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Strategies of statistical windows in PET image reconstruction to improve the user's real time experience

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Abstract. Nowadays, with the increase of the computational power of modern computers together with the state-of-the-art reconstruction algorithms, it is possible to obtain Positron Emission Tomography (PET) images in practically real time. These facts open the door to new applications such as radio-pharmaceuticals tracking inside the body or the use of PET for image-guided procedures, such as biopsy interventions, among others. This work is a proof of concept that aims to improve the user experience with real time PET images. Fixed, incremental, overlapping, sliding and hybrid windows are the different statistical combinations of data blocks used to generate intermediate images in order to follow the path of the activity in the Field Of View (FOV). To evaluate these different combinations, a point source is placed in a dedicated breast PET device and moved along the FOV. These acquisitions are reconstructed according to the different statistical windows, resulting in a smoother transition of positions for the image reconstructions that use the sliding and hybrid window.

1. Introduction

At the present time, Positron Emission Tomography (PET) images can be obtained in practically real time. In this context, a prototype of a semi-robotized stereotactic breast biopsy device incorporated in a dedicated dual-ring PET detector was developed and named MAMMOCARE [1] (see figure 1). The system consists of two rings with 12 modules each forming a transaxial Field Of View (FOV) of 170mm. Each module contains a single trapezoidal continuous LYSO scintillation crystal (not pixelated) coupled to a Position Sensitive Photomultiplier (PSPMT) H8500 from Hamamatsu Photonics and an electronic readout board based on the Anger logic. The crystals have a thickness of 12 mm and their front and back face areas are $40 \times 40mm^2$ and $50 \times 50mm^2$ respectively. The axial FOV is 94mm, including a 4mm gap between rings. To allow the passage of the biopsy needle, the detector ring can be opened up to 60mm in the transaxial plane forming a "C" shape composed of two blocks of 2x6 detectors. In addition, the system can be rotated up to 170 degrees positioning the detector rings in the optimum location to minimize the biopsy path towards to the lesion. The system includes two breast compression pallets for holding the breast on place during the biopsy procedure. This mild compression is performed manually

by the operator and includes a torque limiter (up to 200 Newton) to prevent patient injuries. One of the pallets contains an open window to allow the insertion of the needle.

Figure 1. The Mammocare prototype

In order to visualize the procedure inside the PET device, a radioactive source is placed in the biopsy needle, making the positioning visible in the PET reconstructed images. As the needle is moving towards the lesion several images have to be reconstructed sequentially to provide a visual aid to the user during the intervention.

To obtain an adequate quality in online PET images certain acquired statistic is needed. In this way, a specific amount of events is established forming a block and each of these blocks are sequentially reconstructed. To visualize the images the user has to wait until a block has been acquired and reconstructed, creating a time delay that breaks the real time experience. This work aims to improve the user experience by having the data blocks be reconstructed in different types of subsets obtaining intermediate images that provide a visual impression of tracking of the path of the activity in the Field of View (FOV). Fixed, incremental, overlapping, sliding and hybrid windows are the different statistical combinations of data inside the blocks used to generate intermediate images. To evaluate these different combinations, a point source was moved along the transaxial FOV of MAMMOCARE at a qualitative similar velocity to that of biopsy's needle during operation.

2. Methods
This work is a proof of concept to monitoring the movement of activity in the FOV for online PET images. For this purpose, a Sodium-22 (^{22}Na) point source of 1 mm in diameter and 10uCi of activity was randomly moved during one minute inside of the transaxial FOV. The velocity was qualitatively similar to that of a tissue biopsy procedure. The computer used for the reconstruction was a dual IntelXeon, 8 cores, 12GB RAM.

The entire acquisition had 1.5M total events that were divided into 5 blocks of 300k events. These blocks, in turn were grouped in different types of windows to be reconstructed. These windows that are described below are named as fixed, incremental, overlapping, sliding and hybrid window respectively. The size of the virtual pixel used in the reconstruction is 2 mm^2 and the voxel size is 1 mm^3. The reconstruction was performed using List Mode Ordered Subset algorithm (LMOS) [2] with the Tube Of Response (TOR) projector [3] applying 1 iteration and 16 subsets. The reconstruction is parallelized in order to take advantage of the modern multi-core architectures.

Figure 2 schematically shows how the different window strategies were implemented in the reconstruction. In the fixed window each block is independently reconstructed using 16 subsets as fast as the data are available, obtaining one image for each acquisition block. In the incremental window, when one data block is acquired, the image is reconstructed using all the blocks available, so each image will have more statistics than the previous. The images will not be independent one from another with increasing statistics. In the overlapping window when a data block is available, the image is reconstructed using the block statistics and a sub-block of statistics of the previous block (overlapping data). The images will not be completely independent one from another, but the reconstruction will have more statistics than the fixed window strategy. In the scheme of the sliding window, the first image is

reconstructed with the first data block, and next images will use the same block size but M (100k in our case) events of offsets for each next. The number of events for the offset will determine the number of intermediate images and thus the "smoothness" of the transitions. The drawback of this strategy is that more reconstructions are needed in comparison with the previous methods and the reconstruction time becomes critical. Finally, the hybrid window combines fixed and incremental schemes. Each acquired block is reconstructed using the incremental scheme (b-sub-blocks, where b contains 100k events).
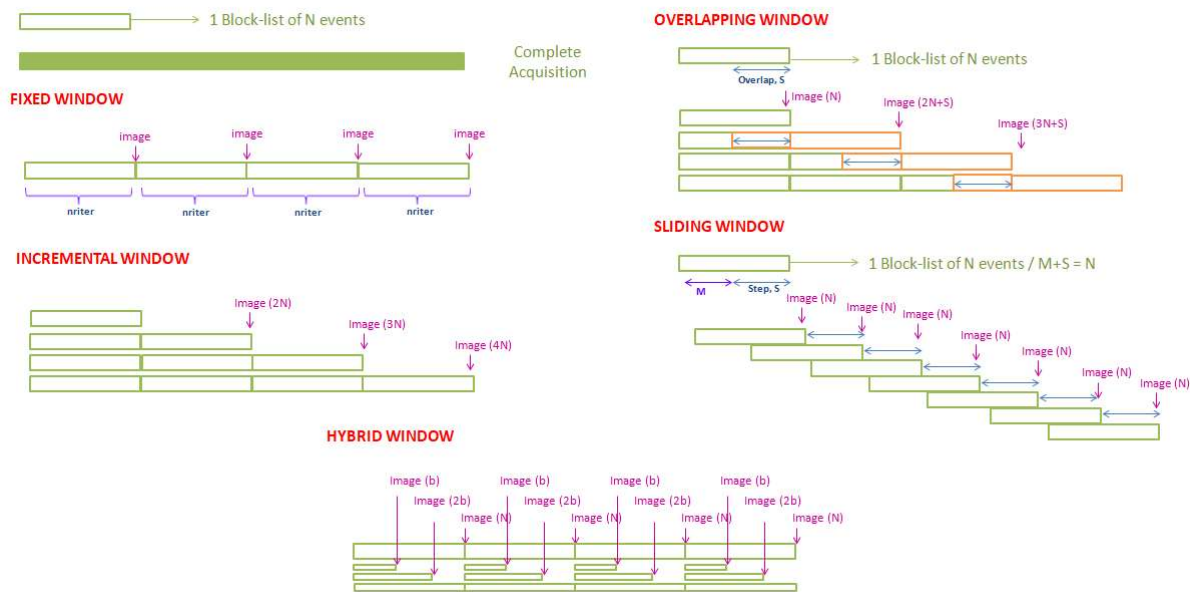

Figure 2. Window Strategies

3. Results and conclusions

The acquisition of the point source was reconstructed according to the different window strategies described above. The reconstruction time was proportional to the number of events reconstructed. For the fixed window it was about 5s (complete statistics). The intermediate images are always reconstructed in less than 1s. As an example, figure 3 shows the different positions reconstructed using the sliding window strategy corresponding to the continuous movement of the point source inside the FOV. Figure 4 shows the images for all the strategies corresponding to the same plane for all the reconstructions and all the intermediate images jointly added in each window strategy. Fixed, incremental and overlapping windows have 5 intermediates images for all the acquisition while sliding and hybrid windows have 15 and 25 intermediate images respectively. As it can be seen, the incremental strategy returns a non-point source image as it can be expected as it is using statistics of different point source positions for the latest images. Even more, the use of LMOS algorithm makes this effect worse as each sub-iteration will use information of different point source locations. In view of the results presented in this work, it can be concluded that obtaining intermediate images improves the user experience while visualizing images in real time. As it can be observed, the sliding and hybrid windows give us a smoother transition of positions for the reconstructions image when compared with the other strategies, generating each image every few hundreds of milliseconds creating a much better user experience.
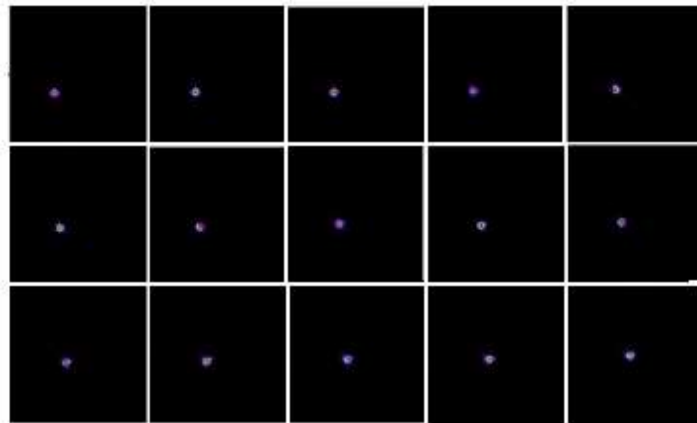
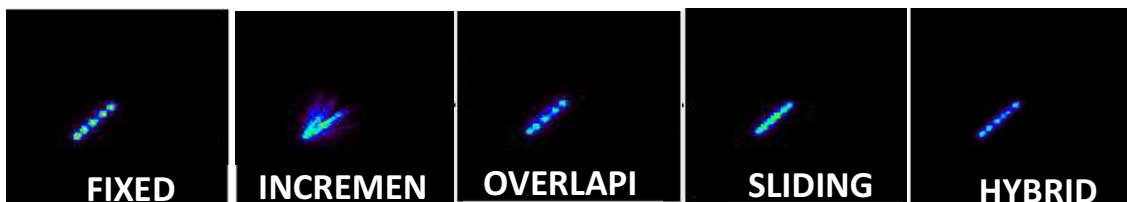**Figure 3.** Sliding window strategy images

Figure 4. Point source images overlapped for all window strategies

Nevertheless, in order to implement these strategies in a real procedure, the statistics acquired during operation and the block size selected can increase the reconstruction time for the intermediate images making the response time non viable for real time operation. The trade-off between strategy, statistics and reconstruction time should be carefully chosen.

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