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A correction method of the spatial distortion in planar images from γ-Camera systems

D. Thanasas,[a] **E. Georgiou,**[b] **N. Giokaris,**[a,c] **A. Karabarbounis,**[a,c] **D. Maintas,**[d] **C.N. Papanicolas ,**[a,c] **A. Polychronopoulou**[a] **and E. Stiliaris**[a,c,1]

[a] *Physics Department, University of Athens, Ilissia University Campus, 15771 Athens, Greece*
[b] *Medical Physics Laboratory, School of Medicine, University of Athens, Mikras Asias 75, 11527 Athens, Greece*
[c] *Institute of Accelerating Systems & Applications, P.O. Box 17214, 10024 Athens, Greece*
[d] *Institute of Isotopic Studies, Medical Center of Athens, Distomou 5-7, 15125 Athens, Greece*

E-mail: dthanas@phys.uoa.gr

ABSTRACT: A methodology for correcting spatial distortions in planar images for small Field Of View (FOV) γ-Camera systems based on Position Sensitive Photomultiplier Tubes (PSPMT) and pixelated scintillation crystals is described. The process utilizes a correction matrix whose elements are derived from a prototyped planar image obtained through irradiation of the scintillation crystal by a ^{60}Co point source and without a collimator. The method was applied to several planar images of a SPECT experiment with a simple phantom construction at different detection angles. The tomographic images are obtained using the Maximum-Likelihood Expectation-Maximization (MLEM) reconstruction technique. Corrected and uncorrected images are compared and the applied correction methodology is discussed.

KEYWORDS: Gamma camera, SPECT, PET PET/CT, coronary CT angiography (CTA); Medical-image reconstruction methods and algorithms, computer-aided so

[1] Corresponding author.

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Contents

1 Introduction

The existence of spatial distortions is a very common problem in planar images from small field of view γ-Camera systems based on Position Sensitive Photomultiplier Tubes PSPMT [1]–[4]. These distortions result in the deterioration of the quality and the clinical value of the image. Consequently, it is very important to use a correction method for the distorted planar images. For this reason several methods for correcting this kind of distortions have been developed [5, 6]. The novel method presented here corrects offline, event by event, the spatial distortions by using a prototyped matrix, whose elements are derived from a planar image after irradiation of the crystal using a ^{60}Co point source. The methodology comprises the extraction of the x and y experimental coordinates of some predefined pixels of the planar image. As long as the nominal coordinates of the predefined pixels are known, a two-dimensional extrapolation technique can be extended to calculate the nominal coordinates of all data points. The method was successfully applied to the prototype image with the ^{60}Co point source, as well as to a set of planar images from a SPECT experiment with a simple ^{99m}Tc phantom detected at different angles. The resulted images, uncorrected and corrected, are compared and the success of the applied correction methodology is discussed.

2 Materials and methods

2.1 The γ-Camera system

The main components of the γ-Camera system are a lead parallel-hole collimator, a 4 mm thick pixelated CsI(Tl) scintillator and a PSPMT, model HAMAMATSU R2486 [7]. The 3" diameter cylindrical envelope photomultiplier tube is composed of a Bialkali photocathode, a 12 stage coarse mesh dynode structure and 32 crossed-wired anodes arranged into two orthogonal groups X and Y. The anode output wires are connected to a resistive current divider network so that the number of the readout signals is reduced to four analogue signals (X_A,X_B,Y_C,Y_D). Both the energy

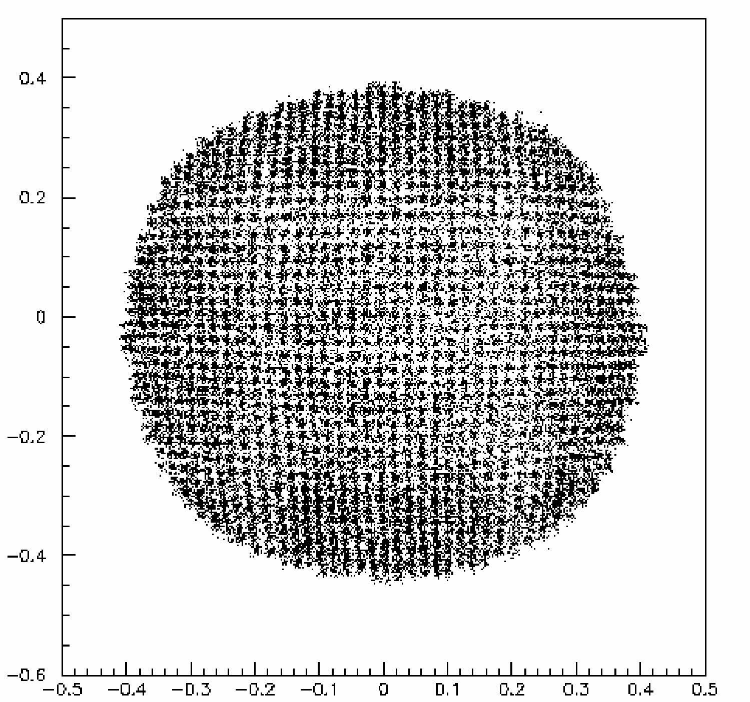

Figure 1. Projection image after irradiation of the γ-Camera with a ^{60}Co point source without using the collimator. Distances are measured in system's units (-1.0, 1.0).

and the position of the incident photons can be reconstructed from these four signals [8]. The read-out system comprises a fast analogue to digital converter (ADC) on a PCI card, model PCI-9812 ADLink [9], with four single ended input channels that lead to four A/D converters simultaneously running with a maximum sampling rate of 20 MHz. The whole digitizing and data acquisition system is controlled by software developed on the LabVIEW environment.

2.2 Correction algorithm

The planar image that was acquired after irradiation of the system, without using the collimator, from a ^{60}Co point source situated at 10 cm far from the crystal surface and after the offline cutoff of the low energy photons is shown in figure 1. The pixels of the crystal are clearly visible in this image, but spatial distortion is also observed, which is significant at the periphery of the FOV. The methodology used to correct this spatial distortion is based on a prototype matrix, which includes the x and y coordinates of predefined pixels of the image.

These coordinates can be extracted with the help of a developed graphical program in FORTRAN. Since the accumulated data are compressed and stored in the well known n-tuple format (rz files), which are suitable for offline analysis with the CERN software (PAW or ROOT), the developed package makes use of the HIGZ (High level Interface of Graphics and ZEBRA) library [10]. In figure 2 the experimental and the nominal coordinates of the predefined pixels are shown. The coordinates of any data point can be now corrected by applying a linear 2D interpolation algorithm, which is also written in FORTRAN language.

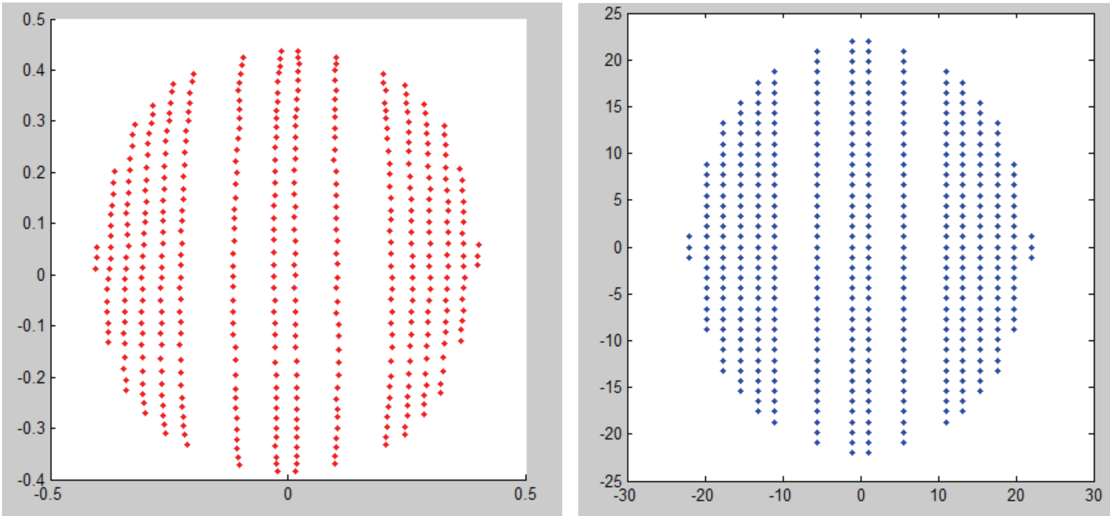

Figure 2. Coordinates of the predefined pixels of the pixelated scintillation crystal for the synthesis of the correction matrix: experimental data (left) and nominal values (right).

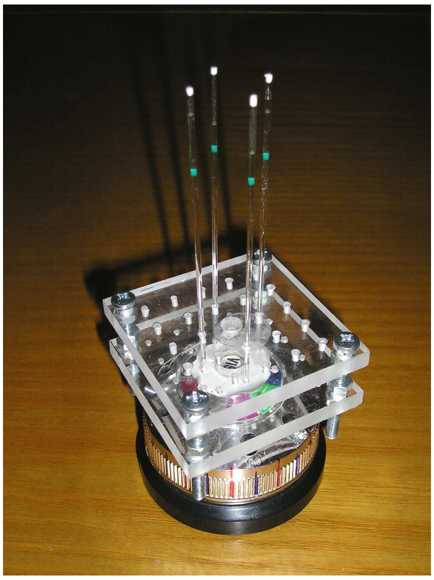

Figure 3. Phantom of 4 capillaries filled with water solution of ^{99m}Tc and placed at the acmes of a rotating orthogonal square prism.

2.3 SPECT experiment

The method was applied in 12 planar images, acquired after a SPECT experiment; the tomographic images were reconstructed by using the maximum-likelihood expectation-maximization (MLEM) reconstruction algorithm. The phantom, which is shown in figure 3, was consisted of four cylindrical capillaries (1.2 mm outer diameter) filled with ^{99m}Tc solution and placed at the acmes of a rotating orthogonal prism. The lead collimator was used during the acquisition.

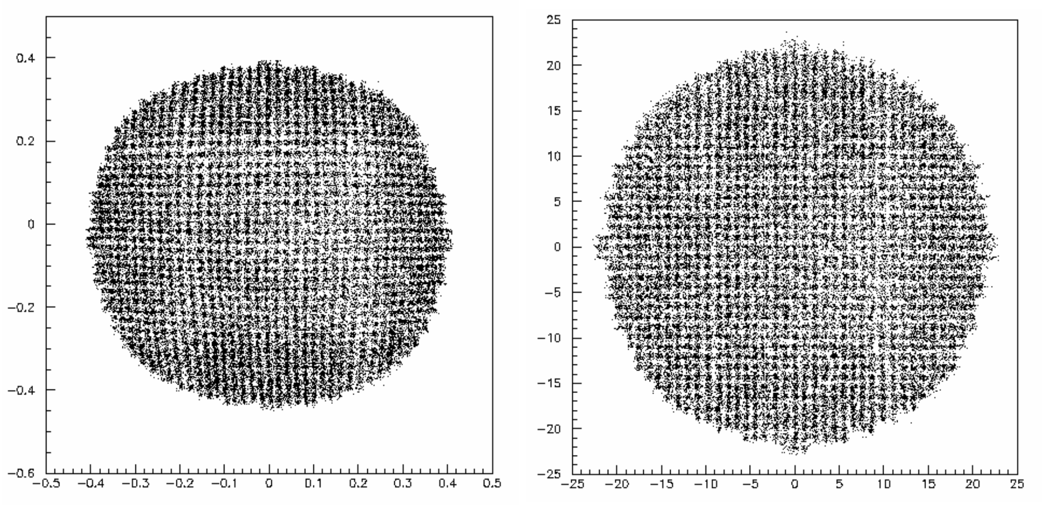

Figure 4. Uncorrected (left) and corrected (right) projection image of the pixelated scintillation crystal. Distances are measured in system's units (-1.0, +1.0) and in true units (mm) in the uncorrected and corrected image respectively.

3 Results

3.1 ^{60}Co irradiation

The method was applied to the data of the prototyped planar image acquired after the irradiation by a ^{60}Co point source. The corrected and uncorrected planar images are shown in figure 4. In the corrected image the spatial distortion has been drastically removed. The distance there is measured in true units (mm) instead of the original system's units (-1.0, +1.0) that appear in the uncorrected image.

3.2 SPECT reconstruction

The method was also applied to the data of the SPECT experiment. Corrected and uncorrected tomographic images for two different tomographic levels are presented in figure 5. At the center of the FOV no differences are observed between the corrected and uncorrected tomographic images. Since spatial distortion is greater at the periphery of the FOV, by approaching the edge of the FOV the differences become maximal. 3D reconstructed images of the capillaries, corrected and uncorrected, are depicted in figure 6. At the uncorrected image due to spatial distortion the capillaries appear to be curved, while at the corrected image their physical linearity has been restored.

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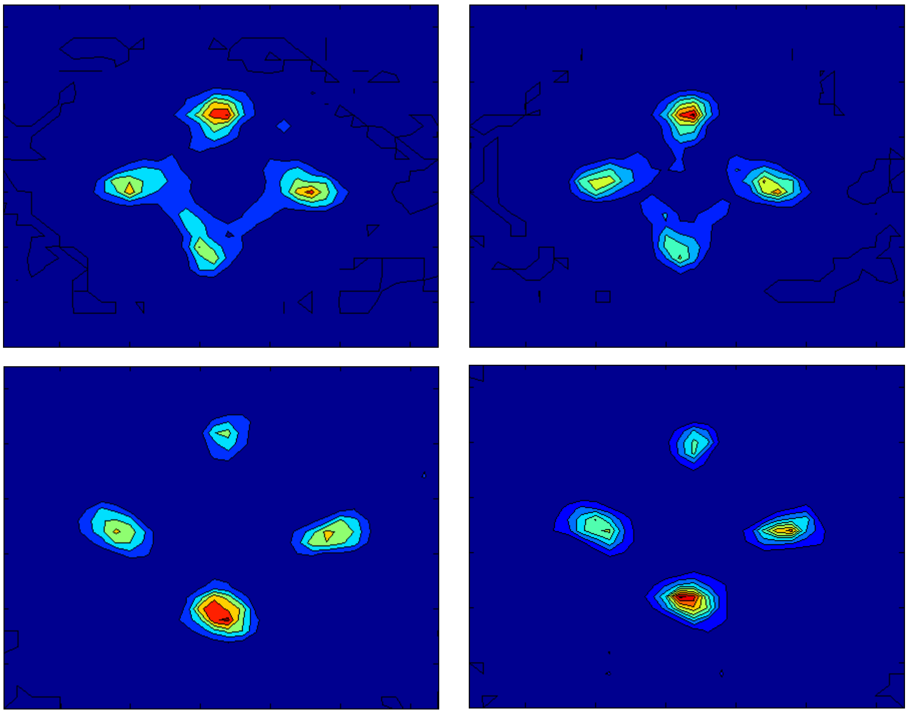

Figure 5. Reconstructed tomographic images of the phantom used in the SPECT experiment for 2 different cuts from the center of the FOV (+12 mm at the upper part and 0 mm at the lower part) of the γ-Camera system. Uncorrected projection images are shown on the left part and corrected projection images are shown on the right part. Differences are greater as the cut distance from the center is increased.

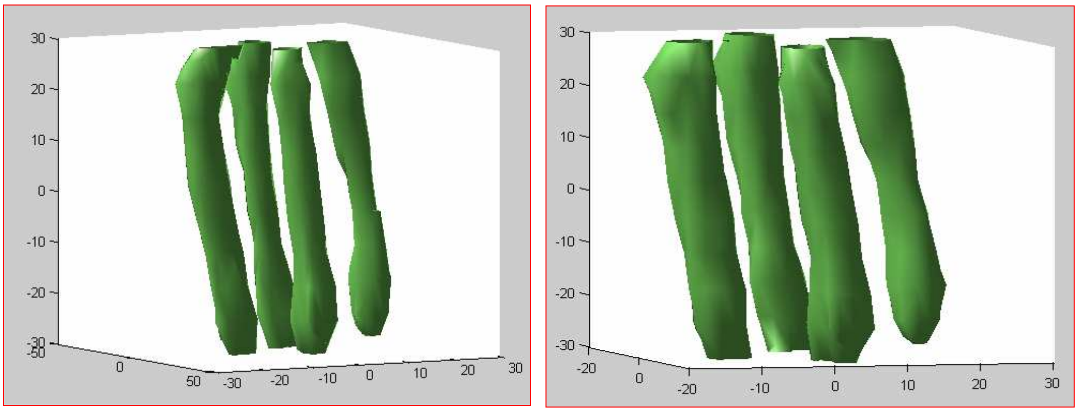

Figure 6. 3D reconstructed images of the capillaries based on the uncorrected (left) and corrected (right) planar images. Distances are measured in mm.

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