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13. ABSTRACT (Maximum 200 Words) This project is to facilitate research in digital mammography and related technologies, in particular computer-aided diagnosis and image processing. A major limitation to the rapid development and subsequent clinical implementation of these technologies is the lack of a standardized set of mammograms to be used in development and evaluation. We are developing a method to produce simulated mammograms. The method relies on a model of image formation that takes into account the absorption of x-rays in the phosphor, subsequent conversion to light and the scattering of the light before escaping the phosphor. The model also takes into account the finite thickness of the phosphor, the divergence of the x-ray beam, scattered radiation, and noise due to film granularity and from the film digitizer. Almost all the components of the model are completed and computer code is being written. We are now testing the model using x-ray phantoms. We are comparing simulated images created based on a high quality film radiograph to an image acquired using a mammographic screen-film system. The resolution properties of the simulated image closely match that of a real image, but the noise properties differ. We are in the process of determining why there is a difference.				
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4. INTRODUCTION

This project is to facilitate research in digital mammography and related technologies, in particular computer-aided diagnosis and image processing. A major limitation to the rapid development and subsequent clinical implementation of these technologies is the lack of a standardized set of mammograms to be used in development and evaluation. We are developing a method to produce computer-simulated mammograms. The approach is to model the creation of the mammogram on the computer -- all steps from x rays exiting the breast to the image being displayed on a light box. This model, which we have developed previously, will be combined with accurate information of the appearance of normal breast anatomy and of benign and malignant breast lesions. These will be obtained from high quality images of mastectomy samples and biopsy specimens. We believe that this technique can produce simulated mammograms that appear to be actual mammograms. We will test this hypothesis by performing quantitative comparisons of simulated and real mammograms. We will also perform an observer study where radiologists choose the real mammogram from a pair of real and simulated mammograms shown side by side.

5. BODY OF REPORT

5.1 Tasks

There are four tasks in the Statement of Work, which are listed below.

1. To obtain radiographs of mastectomy and tissue specimens
 - (a) radiograph 100 different mastectomy breast tissues at 2.0 times geometric magnification recording image on direct film (without intensifying screen) at five different orientations
 - (b) radiograph 240 different tissue specimens at 4.0 times geometric magnification recording images on direct film (without intensifying screen) at five different orientations
 - (c) segment lesions from specimen radiographs and measure their size, contrast, and shape metrics

2. To develop further a computer model of image formation
 - (a) modify previously developed model for point source versus parallel beam
 - (b) measure and model detector noise for film digitizer and screen-film system
 - (c) measure scatter as a function of position in the image
 - (d) measure beam intensity as a function of position in the image

3. To produce simulated mammograms

- (a) produce simulated mammograms with and without lesions
- (b) make preliminary comparison to actual mammograms
- (c) make adjustments to model, if necessary

4. To evaluate simulated images

- (a) collect real mammograms: normals and those with lesions
- (b) compare real and simulated mammograms based on quantitative measurements
- (c) conduct pilot observer study
- (d) conduct observer study comparing ROIs from real and simulated mammograms

5.1.1 Obtain radiographs of tissue specimens and mastectomies

We have decided to use cadaver breasts instead of mastectomy specimens, because they are easier to obtain. We have one cadaver breast for testing and we will collect 13 more in November. We have not yet collected specimen radiographs.

5.1.2 Further development of computer simulation method

The theoretical basis for the model has been developed previously by the PI, but with a number of simplifying assumptions [1]. For this project, we need to check these assumptions and include other relevant factors particular to our application. In addition, we need to cover the theory into a computer program that can produce a simulated image. Our efforts in these areas are described below.

5.1.2.a Modify model from parallel beam of x rays to x rays from a point source.

Completed. See last years report.

5.1.2.b Model detector noise for film digitizer and screen-film system.

Completed. See last years report.

5.1.2.c Measure scatter as a function of position in the image

This will be done using cadaver breasts, which we will do at the beginning of next year.

5.1.2.d Measure beam intensity as a function of position in the image

We are in the process of producing “uniform” air exposure on film from a standard mammography x-ray unit and from our Faxitron unit. These films will be digitized to determine the x-ray intensity distribution incident on the detector and a correction will be built into the model via a look-up table based on position in the image with respect to the central axis of the x-ray beam.

5.1.3 Produce simulated mammogram

Production of simulated mammograms will be done after tissue samples have been collected. Currently, we are testing the technique using phantoms. That is, we are making images of the phantoms as we would the breast tissue – on Kodak XV film (non-screen system) using three times geometric magnification that will produce a high fidelity image. The images are taken on the XV film and are digitized at 50-micron pixel resolution. The resulting image is put through our simulation model to produce an image with the same exposure as used for the standard mammography system – a Kodak Min-R 2000 system. We have compared the resolution properties of the simulated and real images. We simulated a step function (see Fig. 1) and used it to calculate the modulation transfer function (see Fig. 2). The simulated image and published data [2] show reasonably good agreement.

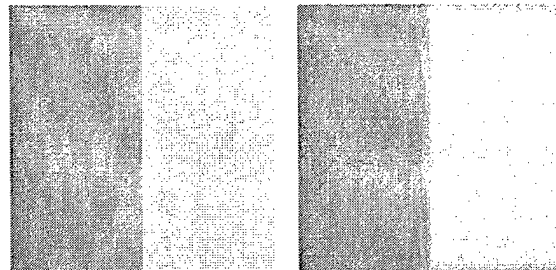


Figure 1. A step image (left image) that was used as input to our simulation method. The output or simulated image is on the right.

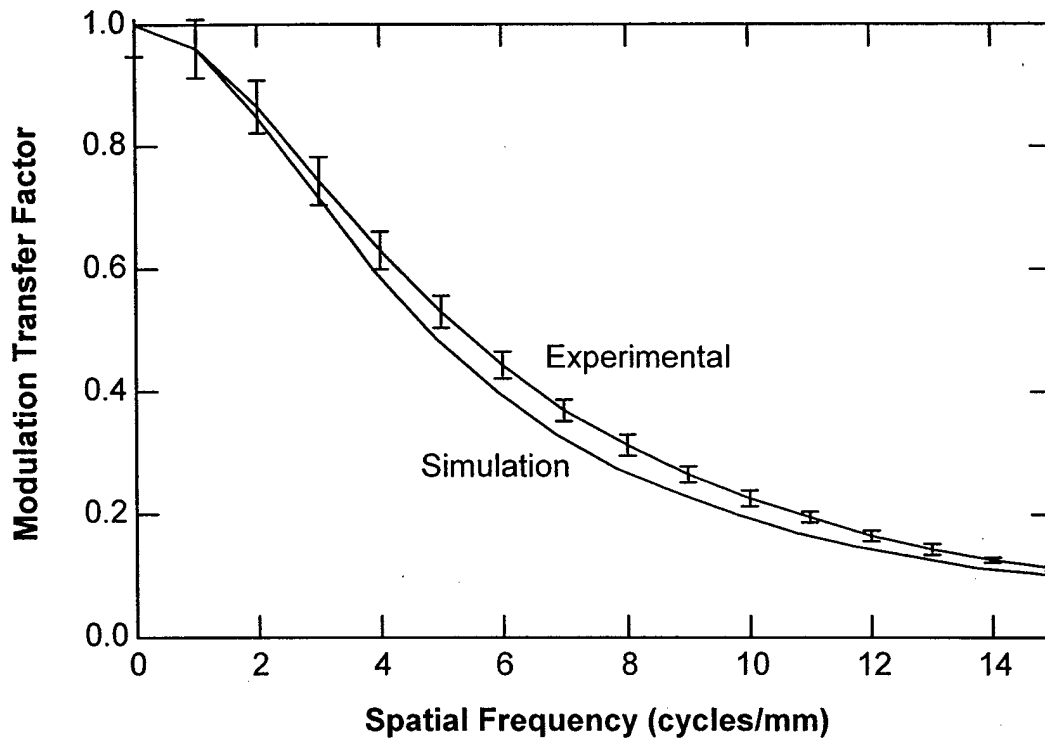
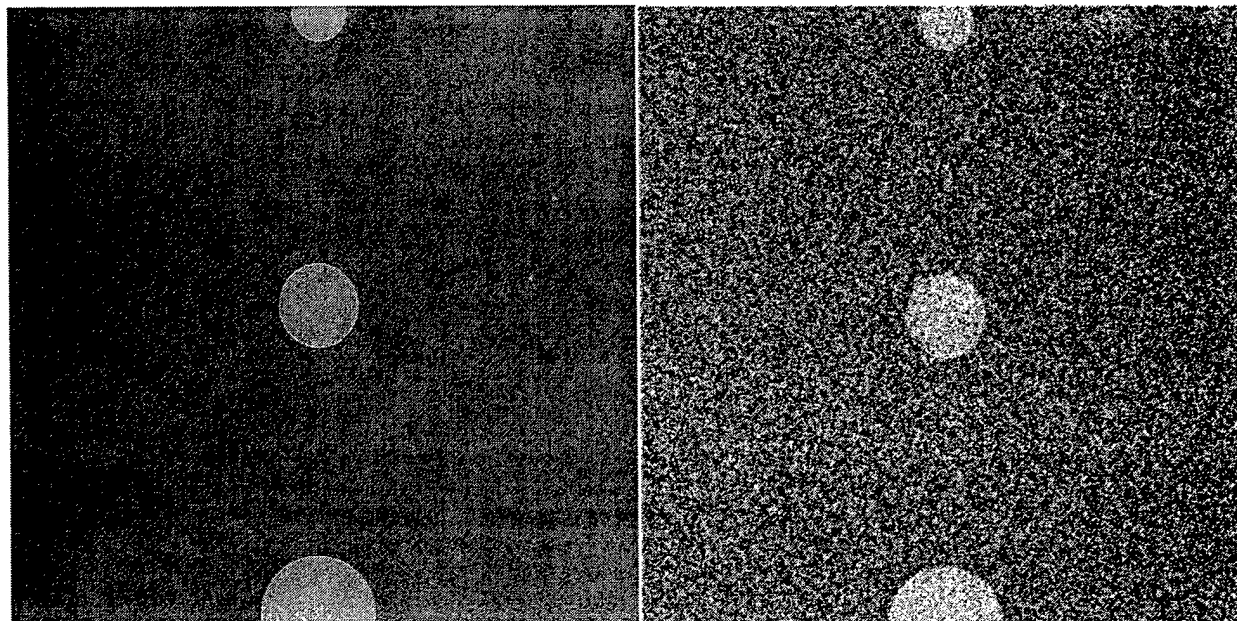


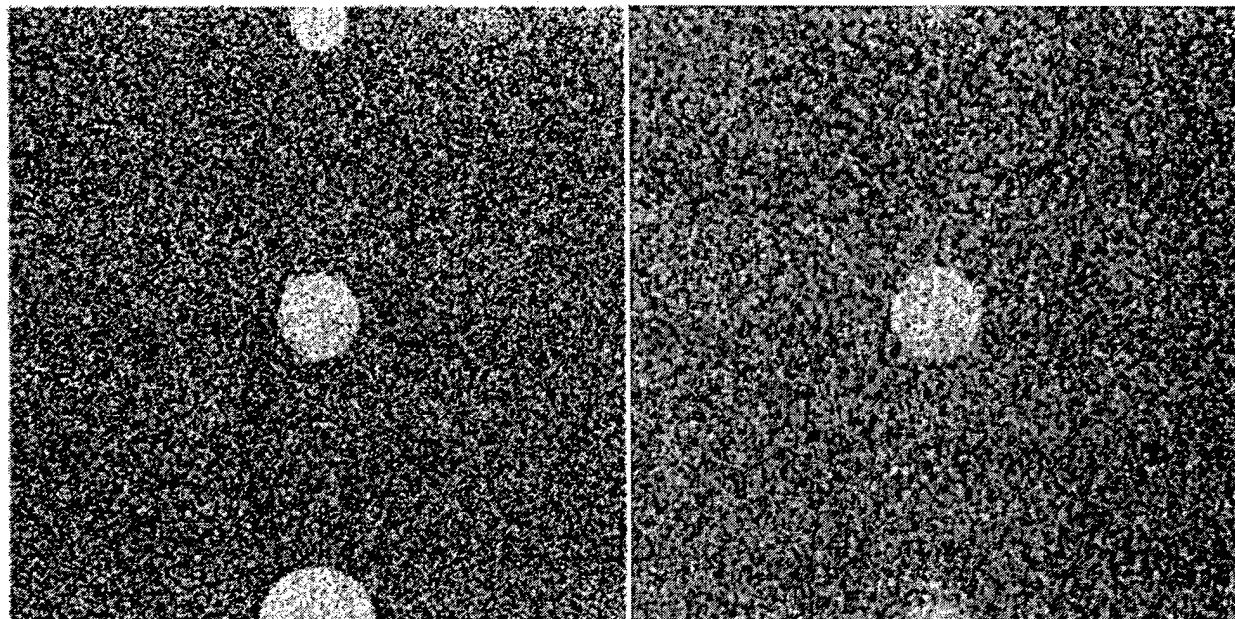
Figure 2. MTF curves for a Kodak Min-R 2000 screen-film system, from published data [2] and from the simulated imaged shown in Fig. 1.

To compare the simulated image to the screen-film image, we digitized the screen-film image at 50 microns and construct a 50-micron resolution simulated image (see Figure 3). Visually the noise in a real image seems to have more high frequency noise than our simulated image. This could be because our simulated image does not contain film granularity noise (which contains high spatial frequency components). We are in the process of determining why we have this discrepancy.



(a)

(b)



(c)

(d)

Figure 3. Simulated phantom image. (a) input image to simulation program; (b) simulated image at 17-micron pixel resolution; (c) simulated image at 50-micron pixel resolution; (d) phantom image made on a Min-R 2000 system.

5.1.4 Evaluation of simulated mammograms

The observer study is planned for year three. It is dependent on completion of 5.1.3.

5.2 Recommendations in relation to the Statement of Work

The only change to our statement of work is to use cadaver breasts instead of mastectomy samples, since it is easier to get cadaver breasts.

6. KEY RESEARCH ACCOMPLISHMENTS

- Computer model is being refined.
- Testing of the simulation technique using phantom images is underway.

7. REPORTABLE OUTCOMES

We have our first simulated images. We still need to improve our technique to make the simulated images more realistic, particularly in noise properties.

8. CONCLUSIONS

We are now capable of producing simulated images. The resolution properties are closely matched to those of real images, however, the noise properties differ. We are now in the process of determining why we have this difference. Progress this past year has been slow. The research technician that was performing the majority of work unexpectedly quit early in the year. It has been difficult to find a replacement, but I am now interviewing candidates for a post-doctoral position who will continue the project using funds from another external source.

9. REFERENCES

1. R M Nishikawa and M J Yaffe, "Model of the spatial frequency-dependent detective quantum efficiency of phosphor screens," *Medical Physics* **17 (5)**, 894-904, 1990.
2. Bunch PC: Advances in high-speed mammographic image quality. *Proc SPIE* **3659**: 120-130, 1999.