Analytical Image Reconstruction Strategies for AX-PET Data

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I. INTRODUCTION

AX-PET\(^1\) stands for a novel detector design for PET scanners based on axially oriented elongated crystals and orthogonally placed wavelength shifter (WLS) strips. It aims at a significant reduction of the parallax error combined with improved sensitivity and resolution [1]. In Fig. 1, we show one AX-PET module consisting of a stack of crystal and WLS strips which are read out by Geiger-mode Avalanche Photo Diodes (G-APDs = Silicon Photo-Multipliers, SiPMs), and marketed as Multi Pixel Photon Counters (MPPCs).

Recent studies with the 2-modules AX-PET demonstrator showed that with the dedicated iterative reconstruction method 1 mm inserts of a NEMA phantom can be resolved. In this study, we are investigating the analytical reconstruction strategies for the list-mode AX-PET data. In order to exploit the novel properties of AX-PET, the selection of the optimum sampling (radial and angular) and the amount of axial compression in construction of the sinograms plays a crucial role. The process consists of pre-processing steps such as histogramming and dedicated geometrical correction (including estimating the inter-crystal gaps) for the list-mode AX-PET data.

II. MATERIALS AND METHODS

As shown in the Fig. 1, the AX-PET module consists of 48 LYSO crystals (of dimensions 3 x 3 x 100 mm\(^3\)) and 156 WLSs (0.9 x 40 x 3 mm\(^3\)). While the transaxial coordinates (x and y) are discrete (cross section of the crystals), the axial coordinate (z) is of continuous nature. The current design of the AX-PET demonstrator consists of two modules. While one of the modules is fixed, the other module can be rotated by up to ±60°. Therefore, larger and better sampled field-of-view (FOV) was obtained by changing the relative angle between the two modules and by rotating the source. In Fig. 2, we illustrate the coverage of two modules in the transaxial plane. It should be noted that one module can be in coincidence with the other module in face-to-face or in an off-the-face configuration (20° in our case). For example, in Fig. 2, the blue line draws the span of the covered angles by using two-modules by aforementioned configurations and green line illustrates the span of the angles covered as the source is rotated by 20°. Consequently, rotating the source in 18 steps for each of the two module configurations covers all possible angles.

The data from the MPPCs are organized in list-mode format. In the current AX-PET demonstrator, we use an in-house list-mode data format which consists of the detector coordinates forming LORs in the 3D space.

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1 https://twiki.cern.ch/twiki/bin/view/AXIALPET/WebHome

The 3D list-mode data were histogrammed by using span3 axial compression scheme. A FOV of 66 x 66 x 80 mm³ was considered for the image reconstruction. The discrete transaxial coordinates (x and y) were used directly in the histogramming. However, the continuous axial coordinates (z) were discretized according to the radial sampling used in the construction of the sinograms in order to have cubic voxels in the reconstructed images. In this study, we used radial samplings of 1, 0.8750, and 0.4375 mm, respectively. For the angular images were of 1°, the inter AX PET, axial compression schemes other than span3 data with finer radial sampling, the compensation of the inter AX properties of the AX reconstruction result for the NEMA phantom. Radial sampling of 1° increments which yielded 180 angular views in the constructed sinograms. With the above settings and by using span3 axial compression scheme, the obtained 3D sinogram data were of size 152 x 180 x 21963 (radial samples x angular views x slices) organized in 121 segments for the radial sampling of 0.4375 mm, 76 x 180 x 5583 in 61 segments for the radial sampling of 0.8750 mm and 66 x 180 x 4215 in 53 segments for the radial sampling of 1 mm.

Even though the list-mode data had only golden events and we did not need to apply correction for randoms or scattered events, we had to apply geometrical corrections to the histogrammed data and data estimation methods for the inter-crystal gaps [2]. For the geometrical correction, we calculated all possible LORs which can be recorded by the current rotating two-module AX-PET demonstrator. The obtained map which shows the probabilities of the individual detector pairs in recording the events was used to correct the constructed sinograms. Depending on the used radial sampling, the inter-crystal gaps change in shape and magnitude. Fig. 3 illustrates the sensitivity map for the sinogram belonging to the transaxial segment. The missing parts of the data were estimated by using the gap-filling methods published previously in [3, 4].

The corrected 3D sinograms were reconstructed analytically by using the 3D reprojection method (3DRP) implemented in Software for Tomographic Image Reconstruction (STIR). We used the 3DRP method with Colsher’s filter. The final reconstructed images were of size 152 x 152 x 363 for the radial sampling of 0.4375 mm, 76 x 76 x 183 for the radial sampling of 0.8750 mm and 66 x 66 x 159 for the radial sampling of 1 mm.

III. RESULTS

In this summary, we show the first preliminary 3DRP reconstruction result for the NEMA phantom. Radial sampling of 0.4375 mm and angular sampling of 1° were used in the histogramming. Transradial bicubic interpolation method [4] was employed after the 3D sinogram data were corrected with the sensitivity map. In the full conference proceeding, we will show the results for the other sampling and axial compression cases.

IV. CONCLUSION

In this work, we investigated analytical image reconstruction approaches for data acquired from the two-module AX-PET demonstrator. The preliminary results show that we are able to resolve the NEMA insert down to 2 mm diameter. In view of upcoming experiments, we aim at finding the optimum sampling (radial and angular) and axial compression which exploits best the novel properties of the AX-PET concept. It is clear that as we histogram the data with finer radial sampling, the compensation of the inter-crystal gaps becomes harder. Moreover, in order to increase counts per slice, axial compression schemes other than span3 will be tested.

REFERENCES