueda, MD., PhD._______________________

St. Luke’s International Hospital
Department of Radiology/Cardiovascular center
E-mail: takueda@luke.or.jp

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Fig. 4

References: Department of Radiology, St. Luke’s International Hospital - Tokyo/JP

Images for this section:
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http://www.ems.okayama-u.ac.jp/suito/CREST/index-e.html

Hiroshi Suito: Numerical simulation. Project leader
Graduate school of environmental and life science, Okayama university.

Takuya Ueda: Radiologist, diagnostic imaging
Department of radiology, St. Luke’s international hospital.

Hitoshi Arai: Mathematical simulation of vision and visual illusion.
Graduate School of Mathematical Sciences, University of Tokyo.

Fig. 4
References