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13. Abstract ***(Maximum 200 Words)*** *(abstract should contain no proprietary or confidential information)*

The aims of this work are to explore the feasibility of developing a *new class* of computer assisted diagnostic (CAD) methods for microcalification cluster (MCC) detection for breast cancer screening using digital mammography. The objectives are to achieve: (a) improved CAD performance that is significantly more robust for large image databases, and (b) an *adaptive* CAD method that is independent of the digital sensor resolution and gray scale characteristics; for the first time. This report includes 3 sections, (1). Summary of the work in first year, which includes data base collection and truth file establishment for different sensors, preprocessing for breast area segmentation, and basic algorithm design and optimization, (2) Summary of the work in second year, which includes algorithm design and modular optimization for enhancement, segmentation, feature extraction and classification. (3). Whole system optimization and evaluation, which includes a design, optimization and evaluation of a successful MCCs detection system.

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Annual Report:

The CAD Method for MCC Detection: Independent of Sensor and Resolution

INTRODUCTION:

A successful MCC detection scheme should consist of several modules aiming at solving different kinds of signal processing problems [1-11]. All published work can be grouped in the following five-step paradigm: (1) breast area segmentation and artifact elimination, (2) MCC structure and normal tissue enhancement, (3) suspicious MCC area segmentation or localization, (4) feature extraction and analysis of suspicious areas, and (5) suspicious area classification as normal or abnormal. Most of the work in the literature addressed only one subset of these procedures and some approaches reorganized these steps [10], [12], [13], [14-23]; *i.e. rather than a holistic approach in this work.* Efforts at enhancing microcalcification structures to refine digital visualization [24]-[26] can be also be incorporated in the above paradigm. The aims of this work are to explore the feasibility of developing a *new class* of computer assisted diagnostic (CAD) methods for microcalification cluster (MCC) detection for breast cancer screening using digital mammography. The objectives are to achieve: (a) improved CAD performance that is significantly more robust for large image databases, and (b) an *adaptive* CAD method that is independent of the digital sensor resolution and gray scale characteristics; for the first time. This report includes 3 sections, **(1). Summary of the work in first year, which includes data base collection and truth file establishment for different sensors, preprocessing for breast area segmentation, and basic algorithm design and optimization, (2) Summary of the work in second year, which includes algorithm design and modular optimization for enhancement, segmentation, feature extraction and classification. (3). Whole system optimization and evaluation, which includes a design, optimization and evaluation of a successful MCCs detection system.**

BODY OF REPORT

I. Summary of the work completed in the first year of the project

(a). Data base collection and truth file establishment for three sensors

In order to make the CAD algorithms for clinical use, the extensive tests of our algorithms are necessary for larger database from different digitizers with different resolutions. The films of the two sets of 200 views was digitized with two different digitizers: **(a)** a CCD-based system (ImageClear R3000, DBA Systems, Inc, Melbourne, FL) maximum resolution at 30 m and 16 bits and **(b)** a LUMISCAN 85 (Lumisys, Sunnyvale, CA) at maximum resolution, at 50 m, and 12 bits. Digitized images will be acquired at 50 microns with one set transformed to 100microns respectively. And another one set from direct digital mammography system from General Electric which was installed at the H. Lee Moffitt Cancer Center and Research Institute (MCCRI) at USF in June 1998. The direct digital images have a spatial resolution of 100 μm and 12 bits per pixel.

(b). Preprocessing for breast area segmentation

Except a few digital mammogram images are with high quality, most of them suffer from more or less extrinsic signals such as images of edges of original X-ray pictures, or large bright regions caused by the cutting of them, various notes made by doctors, uneven illumination, blurred edges due to the exposure of pictures. Sometimes such extrinsic signals in the digital mammogram images may affect the detection result seriously. In the first year, we developed an algorithm to erase the extrinsic signals. They are helpful for the detection.

(c). Basic algorithm design

Basic algorithm design includes nonlinear bank filter design, implementation and segmentation algorithm design and testing. The nonlinear filter design is based on multiresolution techniques. In the first year of the project, we have tested 20 different segmentation algorithms on MCCs segmentation, such as Relaxation, Digital Desk - adaptive, Fuzzy sets, Otsu's method for grey level histograms, iterative selection, Johannsen Kapur method for using entropy, two histogram peaks, Minimum error and mean, Black percentage, Pun method for using entropy, two histogram peaks, etc.

II. Summary of the work completed in the second year of the project

(a). Introduction

The research efforts involve design and optimization of all CAD modules as illustrated in Fig 1. We first implemented a robust CAD module of breast segmentation, already developed, that is generalizable to different sensors, a modification of a reported method. We then focused on the design and optimization of nonlinear filter banks based methods for MCC enhancement. This should be optimized to maintain a high detection sensitivity and low false positive rate. A CAD module for MCC identification criteria, which is an extension of previous work [38], should be modified for more accurate cluster extraction from binary images. Extraction of explicit features (inter-projection) should be greatly emphasized and as extension of our work on implicit features. Existing multistage based NN methods will still be adopted and optimized by using input both implicit and explicit features at different stages.

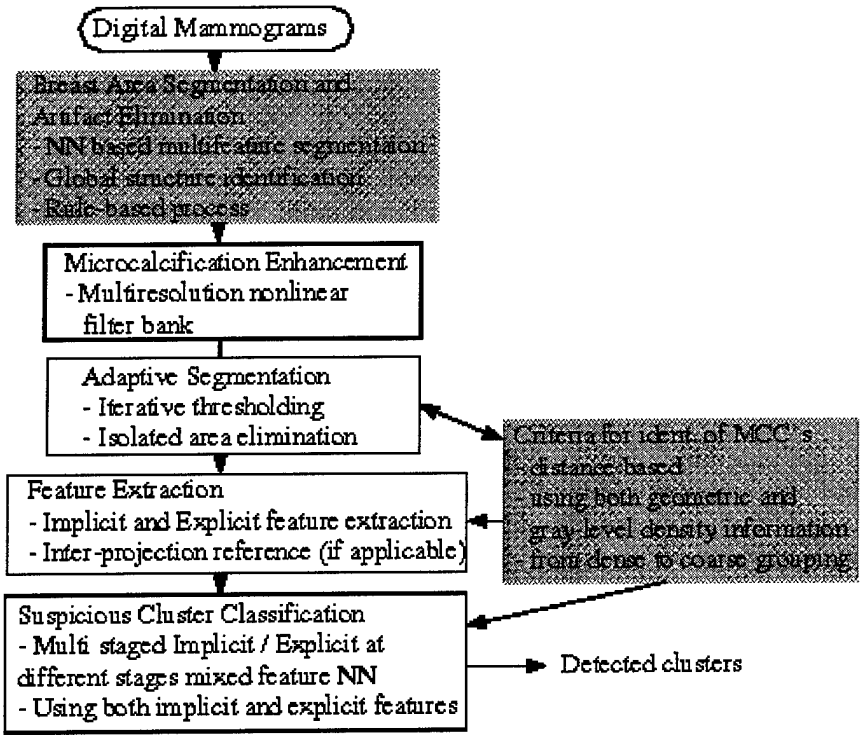

Fig.1. *Block Diagram of the MCCs Detection System, Shaded areas have been fully completed. Preliminary progress has been made for all other CAD modules.*

(b). Multiresolution microcalcification enhancement

The basic structure of the proposed enhancement filter is similar to [29]. We have already done very preliminary testing of this method on simulated images and a representative mammographic image at 60 micron images, with a biopsy proven MCC's, where details of microcalifications were better preserved than using the 4 channel wavelet transform. *The feasibility of the method has been demonstrated.*

(c). Criteria for identification of clusters

We proposed a distance-based area grouping method, instead of the commonly used kernel-based method, to avoid the problems of selection of kernel size and shape. We developed a method based on distance-based and from dense to coarse grouping strategy, this work has been submitted for publication and is attached [38].

(d). Adaptive Method for MCC Segmentation

We propose to modify an existing method that is adaptive and iterative, where the criteria is unique. Preview methods generally focus on simple feature related criteria. The steps are as follows: segmented image is obtained for a given gray level threshold. If the clusters are larger than a geometrical criteria (i.e. fixed area: 1.5 x 1.5 cm) the threshold can be changed until the creterial is fully contained within this area. The process can be conducted in the inverse direction and the threshold adjustment step can be changed iteratively. This segmentation process directly eliminates the isolated areas.

(e). Feature extraction

This research step will mainly address explicit feature design and extraction. Implicit features, calculated within a single region of interest (ROI). We will also explore the use of generic algorithm (GA) for feature selection ranking but may defer most of this optimization step for the ROI proposal.

(f). Classifier design

A multistaged mixed feature neural network method is proposed based on our previous work for microcalcification detection [12], Kalman Filtering technique realized by the PI's group [12] will be used as a powerful tool for training a NN required for large number of input nodes and complex structures.

III. Algorithm Design and Optimization in the current funding year (third year)

1. Introduction

The accuracy of CAD schemes for increasing detection sensitivity and reducing FP rate is the crucial problem for its clinical implementation. Recent reports on advances in CAD applied to mass detection indicate current CAD schemes miss early stage breast cancers, resulting in a relatively large false positive (FP) detection rate in order to achieve a high sensitivity rate. In past years, despite considerable efforts by many researchers studying, CAD schemes have not been reached the acceptable levels of both detection sensitivity and FP rate for clinical requirements. The drawbacks of current CAD methods *can be attributed to the lack of a full optimization scheme.* The major problem is that full optimization of any CAD algorithms requires the fine tuning of several parameters. For example, if five values are to be tested for each of six key parameters in our algorithm, their combination is actually 5 x 5 x 5 x 5 x 5 x 5 = 15,625. By using a FROC experiment as the measurement for CAD optimization, at least three confidence levels, (corresponding to three threshold values for the output of the algorithm), are used to compare results of different parameter settings based on our planned database of 2000 images. So at least 2000 x 15, 625 x 3 = 93,750,000 images should be examined to count for the pairs of TPF and FPs. An operator usually takes one day to examine 50 resulting images, resulting in 1,875,000 days (about 5120 years) of work, unrealistic for completing the optimization of the algorithm. The existing CAD methods, including all reported methods in literature, are far away from fully optimized parameter settings of the CAD system. In consequence, a novel, fully automatic and highly efficient method is developed in this project for the parameter optimization using FROC experiments, which reveals the future of CAD design.

This project presents a promising CAD scheme as a pre-clinical lead-up study. The research plan involves the further development and optimization of the CAD method, as shown in Fig.1. Three parts are stated as, (1) the modification of CAD modules under signal processing criteria, focused on modular design; (2) the full optimization of CAD algorithms based on the clinical objective functions, focused on all parameter optimizations; and (3) the design of the statistical tests used to validate the created model. The final optimized CAD system will be evaluated by computed FROC analysis to measure the stand-alone performance of the optimized CAD system

2. Modification of preprocessing CAD modules using the adaptive strategy

Adaptive TSF CAD module: The advantage of the current TSF for image noise suppression is that its application does not require an *a priori* knowledge of the local statistics within the filter window; i.e., it is computationally efficient [28]. Although the TSF has already demonstrated good performance, adaptive methods as an optimization strategy will be explored. These strategies will include development of an adaptive technique for automatic parameter selection for the TSF (i.e., parameters K_1, K_2, and K_3 as defined in Equations 7-10 [28]) and development of an adaptive method for selecting the filter window sizes (i.e., from 3 x 3 to 7 x 7), depending on requirements for image detail preservation.

Adaptive DWT CAD module: This module was designed as a bank of wavelet filters, implemented using adaptive combiners with different weight factors [40 Fig.4], and can therefore be uniquely modified for a higher order N directional filter. *It is proposed to adaptively select* N *for each pixel to match these changes. By adaptively selecting N, the sampling problem is potentially improved for detection of spiculations that may lie inside more than one arc. Alternatively, for the higher order N, an improvement in the signal/noise*

ratio for the detection of a spiculation is possible. The range of N, which influences the angular bandwidth frequency and directional sensitivity, will be adaptively selected within 4-32, which corresponds to a 45°-5.63° arc width [41 Equation 7]. This provides higher sampling and a more mathematically rigorous method.

Adaptive TSWT/AC CAD module: The M-channel TSWT has the advantage that it can be readily expanded to M x M different resolutions information, generating M^2 subimages [28,29]. The following methods will be explored: (a) the use of M=4 channel wavelets to increase the choice for selection of 16 subimages that should improve suspicious area enhancement and subsequent segmentation [29] and (b) adaptive selection of subimages to zoom into the desired features for mass enhancement. FROC experiments will be performed based on the results of each combination of the three nonadaptive and adaptive image processing modules: TSF, DWT and TSWT, so that the best of the eight FROC curves will indicate the combination to be used. The best is selected for full optimization and ROC evaluation.

Classification for MCCs detection using the neural network (NN)

A fuzzy binary decision tree (FBDT) was previously used in this work for MCCs detection [40]. The FBDT was constructed empirically using the physician's knowledge. However, knowledge extraction may be difficult and error rates may be high with the proposed expanded database. The use of a standard three-layer feed-forward NN is proposed [12], extensively reported for CAD methods. The input number will depend on the number of features used, as described in the previous section, and the number of hidden nodes determined empirically. One node is used in the output layer. A sigmoid function is used as the activation function for each processing unit in the NN. In the training process, the internal parameters, including the connection weights and unit thresholds, will be adjusted iteratively. *A learning algorithm for back propagation with Kalman filtering is proposed for more efficient training. A modified k-fold cross-validation error estimation technique is proposed, which is a generalization of the leave-one-out technique to achieve reliable evaluation, as previously used by other investigators [12].* The sigmoid function slope is adjusted and output normalized to yield a computed FROC using different output thresholds (i.e., output values 0.1 to 0.9).

Preliminary evaluation data for initial optimized methods and adaptive CAD modules for mass detection at different resolutions are shown in Fig.2-5. The results demonstrate the advantage of using the adaptive modules and their potential for improving the overall performance of the proposed fully optimized CAD method [42].

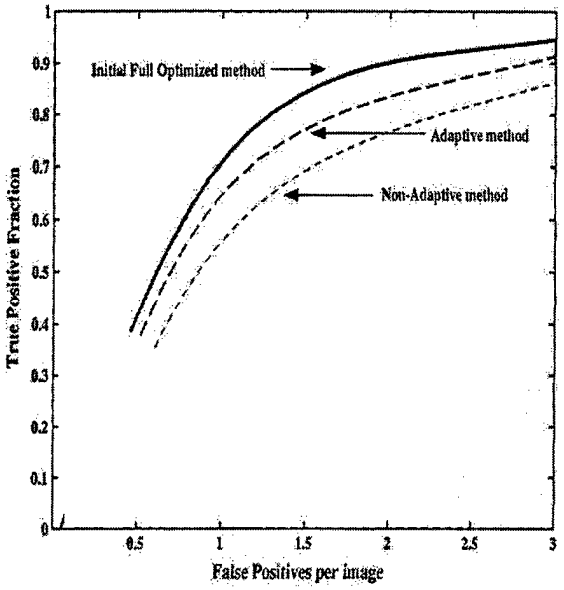

Fig.2, FROC curves showing the comparison of the performance of mass detection for non-adaptive method, adaptive method and initial full optimized method, described in the proposal, based on the Mindex digitized database, 200 images, in 220 micron resolution, where 150 normal and 50 abnormal with microcalcification clusters.

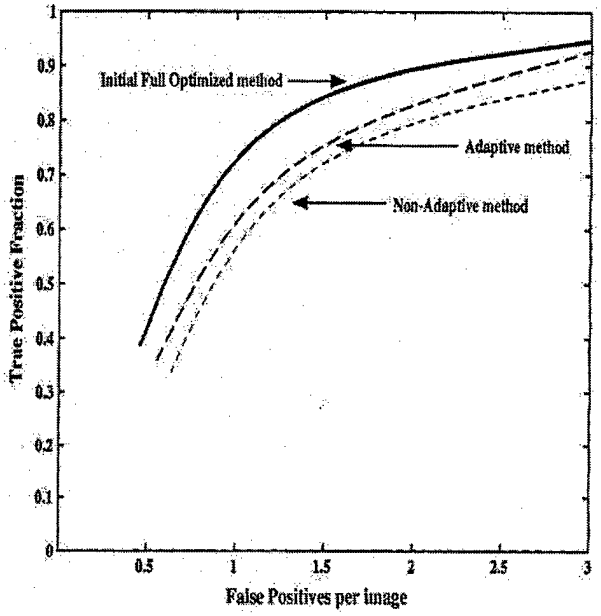

Fig.3, FROC curves showing the comparison of the performance of microcalcification clusters detection for non-adaptive method, adaptive method and initial full optimized method, described in the proposal, based on the Mindex digitized database, 100 images in 100 micron resolution, where 70 normal ad 30 abnormal respectively.

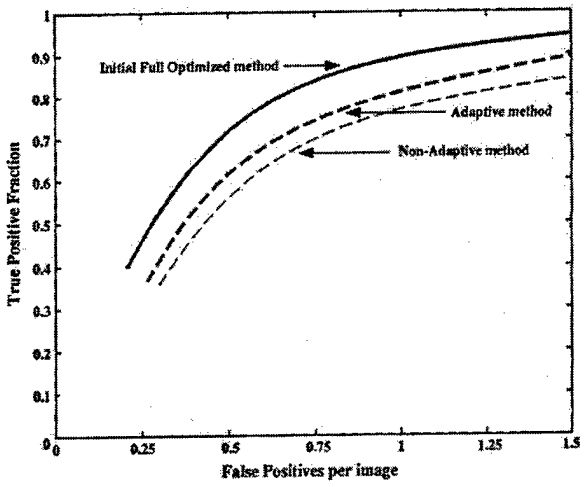

Fig.4. FROC curves showing the comparison of the performance of microcalcification clusters detection for non-adaptive method, adaptive method and initial full optimized method, described in the proposal, based on the DBA digitized database, 800 images, in 90 micron resolution, where 708 normal and 92 abnormal

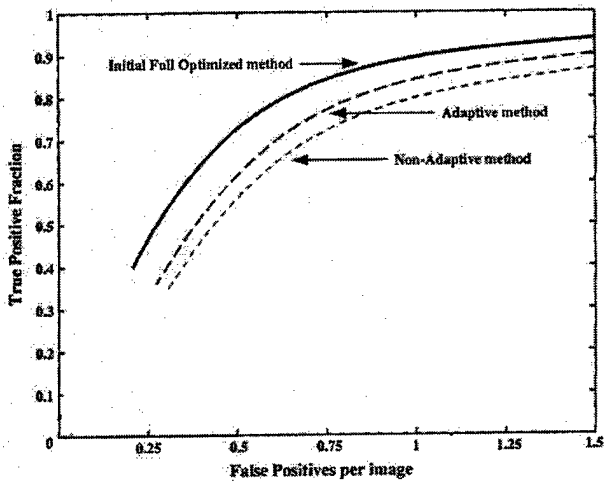

Fig.5. FROC curves showing the comparison of the performance of microcalcification clusters detection for non-adaptive method, adaptive method and initial full optimized method, described in the proposal, based on the Lumisys digitized database, 992 images, in 60 micron resolution, where 846 normal and 146 abnormal respectively.

Key Research Accomplishments

(1) Well done the enhancement module including multiresolution microcalcification cluster enhancement for (a) The Mindex digitized database, 200 images, in 220micron resolution, Where 150 normal and 50 abnormal with microcalcification clusters. (b) The Mindex digitized database, 100 images in 100 micron resolution, where 70 normal ad 30 abnormal respectively. (c) DBA digitized database, 800 images, in 90 micron resolution, where 708 normal and 92 abnormal. (d) The Lumisys digitized database, 992 images, in 60 micron resolution, where 846 normal and 146 abnormal respectively.

(2) Well done the grouping criteria design for identification of microcalcification clusters on (a) The Mindex digitized database, 200 images, in 220micron resolution, Where 150 normal and 50 abnormal with microcalcification clusters. (b) The Mindex digitized database, 100 images in 100 micron resolution, where 70 normal ad 30 abnormal respectively. (c) DBA digitized database, 800 images, in 90 micron resolution, where 708 normal and 92 abnormal. (d) The Lumisys digitized database, 992 images, in 60 micron resolution, where 846 normal and 146 abnormal respectively.

(3) Well done the adaptive method design for MCCs segmentation module for (a) The Mindex digitized database, 200 images, in 220micron resolution, Where 150 normal and 50 abnormal with microcalcification clusters. (b) The Mindex digitized database, 100 images in 100 micron resolution, where 70 normal ad 30 abnormal respectively. (c) DBA digitized database, 800 images, in 90 micron resolution, where 708 normal and 92 abnormal. (d) The Lumisys digitized database, 992 images, in 60 micron resolution, where 846 normal and 146 abnormal respectively.

(4) Well done the feature extraction and analysis module including implicit feature and explicit features for digital mammograms on (a) The Mindex digitized database, 200 images, in 220micron resolution, Where 150 normal and 50 abnormal with microcalcification clusters. (b) The Mindex digitized database, 100 images in 100 micron resolution, where 70 normal ad 30 abnormal respectively. (c) DBA digitized database, 800 images, in 90 micron resolution, where 708 normal and 92 abnormal. (d) The Lumisys digitized database, 992 images, in 60 micron resolution, where 846 normal and 146 abnormal respectively.

(5) Well done the correlation analysis for inter-projection features. Based on (a) The Mindex digitized database, 200 images, in 220micron resolution, Where 150 normal and 50 abnormal with microcalcification clusters. (b) The Mindex digitized database, 100 images in 100 micron resolution, where 70 normal ad 30 abnormal respectively. (c) DBA digitized database, 800 images, in 90 micron resolution, where 708 normal and 92 abnormal. (d) The Lumisys digitized database, 992 images, in 60 micron resolution, where 846 normal and 146 abnormal respectively.

(6) Well done the classification module design for classification of MCCs versus normal cases of mammograms for (a) The Mindex digitized database, 200 images, in 220micron resolution, Where 150 normal and 50 abnormal with microcalcification clusters. (b) The Mindex digitized database, 100 images in 100 micron resolution, where 70 normal ad 30 abnormal respectively. (c) DBA digitized database, 800 images, in 90 micron resolution, where 708 normal and 92 abnormal. (d) The Lumisys digitized database, 992 images, in 60 micron resolution, where 846 normal and 146 abnormal respectively.

(7) Well done the whole system design and optimization.

Reportable Outcomes

---Manuscripts, abstracts, presentations;

1. Qian W, Xuejun Sun, Hong Liu and Robert Clark, "Wavelet-based image processing for digital mammography" Invited paper and Invited symposium speaker: Wavelet Application in Signal and Image

Processing VIII, SPIE's International Symposium on Optical Science and Technology, July 30th -August 4th 2000, San Diego, USA

2. Qian W, Eshan Sheybani, Ravi Sankar, Dansheng Song, Xuejun Sun, Lin Zhang Hong Liu and Robert Clark, "High Speed Network for Telemammography", International Workshop in Digital Mammography, June 11-14, 2000, in Toronto, Canada
3. Qian W, Hong Liu, Lihua Li, Robert Clark,"A Novel CAD Method for Mass Detection in Digital Mammography" IEEE INTERNATIONAL CONFERENCE ON MULTIMEDIA AND EXPO, JULY 30 -- AUGUST 2, 2000, NEW YORK CITY.
4. Wei Qian " A Novel Hybrid Filter Architecture for Image Enhancement in Medical Imaging "Chapter in the Handbook of Medical Image Processing, Academic Press, 2000, pages 57-69.
5. Wei Qian, Dansheng Song, Xuejun Sun, "Multistage statistical order with neural network for false positive reduction in full field digit mammography" on Nonlinear Signal and Image Processing June 3-6, 2001 Baltimore, USA
6. Wei Qian, Xunjue Sun, DanSheng Song, and R. A. Clark, "Digital Mammography: Wavelet Transform and Kalman Filtering Neural Network in Mass Segmentation and Detection," Academic Radiology, Aug. 2001, pp1074-1082.
7. Wei Qian, Xuejun Sun, Dansheng Song, Robert A. Clark, "A Novel Hybrid Filter Architecture for Image Enhancement and Detection in Digital Mammography", Submitted to Computerized Medical Imaging and Graphics, 2001
8. L. Zhang, W. Qian, R.Sankar, D. Song, R.Clark, 'A New False Positive Reduction Method for MCCs Detection in Digital Mammography', International conference on acoustics speech, and signal processing May 7-11,2001 Salt Lake city, Utah
9. Dansheng Song, Wei Qian, Xuejun Sun, and Robert A Clark, "Neural Network for False Positive Reduction in Full Field Digital Mammography with Microcalcification Shape preservation," SPIE Multispectral Image Processing and Pattern Recognition, 22-24 Oct. 2001 Wuhan, China
10. Xuejun Sun, Wei Qian, Dansheng Song, and Robert A Clark, "Ipsilateral Multi-View CAD System for Mass Detection in Digital Mammography," IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 9-14. December 2001 Kauai, Hawaii USA
11. Xuejun Sun and Wei Qian "System Oriented Optimization of CAD for Mass Detection in Digital Mammography", SPIE international Symposium on Medical Imaging, 23-28 February 2002, San Diego, California USA
12. Xiaoshan Song,Wei Qian and Ravi Sankar "Standardization for image characteristics in telemammography" Proceedings of IEEE ICASSP'2002, Orlando Florida, May 13-17, 2002
13. Maria Kallergi,[1] Wei Qian,[1] Jerry A. Thomas,[2] Jeffrey W. Eberhard,[3] Bernhard EH Claus,[3] and Robert A. Clark[1] "CAD methodology transfer from 2D to 3D digital mammography for calcification enhancement and segmentation: A feasibility study" International Workshop on Digital Mammography, June, 2002, Germany.
14. Wei Qian, Xuejun Sun and Robert A. Clark, "Multiresolution/multiorientation based nonlinear filters for image enhancement and detection in digital mammography" Journal of X-Ray Science and Technology 9 (2002)1-15 XST 54. The Netherlands.

------ Degree obtained that are supported by this award ;

Yue Shen and Xiaoshan Song, got Master degree in March of 2002, They are currently working in CISCO Inc. in California.
Jie Lin, Working on Master degree, Will be finished in Decemeber of 2002.
Kaushik Narayan, Working on Master degree, Will be finished in Decemeber of 2002.
Hongshun Su, Working on Master degree, Will be finished in Decemeber of 2002.

------Funding applied for based on the work supported by this award;

Proposal Submitted to Agency: U.S Army Medical Research and Materiel Command DOD 2002 Breast Cancer Research Program on 13/06/2002

1. "A New Global Optimization Technology for CAD System Design."
   Wei Qian, Ph.D. Principal Investigator - Exploration awards Recipient

2. "A new CAD Algorithm for Best Reconstructed 3-D Tomosynthesis Image"
   Wei Qian, Ph.D. Principal Investigator - Exploration awards Recipient

3. "Multi-view CAD System for Mass Detection in Digital Mammography"
   Wei Qian, Ph.D. Principal Investigator-Idea Award Recipient

4. "Telemedicine, Telediagnosis and Telemammography Using a Satellite Network for Remote Areas Including Oversea U.S. Military Bases"
   Wei Qian, Ph.D. Principal Investigator-Innovator Award Recipient

5. "Multimedia Telediagnosis Via Internet and Wireless Communication Networks for Breast Cancer"
   Wei Qian, Ph.D. Principal Investigator-Idea Award Recipient

Conclusion

In the third year of the project, we focused on evaluation of the whole system and we successfully completed the design and optimization of our MCCs detection system which includes the following five-step paradigm: (1) breast area segmentation and artifact elimination, (2) MCC structure and normal tissue enhancement, (3) suspicious MCC area segmentation or localization, (4) feature extraction and analysis of suspicious areas, and (5) suspicious area classification as normal or abnormal. The final full evaluation and further optimization is planned for the coming budget year.

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[1] Wei Qian, Dansheng Song, Xuejun Sun, "Multistage statistical order with neural network for false positive reduction in full field digit mammography" on Nonlinear Signal and Image Processing June 3-6, 2001 Baltimore, USA

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[3] Wei Qian, Xuejun Sun, Dansheng Song, Robert A. Clark, "A Novel Hybrid Filter Architecture for Image Enhancement and Detection in Digital Mammography", Submitted to Computerized Medical Imaging and Graphics, 2001

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Appendices

Key Research Accomplishments

1. Well done the enhancement module including multiresolution microcalcification cluster enhancement for (a) The Mindex digitized database, 200 images, in 220micron resolution, Where 150 normal and 50 abnormal with microcalcification clusters. (b) The Mindex digitized database, 100 images in 100 micron resolution, where 70 normal ad 30 abnormal respectively. (c) DBA digitized database, 800 images, in 90 micron resolution, where 708 normal and 92 abnormal. (d) The Lumisys digitized database, 992 images, in 60 micron resolution, where 846 normal and 146 abnormal respectively.
2. Well done the grouping criteria design for identification of microcalcification clusters on (a) The Mindex digitized database, 200 images, in 220micron resolution, Where 150 normal and 50 abnormal with microcalcification clusters. (b) The Mindex digitized database, 100 images in 100 micron resolution, where 70 normal ad 30 abnormal respectively. (c) DBA digitized database, 800 images, in 90 micron resolution, where 708 normal and 92 abnormal. (d) The Lumisys digitized database, 992 images, in 60 micron resolution, where 846 normal and 146 abnormal respectively.
3. Well done the adaptive method design for MCCs segmentation module for (a) The Mindex digitized database, 200 images, in 220micron resolution, Where 150 normal and 50 abnormal with microcalcification clusters. (b) The Mindex digitized database, 100 images in 100 micron resolution, where 70 normal ad 30 abnormal respectively. (c) DBA digitized database, 800 images, in 90 micron resolution, where 708 normal and 92 abnormal. (d) The Lumisys digitized database, 992 images, in 60 micron resolution, where 846 normal and 146 abnormal respectively.
4. Well done the feature extraction and analysis module including implicit feature and explicit features for digital mammograms on (a) The Mindex digitized database, 200 images, in 220micron resolution, Where 150 normal and 50 abnormal with microcalcification clusters. (b) The Mindex digitized database, 100 images in 100 micron resolution, where 70 normal ad 30 abnormal respectively. (c) DBA digitized database, 800 images, in 90 micron resolution, where 708 normal and 92 abnormal. (d) The Lumisys digitized database, 992 images, in 60 micron resolution, where 846 normal and 146 abnormal respectively.
5. Well done the correlation analysis for inter-projection features. Based on (a) The Mindex digitized database, 200 images, in 220micron resolution, Where 150 normal and 50 abnormal with microcalcification clusters. (b) The Mindex digitized database, 100 images in 100 micron resolution, where 70 normal ad 30 abnormal respectively. (c) DBA digitized database, 800 images, in 90 micron resolution, where 708 normal and 92 abnormal. (d) The Lumisys digitized database, 992 images, in 60 micron resolution, where 846 normal and 146 abnormal respectively.
6. Well done the classification module design for classification of MCCs versus normal cases of mammograms for (a) The Mindex digitized database, 200 images, in 220micron resolution, Where 150 normal and 50 abnormal with microcalcification clusters. (b) The Mindex digitized database, 100 images in 100 micron resolution, where 70 normal ad 30 abnormal respectively. (c) DBA digitized database, 800 images, in 90 micron resolution, where 708 normal and 92 abnormal. (d) The Lumisys digitized database, 992 images, in 60 micron resolution, where 846 normal and 146 abnormal respectively.
7. Well done the whole system design and optimization.

Reportable Outcomes

---Manuscripts, abstracts, presentations;

1. Qian W, Xuejun Sun, Hong Liu and Robert Clark, "Wavelet-based image processing for digital mammography" Invited paper and Invited symposium speaker: Wavelet Application in Signal and Image Processing VIII, SPIE's International Symposium on Optical Science and Technology, July 30th -August 4th 2000, San Diego, USA
2. Qian W, Eshan Sheybani, Ravi Sankar, Dansheng Song, Xuejun Sun, Lin Zhang Hong Liu and Robert Clark, "High Speed Network for Telemammography", International Workshop in Digital Mammography, June 11-14, 2000, in Toronto, Canada
3. Qian W, Hong Liu, Lihua Li, Robert Clark,"A Novel CAD Method for Mass Detection in Digital Mammography" IEEE INTERNATIONAL CONFERENCE ON MULTIMEDIA AND EXPO, JULY 30 -- AUGUST 2, 2000, NEW YORK CITY.
4. Wei Qian " A Novel Hybrid Filter Architecture for Image Enhancement in Medical Imaging "Chapter in the Handbook of Medical Image Processing, Academic Press, 2000, pages 57-69.
5. Wei Qian, Dansheng Song, Xuejun Sun, "Multistage statistical order with neural network for false positive reduction in full field digit mammography" on Nonlinear Signal and Image Processing June 3-6, 2001 Baltimore, USA
6. Wei Qian, Xunjue Sun, DanSheng Song, and R. A. Clark, "Digital Mammography: Wavelet Transform and Kalman Filtering Neural Network in Mass Segmentation and Detection," Academic Radiology, Aug. 2001, pp1074-1082.
7. Wei Qian, Xuejun Sun, Dansheng Song, Robert A. Clark, "A Novel Hybrid Filter Architecture for Image Enhancement and Detection in Digital Mammography", Submitted to Computerized Medical Imaging and Graphics, 2001
8. L. Zhang, W. Qian, R.Sankar, D. Song, R.Clark, 'A New False Positive Reduction Method for MCCs Detection in Digital Mammography', International conference on acoustics speech, and signal processing May 7-11,2001 Salt Lake city, Utah
9. Dansheng Song, Wei Qian, Xuejun Sun, and Robert A Clark, "Neural Network for False Positive Reduction in Full Field Digital Mammography with Microcalcification Shape preservation," SPIE Multispectral Image Processing and Pattern Recognition, 22-24 Oct. 2001 Wuhan, China
10. Xuejun Sun, Wei Qian, Dansheng Song, and Robert A Clark, "Ipsilateral Multi-View CAD System for Mass Detection in Digital Mammography," IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 9-14. December 2001 Kauai, Hawaii USA
11. Xuejun Sun and Wei Qian "System Oriented Optimization of CAD for Mass Detection in Digital Mammography", SPIE international Symposium on Medical Imaging, 23-28 February 2002, San Diego, California USA
12. Xiaoshan Song,Wei Qian and Ravi Sankar "Standardization for image characteristics in telemammography" Proceedings of IEEE ICASSP'2002, Orlando Florida, May 13-17, 2002
13. Maria Kallergi,[1] Wei Qian,[1] Jerry A. Thomas,[2] Jeffrey W. Eberhard,[3] Bernhard EH Claus,[3] and Robert A. Clark[1] "CAD methodology transfer from 2D to 3D digital mammography for calcification enhancement and segmentation: A feasibility study" International Workshop on Digital Mammography, June, 2002, Germany.
14. Wei Qian, Xuejun Sun and Robert A. Clark, "Multiresolution/multiorientation based nonlinear filters for image enhancement and detection in digital mammography" Journal of X-Ray Science and Technology 9 (2002)1-15 XST 54. The Netherlands.

------ Degree obtained that are supported by this award ;

Yue Shen and Xiaoshan Song, got Master degree in March of 2002, they are currently working in CISCO Inc. in California.
Jie Lin, Working on Master degree, Will be finished in Decemeber of 2002.
Kaushik Narayan, Working on Master degree, Will be finished in Decemeber of 2002.
Hongshun Su, Working on Master degree, Will be finished in Decemeber of 2002.

------Funding applied for based on the work supported by this award;

Proposal Submitted to Agency: U.S Army Medical Research and Materiel Command DOD 2002 Breast Cancer Research Program on 13/06/2002

1. "A New Global Optimization Technology for CAD System Design."
   Wei Qian, Ph.D. Principal Investigator - Exploration awards Recipient

2. "A new CAD Algorithm for Best Reconstructed 3-D Tomosynthesis Image"
   Wei Qian, Ph.D. Principal Investigator - Exploration awards Recipient

3. "Multi-view CAD System for Mass Detection in Digital Mammography"
   Wei Qian, Ph.D. Principal Investigator-Idea Award Recipient

4. "Telemedicine, Telediagnosis and Telemammography Using a Satellite Network for Remote Areas Including Oversea U.S. Military Bases"
   Wei Qian, Ph.D. Principal Investigator-Innovator Award Recipient

5. "Multimedia Telediagnosis Via Internet and Wireless Communication Networks for Breast Cancer"
   Wei Qian, Ph.D. Principal Investigator-Idea Award Recipient