A New Scatter Compensation Method for Ga-67 Imaging Using Artificial Neural Networks

G. El Fakhri, S.C. Moore, and P. Maksud

Abstract-- **A new scatter correction method for Ga-67 based on Artificial Neural Networks (ANN) with error back-propagation was designed and evaluated. The ANN consisted of a 37-node input layer (37 energy channels in the range 60-370 keV), an 18-node hidden layer, and a 3-node output layer to estimate the scatter-free distribution in the 93, 185 and 300 keV photopeaks. Two separate activity and attenuation distribution sets, based on a segmented realistic anthropomorphic torso phantom, were simulated. The first set was used for ANN learning and the second to evaluate the scatter correction. Our Monte Carlo simulation modeled all photon interactions in the patient, collimator and detector. Interactions simulated in the collimator included Compton and coherent scatter, and photoelectric absorption with forced production of lead K-shell x-rays. Ninety very-high-count projections were simulated and used as a basis for generating 15 Poisson noise realizations for each angle; noise levels were characteristic of 72-hour post-injection Ga-67 studies. The energy window images (WIN) used clinically were also generated for comparison. Bias and variance were computed with respect to the primary distributions over reconstructed volumes of interest in the lungs, abdomen, liver and tumors. ANN overall bias in all structures was less than 16% (8% in the abdomen) as compared to 85% with WIN. The variance of the activity estimates was systematically greater with WIN than ANN. ANN is a promising approach to scatter correction in Ga-67 studies.**

Index terms- Artificial neural networks, Ga-67 SPECT, Monte Carlo simulation, scatter correction.

I. INTRODUCTION

Gallium avidity in non-Hodgkin s lymphoma is correlated with the histo-pathologic grade of the tumor [1,2]. However, a wide spread in the activity estimates among tumors of the same grade has been reported, owing to several tumor specific biases as well as physical factors such as scatter, attenuation and contamination from high-energy photons. Therefore, better correction techniques should yield better quantitation and minimization of the variability due to physical factors. The aim of this study was to develop and evaluate a new scatter compensation technique for Ga-67 based on Artificial Neural Networks (ANN) with error back-propagation as a learning tool. Our approach was evaluated using realistic Monte Carlo (MC) simulations of a digitized anthropomorphic torso phantom containing a thoracic cavity, lungs, liver, heart and anatomically accurate bones (Figure 1).

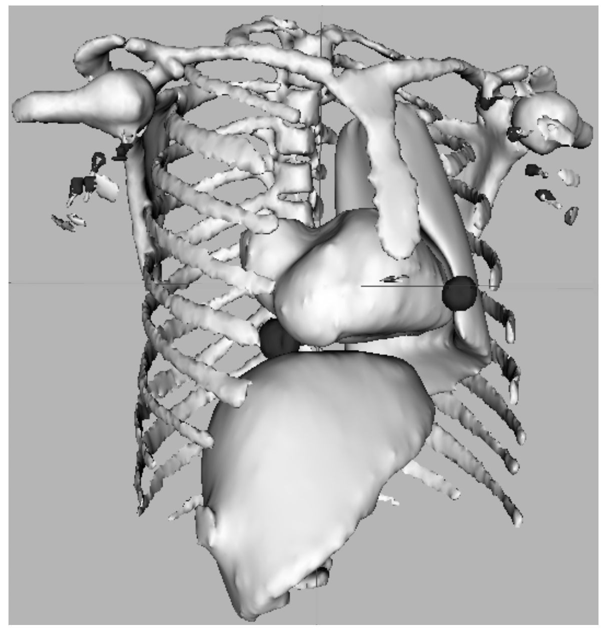

Fig. 1. Surface rendering of the digitized torso phantom, with the right lung not shown for better visualization of the spine and the posterior tumor. Axilliary nodes and anterior and posterior tumors are shown darker than normal structures.

II. MATERIAL AND METHODS

A. Artificial Neural Network (ANN)

1) ANN architecture

The Artificial Neural Network (ANN) devised for scatter compensation is a multilayer perceptron (MP) which uses a back-propagation algorithm as a learning tool [3]. This ANN has been evaluated and used previously to correct for scatter in Tc-99m studies [4] as well as dual Tc-99m/I-123 studies [5, 6]. It is made of partly connected artificial neurons organized in multiple layers. Each neuron has several inputs and one output. Inputs are either external data or outputs of other neurons. The effect of each input is regulated through a specific weight established during the learning phase. The MP was composed of an input layer (37 neurons), a hidden layer (18 neurons) and an output layer comprising 3 neurons, therefore, the total number of weights was 1,998 (Figure 2). For each pixel of each projection, the thirty-seven inputs were the energy channel values, expressed as fractions of the total counts detected in all thirty-seven energy channels. The three

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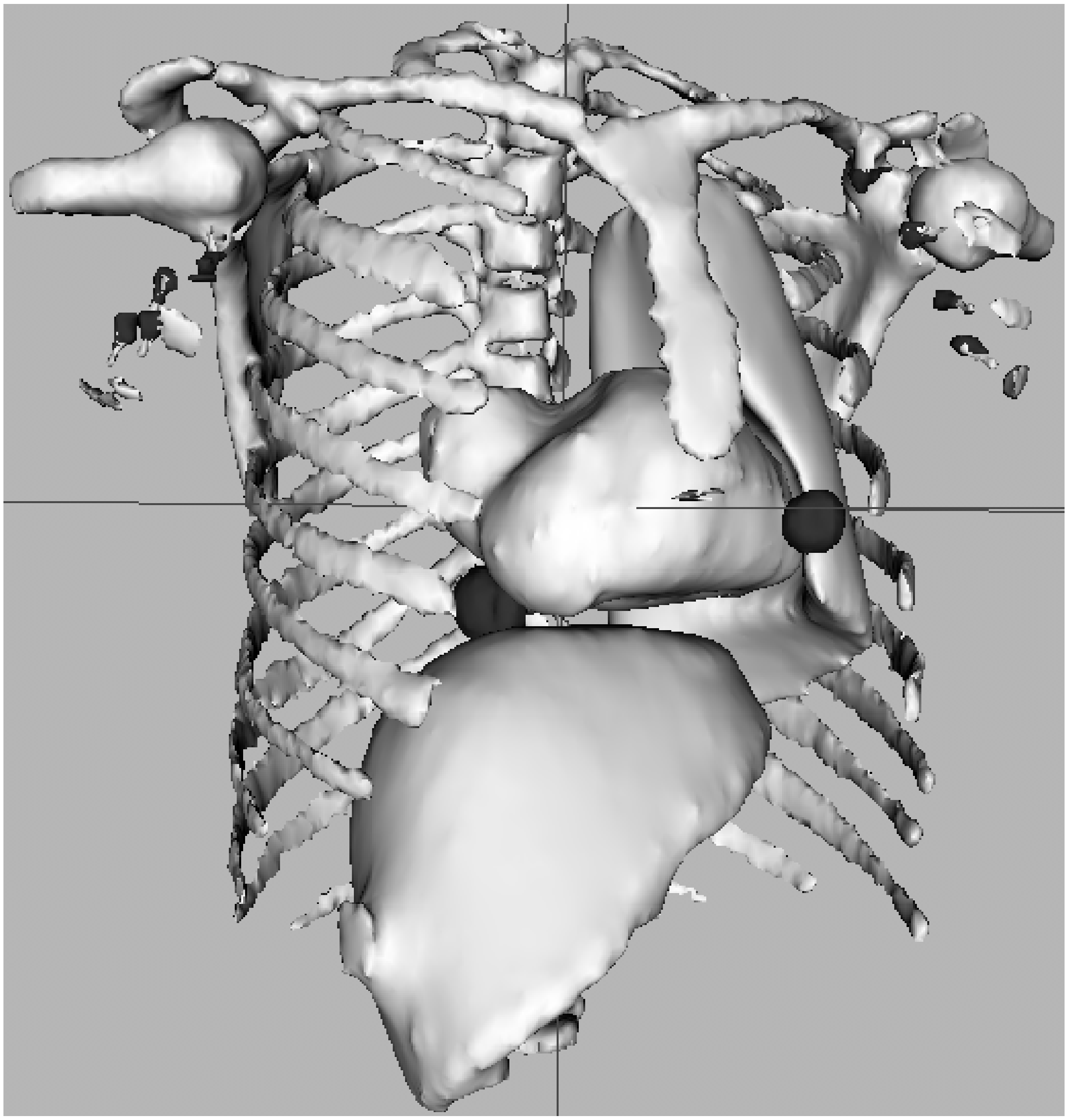
Representative Figures:



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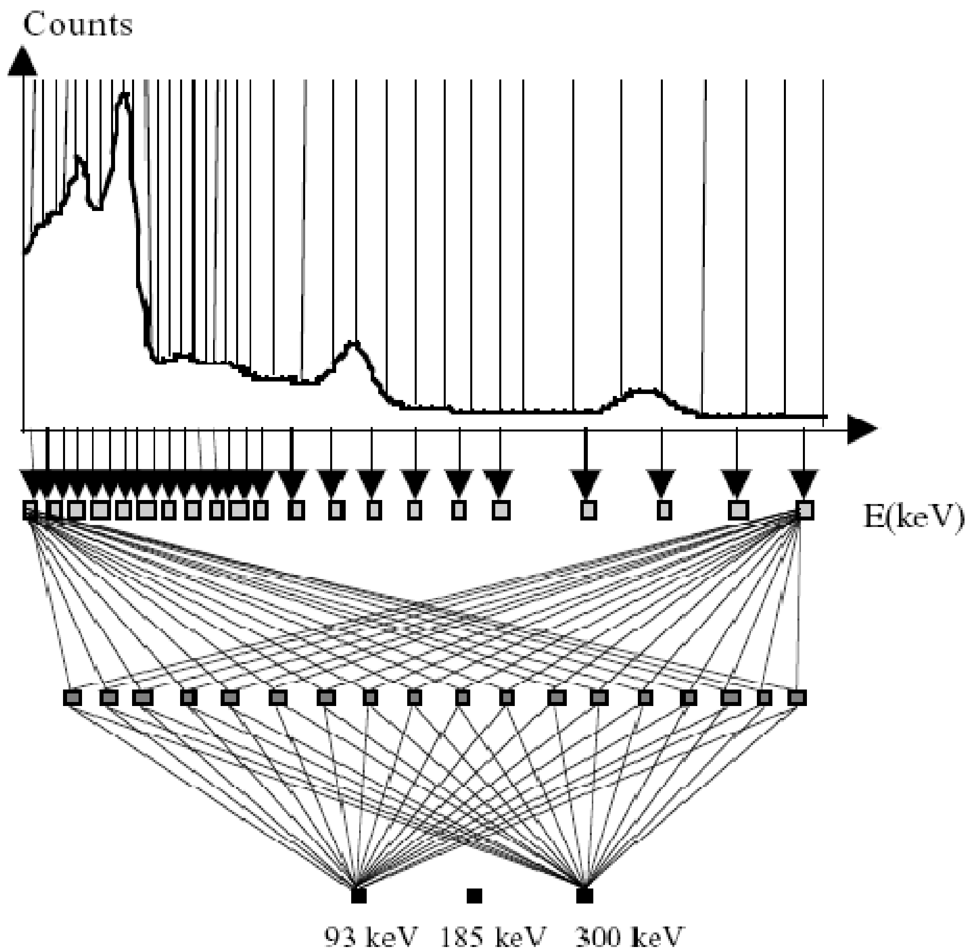

Figure 2. Architecture of the artificial neural network (ANN) designed for scatter correction in Ga-67 SPECT studies. Each node in the input layer is connected to all nodes in the hidden layer (only two input connection sets are shown)

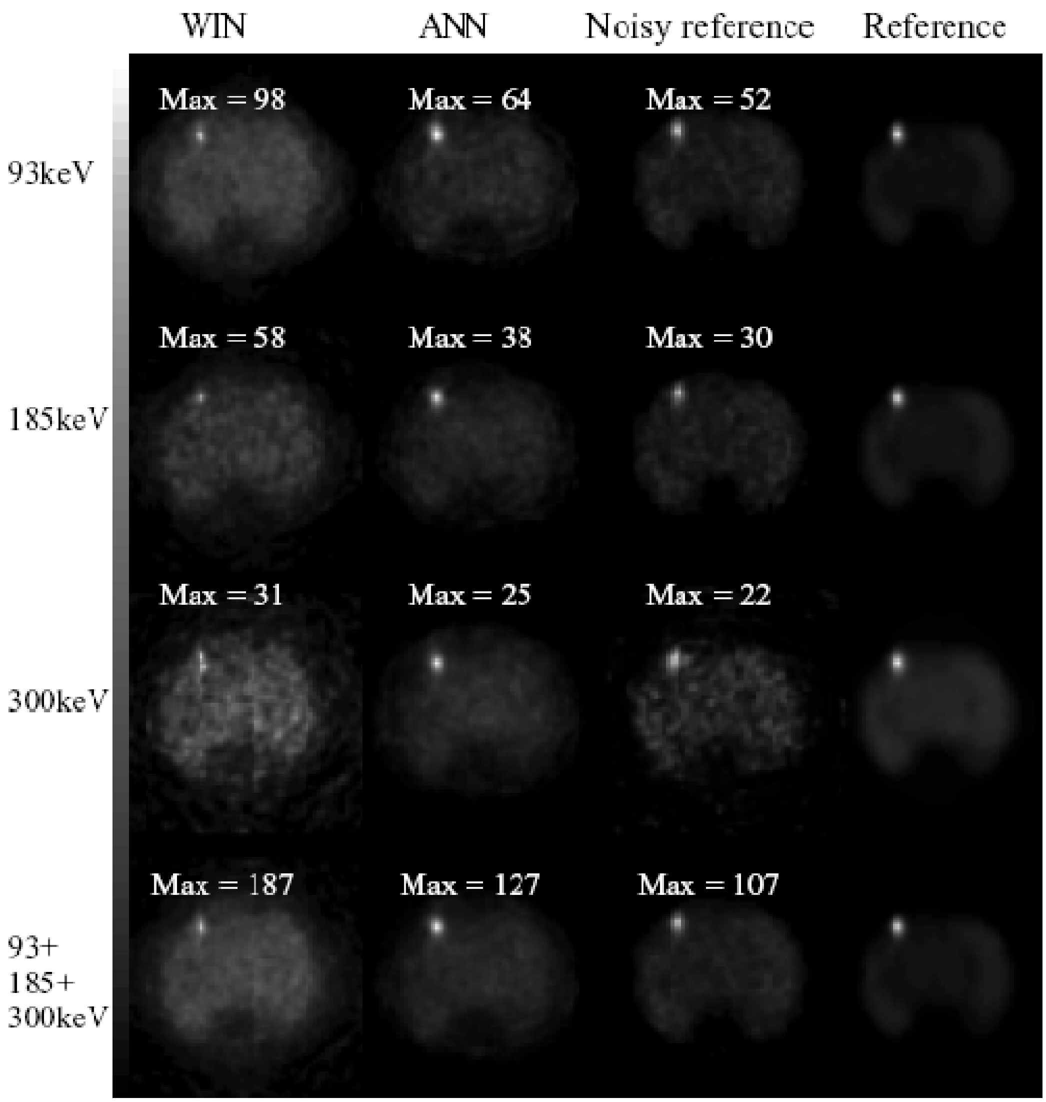

Fig. 5. Estimated primary distributions in the three energy photopeaks in a representative slice of the torso phantom. Each image is displayed relative to its own maximum value.