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This report summarizes the work completed in Year 2 of this grant. The work included continuing to optimize the geometry of the system configuration, emulating the system point spread function, developing an algorithm to generate three-dimensional reconstructions, collecting projection data for the small and large cameras, and generating three-dimensional reconstructions of the radiotracer distribution within the breast phantom.

The work was significantly hampered by the catastrophic failure of an essential computer system. A significant amount of time and energy was consumed in the efforts to fully recover from the failure, and, as a result, the principal investigator was not able to complete several of the tasks specified in Year 2 of the grant. Work on these unfinished tasks will continue into Year 3, but modifications to the Statement of Work will most likely be required.

The parallel-hole collimator for the small camera was selected and installed. Projection data of the large breast phantom was collected for the small camera. Projection data of the large breast phantom was emulated for the proposed large camera by combining several shifted but overlapping projections collected with the small camera.

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John D. Sain 6-15-99

PI - Signature Date

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INTRODUCTION

This report contains a description and summary of the work completed in Year 2 of the three-year grant entitled "The Design and Emulation of a Multiple-Camera SPECT Breast Imager". The purpose of the research in Year 2 was to use the emulated imaging system to generate three-dimensional images of radioactivity within breast phantoms. Specifically, several tasks were to be undertaken. (1) The point spread function of the imaging system was to be measured. (2) Projection data for the small and large cameras was to be collected. (3) A reconstruction algorithm was to be developed. (4) Three-dimensional images of the radiotracer distribution within the breast phantoms were to be generated. Finally, (5) the optimization of the geometry of the system configuration, begun in Year 1, was to be continued. The main body of the report contains a full description of the work completed in each task.

IMPORTANT NOTE

The work to be performed in Year 2 of this grant was significantly hampered by the catastrophic failure of an essential computer system. Two computer systems are required to perform the proposed tasks. The first system, used only for calibration, controls the movement of a radioactive point source that is mounted on a xyz-stage. The second system, used both for calibration and imaging, controls the operation of the small modular gamma cameras. The failure occurred in the form of a complete disk failure on the first computer system. A significant amount of the principal investigator's time and energy was consumed in the efforts to fully recover from the failure. Due to the circumstances surrounding the failure and the state of several research projects going on in the same lab, the recovery effort lasted longer than our research group expected. Since the computer system responsible for system calibration was unavailable for use during this time, the principal investigator was not able to complete several of the tasks specified in Year 2 of the grant. Work on these unfinished tasks will continue into Year 3, but modifications to the Statement of Work will most likely be required.

OBJECTIVE 2

Task 5. Optimize the geometry of the system configuration.

The purpose of the optimization of the geometry of the system configuration was to define the position and field of view of each camera, the type, size, and arrangement of aperture for each camera, and the magnification of the object. As noted in the Year 1 report, such optimization is a process that goes hand in hand with determining how well the system can detect various types of lesions within a breast. Thus, the optimization will continue as the system capabilities evolve.

In Year 1 of this grant, two significant modifications occurred. First, the orientation of the small cameras was slightly changed. Second, the pinhole apertures for the small cameras were replaced with parallel-hole collimators.

In Year 2 of this grant, no optimizations were completed. The only decision made with respect to the system configuration was to use a general-purpose parallel-hole collimator with a 23.6-mm bore length, a 1.5-mm bore diameter, and an efficiency of 0.01 %. Initial imaging studies will be done with this collimator, and the tradeoffs between collimator resolution, object-to-camera distance, and data collection time will be observed. These observations may provide avenues for further optimization of the system configuration.

The lack of further optimization of the system was due, in part, to the system failure described earlier. Optimization at this stage requires feedback from the system in terms of reconstructed images, and these could not be generated.

OBJECTIVE 3

Task 7. Emulate the system point spread function.

The system point spread function has not been emulated. Due to the aforementioned equipment failure, the calibration system has not been available for use. Thus, the principal investigator has not been able to perform this measurement yet.

Task 8. Develop an algorithm to generate three-dimensional reconstructions of the injected radiotracer activity.

An algorithm has not been developed. As noted in the proposal, robust algorithms of the required type are already extensively used within this research group. An investigation of which algorithm might be best suited for this imaging system were supposed to begin once the principal investigator had both a system point spread function and projection data from each of the cameras. Due to the aforementioned equipment failure, a system point spread function has not been measured, and so no work has been done on algorithm selection.

OBJECTIVE 4

Task 9. Collect and estimate projection data for small cameras.

Projection data for the small camera was collected. The object for the study was a large breast phantom filled with water. The phantom, built in Year 1 of this grant, has a base (chest wall) diameter of 10 cm, a base-to-nipple height of 8 cm, and a volume of 500 ml. A water-filled, 30-mm diameter, plastic sphere, used to model a lesion, was available for insertion into the breast phantom. The small camera, outfitted with a parallel-hole collimator, was positioned parallel to the torso phantom such that its field of view included only the breast phantom (as shown in Figure 11 of the Year 1 report).

The amount of activity injected into each part of the phantom was chosen such that, on a per unit volume basis, the lesion contained about six times as much activity as the background. As noted in the Year 1 report, pathological studies have shown that some types of carcinoma exhibit a mean uptake of radioactivity that is about six times that of the surrounding normal tissue. The mean tumor-to-background ratio (TBR) in corresponding mammoscintigrams is about 2:1.

Two sample images are shown below. Each consists of a 64 x 64 array of 1.5625-mm x 1.5625-mm pixels. For the first image (Figure 1), 14.0 mCi of Tc-99m was injected into the water, and an image was collected. The number of counts in the image is approximately 140,000. For the second image (Figure 2), the 30-mm diameter spherical lesion, filled with water containing 2.0 mCi of Tc-99m, was inserted into the phantom, and an image was collected. The number of counts in the image is approximately 570,000.

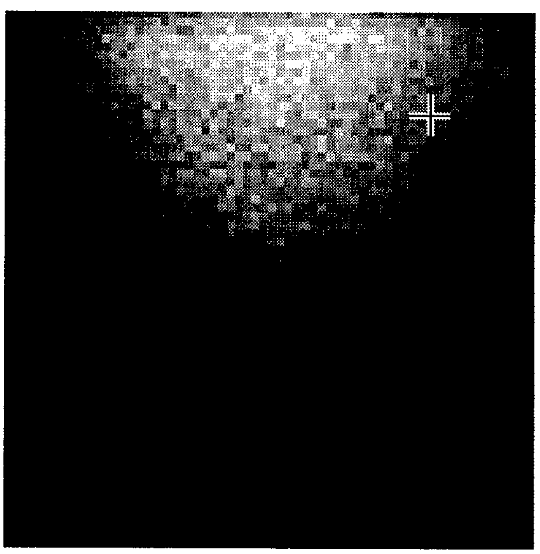

Figure 1. Planar image of large breast phantom (140,000 counts).

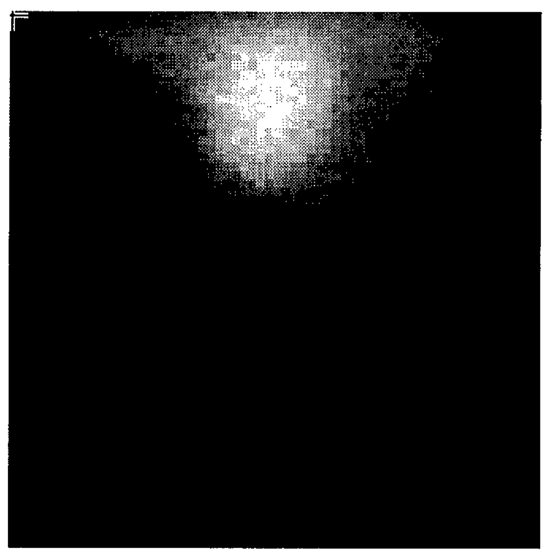

Figure 2. Planar image of large breast phantom with lesion (570,000 counts).

Task 10. Collect and estimate projection data for large camera.

Projection data for the large camera was collected. The object for the study was the large breast phantom described above in Task 9. The small camera was placed in the same orientation as in Task 9. The imaging procedure, however, required moving it to four separate locations (as shown in Figures 5 and 12 of the Year 1 report) at each of which data was collected from a different field of view. The four overlapping fields of view provided a means of generating a larger effective field of view that would have been seen by a larger camera. The larger composite image was created by, first, cutting a 48-pixel x 48-pixel segment out of each of the four 64-pixel x 64-pixel images and, second, juxtaposing the four segments such that they formed a 96-pixel x 96-pixel image. No data was averaged or resampled.

One sample image is shown below (Figure 3). The image consists of a 96 x 96 array of 1.5625-mm x 1.5625-mm pixels. No lesion is present, and the number of counts in the image is approximately 500,000.

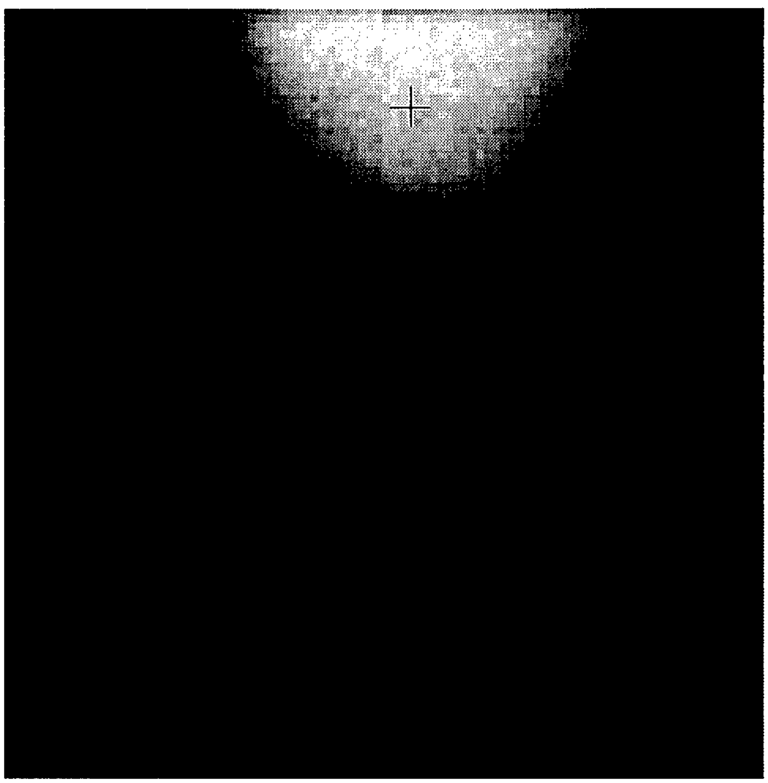

Figure 3. Planar image of large breast phantom (500,000 counts).

Task 11. Generate three-dimensional reconstructions of the radiotracer distribution.

Three-dimensional reconstructions of the radiotracer distribution have not been generated. Due to the aforementioned equipment failure, a system point spread function has not been measured, and so no work has been done on reconstruction.

APPENDIX

Key research accomplishments

- Collected planar images (projections) of the large breast phantom with the small camera. The phantom sometimes contained a "hot" or "cold" lesion.
- Emulated planar images (projections) of the breast phantom for the proposed large camera by combining several shifted but overlapping small camera images.