A simple framework for dPET phantom generation with an example dataset for hypometabolic temporal lobe lesions

N. Martínez[1], M. Bertrán[1], Á Gómez[1], G. Carbajal[1], A. Fernádez[1],R. Ferrando[2]

[1] **Facultad de Ingenieríía, Universidad de la República, Uruguay**
[2] **Centro de Medicina Nuclear, Universidad de la República, Uruguay**

Purpose

Dynamic Positron Emission Tomography (dPET) consists of asequence of PET scans in consecutive time frames that allow the exploration of the temporal variations of tracer concentration in normal and pathological conditions. One of the most common hassles for conducting research in this field is obtaining or simulating imaging studies on which to test algorithms and hypothesis. The purpose of this article is to present a framework for dPET phantom generation using Matlab [2], and a streamlined integration with PET acquisition simulator SimSET [3] and the tomographic reconstruction software STIR [4].

Methods

In order to generate a realistic phantom, it is necessary to define the overall anatomy, the attenuation and the activity properties of the different regions of the phantom. The process requires also the defi- nition of the time frames durations, the simulation parameters that control how the phantom is acquired (observed) by the scanner, and how the raw data from the scanning is corrected for attenuation and finally reconstructed.

The anatomy of the phantom is defined by a 3D volume where each voxel is labeled as belonging to a region. Regions differ in their physical properties (e.g.: attenuation coefficient for bone vs. cere- brospinal fluid), and pharmacokinetic properties (e.g.: grey matter vs. white matter). As such, each labeled region has a corresponding attenuation coefficient, which depends on the material properties of the region, as well as a time-varying tracer concentration (time activity curve or TAC). The tracer activity is calculated using the multi-compartment pharmacokinetic model [1].

The procedure for phantom creation involves two stages done in tandem. First, the designed anatomy and activity is acquired by a dPET scanner. This process, done with the SimSET simulator, yields a sequence of sinograms. Then, the acquired sinograms are attenua- tion corrected and reconstructed into an easy to interpret sequence of 3D images. Reconstruction and attenuation correction are performed using the STIR software.

The presented framework consists of two blocks as shown in Fig. 1. The first stage is Phantom Design, in this stage we define the anatomy (labelmap), material, and tracer activity for every region as well as the duration of the time frames. This procedure is done on Matlab and outputs the required parameter files for SimSET simula- tion and STIR reconstruction. The following stage is Phantom Generation, in this section we simulate and reconstruct the dPET study. This step is performed by running a configurable shell script that executes the required SimSET and STIR processes, using the parameter files obtained in the previous step.
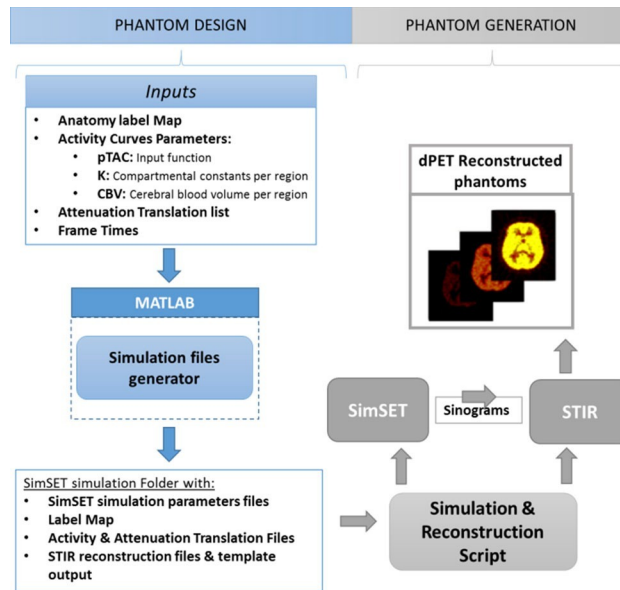
Fig. 1 Phantom generation workflow

Simulation and reconstruction shell scripts can be executed in a cluster if available. This drastically reduces the required computing time. Since all frames are processed in parallel, a complete phantom takes as long as the longest frame to generate.

Results

A dataset of twelve hypometabolic temporal lesions was generated with the proposed framework for the 18F-FDG tracer. The phantoms simulate temporal lobe hypometabolic lesions.The twelve brain phantoms correspond to 3 variations in lesion activity, 2 different numbers of simulated photons, and reconstruction using two methods: filtered backprojection and the ordered subset algorithms. Figure 2 presents the result images for one of the phantoms. Source codes and the phantom dataset is available at the Midas repository. Figure 2 shows slices of one of the phantoms using the filtered backprojection and the ordered subset reconstruction algorithms.
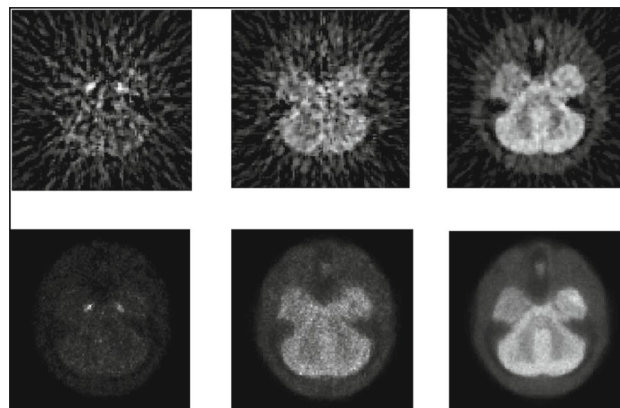

Fig. 2 First and second rows show frame 5, 10 and 16 reconstructed with filtered backprojection and ordered subsets algorithms respectively

Conclusion

The main contribution of this work is the creation of a tool to simplify the generation of dynamic Pet phantoms. The proposed framework considerably reduces the effort needed to set up a phantom generation pipeline, while allowing for relatively complex phantoms. The framework scripts and the dataset of temporal lesions are available for download and can be freely evaluated by the research community. The example brain phantoms were generated for the 18F-FDG tracer but the same pipeline can be adapted for other anatomies and tracers.

Acknowledgements

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