Wavelet Processing Techniques for Enhancement and Computer Aided Diagnosis of Digital Mammography

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SUMMARY

Mammography’s role is the early detection of breast cancer. Although more accurate than any other modality, existing techniques for mammography only find 80 to 90 percent. It has been suggested that mammograms as normally viewed, display only about 3 percent. Perception is a problem particularly for patients with dense fibroglandular patterns.

This talk describes the development of a methodology for accomplishing adaptive contrast enhancement by multiscale representations. Our studies demonstrate that features extracted from multiresolution representations can provide an adaptive mechanism for the local emphasis of salient and subtle features of importance to mammography.

This talk will present the development of an interactive diagnostic tool for radiologists that is able to refine the perception of mammographic features (including lesions, masses and calcifications) and thus increase sensitivity of diagnosis. By improving the visualization of breast pathology we can increase the chances of early detection of breast cancer (improve quality) while requiring less time to evaluate mammograms for most patients (lower costs).

Preliminary studies have shown that multiscale methods of analysis can make more obvious unseen or barely seen features of a mammogram without requiring additional radiation. Our approach consists of both theoretical and empirical studies. We first identify those methods of wavelet analysis that perform best in terms of extracting, preserving, and enhancing specific types of breast carcinomas and other mammographic features of diagnostic importance. We then formally evaluate each method using conventional ROC analysis for their ability to lower the threshold of early detection of breast cancers.

We shall establish connections between dyadic wavelet enhancement algorithms and traditional unsharp masking. We show that two cases of linear enhancement are mathematically equivalent to traditional unsharp masking with Gaussian low-pass filtering. We present a methodology for accomplishing multiscale nonlinear enhancement using a single operator. We demonstrate that artifacts can be eliminated, by judicious selection of wavelet filters and enforcing design constraints of a nonlinear enhancement function.

We also show how an edge-preserved denoising stage (wavelet shrinkage) can be incorporated into a multiscale framework for contrast enhancement, and introduce a method for adaptive threshold estimation. Next we give an example of how denoising and enhancement operations can be carried out for two dimensional images to avoid orientation distortions and eliminate artifacts introduced by possible new extrema.

We suggest that it is desirable to compute an analysis over an arbitrary scale, since mammographic features (e.g. masses) may lie between two dyadic scales, depending upon size and density. We show that regions corresponding to masses can be identified reliably through the zero-crossings representations of a continuous wavelet transform. Whereas traditional methods for wavelet analysis compute coefficients on a dyadic level of scale, we show that the subtle characteristics of mammographic features requires a finer parameterization of scale space.

Specifically, we demonstrate that masses located in dense and somewhat dense mammograms (80 cases) can be reliably characterized and identified via geometric constraints (size and shape) by segmented regions extracted from a continuous wavelet representation. In addition, digital radiographs of an RMI phantom are used to demonstrate the advantage of subjective adaptive segmentation. Here, closed regions identified as possible masses are labelled to provide local support for non-linear amplification of wavelet coefficients. The method shows that a mass known to exist in the physical RMI phantom but invisible via traditional image processing techniques (window and level, histogram equalization, contrast stretching, etc.) is made clearly visible after processing!

Finally, we shall discuss our future research plans that include a systematic study of gain and threshold parameters for selected nonlinear enhancement operations. Our objective here is to develop techniques to evaluate wavelet algorithms so they can then be optimized for clinical use in mammography.

If time permits, we shall discuss ways to integrate the most effective wavelet algorithms for execution on an interactive diagnostic workstation to facilitate the visualization of breast pathology. The purpose of this effort is to improve the detection/classification of mammographic abnormalities using computer-aided diagnosis and wavelet representations. Our study includes the construction of four-view database of 100 cases containing benign/malignant abnormalities. Each abnormality was ranked on the basis of detectability and classification difficulty to provide a measure of human
performance and to allow for the evaluation of our algorithms based on the abnormality's degree of
difficulty.

Preliminary results show that features derived from wavelet representations (e.g. edges, regularity) can be
used for the detection of mammographic abnormalities. Classification schemes are being developed to produce a
diagnostic output based on the ACR-BIRADS scale to reduce the number of false positives from abnormalities
that cannot be reliably differentiated from carcinoma without biopsy (e.g. radial scar). Rather than classifying
an abnormality incorrectly our CAD system labels difficult to diagnose abnormalities into two categories to
indicate follow-up or biopsy will be necessary for reliable diagnosis.

In summary, we have developed a methodology for accomplishing adaptive contrast enhancement by
multiscale representations. Our studies have demonstrated that features extracted from multiresolution
representations can provide an adaptive mechanism for the local emphasis of salient and subtle features of
importance to mammography. The improved contrast of mammographic features make these techniques appealing
for computer aided diagnosis (CAD) and screening mammography. Screening mammography examinations are
certain to grow substantially in the next few years, and analytic methods that can assist general radiologists in
reading mammograms shall be of great importance.

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