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High Resolution Emission and Transmission Imaging Using the Same Detector

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Abstract

We demonstrate the capability of one detector, the Micro-Angiographic Fluoroscope (MAF) detector, to image for two types of applications: nuclear medicine imaging and radiography. The MAF has 1024×1024 pixels with an effective pixel size of 35 microns and is capable of real-time imaging at 30 fps. It has a CCD camera coupled by a fiber-optic taper to a light image intensifier (LII) viewing a 300-micron thick CsI phosphor. The large variable gain of the LII provides quantum-limited operation with little additive instrumentation noise and enables operation in both energy-integrating (EI) and sensitive low-exposure single photon counting (SPC) modes. We used the EI mode to take a radiograph, and the SPC mode to image a custom phantom filled with 1 mCi of I-125. The phantom is made of hot rods with diameters ranging from 0.9 mm to 2.3 mm. A 1 mm diameter parallel hole, medium energy gamma camera collimator was placed between the phantom and the MAF and was moved multiple times at equal intervals in random directions to eliminate the grid pattern corresponding to the collimator septa. Data was acquired at 20 fps. Two algorithms to localize the events were used: 1) simple threshold and 2) a weighted centroid method. Although all the hot rods could be clearly identified, the image generated with the simple threshold method shows more blurring than that with the weighted centroid method. With the diffuse cluster of pixels from each single detection event localized to a single pixel, the weighted centroid method shows improved spatial resolution. A radiograph of the phantom was taken with the same MAF in EI mode without the collimator. It shows clear structural details of the rods. Compared to the radiograph, the sharpness of the emission image is limited by the collimator resolution and could be improved by optimized collimator design. This study demonstrated that the same MAF detector can be used in both radioisotope and x-ray imaging, combining the benefits of each.

I. Introduction

Our group at University at Buffalo, Toshiba Stroke Research Center (UB-TSRC) has developed a high resolution CCD based x-ray detector called the Micro Angiographic Fluoroscope (MAF). It has been shown that we can use the MAF in Single Photon Counting

(SPC) mode for x-ray transmission imaging, achieving a resolution of 10 lp/mm[1] as can be seen in Fig 1. This project aims at using high spatial resolution and high sensitivity of the MAF for near simultaneous transmission and radionuclide emission imaging.

II. Method and Materials

A. Micro Angiographic Fluoroscope

The MAF is a CCD based x-ray detector (Fig. 2). The CCD camera is a 1024×1024 array of 12 μm size pixels. A 300 μm thick structured CsI(Tl) is coupled to a Gen 2 Dual Microchannel Plate LII. The LII equips the camera with a large variable gain enabling it to acquire images in SPC mode. The LII is coupled to the CCD camera through a 2.88:1 ratio fiber optic taper, thus giving the MAF an effective pixel size of 35 μm .

B. Collimator

We used a medium energy gamma camera collimator with holes of 1 mm diameter and height 24.5 mm that was available to us. Septa material is lead. The estimated collimator resolution is 1.24 mm at the surface of the collimator. Fig. 3 shows a part of the collimator that was used.

C. Phantom

The phantom is a hot-rod phantom as shown in Fig. 4, where the white circles represent cylindrical cavities in a plastic insert shown solid blue. This insert is placed in a cylindrical container which is filled with a solution containing 1 mCi of ^{125}I . The diameter of the phantom is about 3.5 cm. The depth of the hot rods is about 2 cm.

D. Setup

The emission images were acquired by placing the collimator in between the phantom and the MAF as shown in Fig. 5(a).

To achieve “near-simultaneous” imaging, the collimator was removed from the field of view during transmission imaging as shown in Fig. 5(b).

E. Emission Image Acquisition

Software that controls the MAF and acquires images is the Control, Acquisition, Processing and Image Display System (CAPIDS) [2]. Images were acquired at a rate of 20 fps. Fig 6 shows one of the frames acquired. The white blobs represent one event. An average each frame has 80 to 100 events; 25,000 such frames were collected.

III. Results

A. Collimator Placement

Image shown in Fig 7 was generated by processing frames acquired keeping the collimator stationary. The hexagonal grid pattern corresponds to the collimator pattern. To get rid of the pattern, the collimator was moved in random directions.

B. Need for event localization

Fig 8 shows the result of averaging all the 25,000 frames without any processing. It can be seen that we cannot identify any of the features of the phantom. To overcome this, two event localization algorithms were used, viz. simple threshold method, and weighted centroid method.

C. Simple Threshold Method

In this method, a threshold was applied to the raw image. The set of images on the left in Fig 9 show a zoomed in part of Fig 6 indicated by the red square. A threshold of digital number 60 was applied to the image to get the binary image. This was done to all the images acquired. The resultant binary images were then added to form the final image shown on the right in Fig 9.

D. Weighted Centroid Method

In this method, we calculated the weighted centroids of each event to obtain the image as shown in Fig 10. The events are localised to single pixels and are marked with red arrows below.

E. Transmission Imaging

Transmission images were acquired at 20 fps using a custom CAPIDS. Fig 11 shows a temporal-filtered transmission image using 3 frames. The image appears blotchy because the phantom is enclosed in layers of plastic and absorbent paper and sealed with fiberglass-reinforced sealing tape.

IV. Summary

It was shown that the MAF can be used for both emission and transmission imaging and each hot rod in the phantom is identified in both the modalities.

The grid pattern was eliminated by moving the collimator in random directions during emission imaging.

Currently emission imaging performance is limited by the collimator resolution. The collimator resolution is about 1.24 mm and the MAF resolution is 10 lp/mm. A higher resolution collimator is required for better emission imaging performance.

V. Discussion and Future Work

A. Energy resolution

One event is spread among many pixels. The intensity of the pixels, and the number of pixels in which the event is spread, can be correlated to the energy of the incident photon. By adding the intensities of the pixels in one event, and correlating the resultant number to the incident energy photon, we can determine the energy resolution performance of the system.

B. Spatial resolution

This paper discusses the proof of concept, that the MAF can be used for both emission and transmission imaging. A carefully designed collimator can be used to improve the spatial resolution.

C. Higher energy isotopes

Currently this application is limited to low energy isotopes like ^{125}I . If we replace the 300 μm thick CsI, with a 1000 μm thick CsI, we can achieve better absorption efficiency for higher energy isotopes like Tc99m. The drawback of replacing the scintillator with a thicker one is loss in the x-ray imaging resolution performance. For applications where the resolution requirement for x-ray imaging is not critical and absorption efficiency for emission imaging is important, this can be used.

Acknowledgments

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Fig. 1.
Image of mammography line pair phantom taken with the MAF in SPC mode

Fig. 2.
Schematic of Micro Angiographic Fluoroscope

Fig. 3.
Collimator used

Fig. 4.
Custom phantom designed for the experiment

Fig. 5.
Custom phantom designed for the experiment

Fig. 6.
One frame of emission imaging. The red box shows the two events that will be used in this paper to demonstrate the event localization algorithms used to form the emission image.

Fig. 7.
Image generated from frames acquired by keeping the collimator stationary

Fig. 8.
Image generated by averaging all the emission imaging frames without any processing

Fig. 9.
Simple threshold method

Fig. 10.
Weighted centroid method

Fig. 11.
Transmission image of the phantom acquired by the MAF