PhD Thesis title: 'Image processing and analysis methods in thyroid ultrasound imaging'

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ABSTRACT:

High-resolution thyroid ultrasonography (US) is exceptionally sensitive in locating the size and number of thyroid nodules. The sonographic findings of the thyroid nodule are often employed as criteria in assessing the risk factor of malignancy and are crucial in patient management, i.e., whether to recommend surgical operation or not. Such criteria include echogenicity, absence of halo, calcifications, irregular margins and intra-nodular vascular patterns or spots. However, estimation of the risk factor involves the subjective physician evaluation of US images and, thus, depends upon the examiner's experience. Previous US studies on thyroid nodules have reported different diagnostic accuracies in predicting malignancy based on the visual analysis of US images. It is evident that a quantitative assessment of the thyroid nodules' risk factor may be of value in avoiding unnecessary invasive intervention.
The aim of the present thesis was the design and implementation of new image processing and analysis methods in ultrasound thyroid images. The research procedure comprised of two main concepts towards optimization of thyroid ultrasonography: Wavelet-based image processing methods towards speckle suppression and thyroid nodule segmentation, followed by image analysis methods in order to evaluate the thyroid nodules malignancy risk factor.
Speckle phenomenon that dominates ultrasound imaging has been suppressed by means of a wavelet-based speckle reduction algorithm. An inter-scale wavelet analysis has been made towards edge detection and isolation edges across scales. Consequently, singularity detection has been held in these edges in order to discriminate speckle from important image features within the ultrasonic image. The success of the proposed method has been proven with various indices compared to several well-known speckle reduction algorithms. In addition, a clinical study has proven that the proposed algorithm can enhance the overall diagnostic accuracy.
Within the same wavelet framework a new segmentation hybrid algorithm has been introduced towards thyroid boundary detection. The proposed model combined the wavelet transform, an inter-scale model and the constrained Hough Transform to extract round-like objects from a rather noisy environment. The segmentation method may assist in the thyroid nodule categorization from the physician based in morphology characteristics.
The classification between high and low risk thyroid nodules has been made with various pattern recognition algorithms that employed several textural,

morphological and wavelet-based features. The primary model incorporated in the present study was the Support Vector Machines (SVM) that was compared with other models such as the Quadratic Bayesian (QB), Multi-Layer Perceptron (MLP), and probabilistic Neural Network (PNN) classifiers. Various textural features have proved to discriminate with relatively high accuracy the thyroid nodules, such as the Sum Variance from the Co-Occurrence matrix, the gray-level mean value, the Run Length Non-Uniformity from the run length matrices along with various shape features (i.e. concativity, roundness, fractal dimension etc.).
Moreover, the speckle effect in the classification procedure has been evaluated. Two independent studies have been performed that employed wavelet-based features with and without the presence of speckle. The important conclusion of this study was that speckle reduced the performance of the classifiers.
As a final conclusion we can say that an extensive study regarding image processing and analysis methods has been made in thyroid ultrasonography. The study comprised denoising, segmentation and pattern recognition algorithms. All methods implemented can be utilized as a useful diagnostic tool by providing a second opinion to the physician and, thus, may be of value to patient management in avoiding unnecessary invasive procedures.

References to author publications that relate specifically to the dissertation:

1. **S. Tsantis**, D. Cavouras, I. Kalatzis, N. Piliouras, N. Dimitropoulos, and G. Nikiforidis.Development of a support vector machine-based image analysis system for assessing the thyroid nodule malignancy risk on ultrasound. Ultrasound in Medicine and Biology, 2005;31(11) 1451–1459.
2. **S. Tsantis**, N. Dimitropoulos, D. Cavouras, and G. Nikiforidis, Morphological and Wavelet Local Maxima Features towards Evaluation of Thyroid Nodules Malignancy Risk in Ultrasonography, Computerized Medical Imaging and Graphics 2009;33(2) 91-99.
3. **Tsantis S**, N. Dimitropoulos, M. Ioannidou, D. Cavouras and G. Nikiforidis Inter-Scale Wavelet Analysis for Speckle Reduction in Thyroid Ultrasound Images. Computerized Medical Imaging and Graphics, 2007;31(3) 117-127.
4. **S. Tsantis**, N. Dimitropoulos, D. Cavouras and G. Nikiforidis. A Hybrid Multi-Scale Model for Thyroid Nodule boundary detection on Ultrasound Images. Computer Methods and Programs in Biomedicine, 2006;84(2-3) 86-98.