A Demonstration of STIR-GATE-Connection

Robert Twyman*, Ludovica Brusaferri†‡, Elise C. Emond†‡, Francesca Leek*, Simon Arridge§, Brian F. Hutton*, Vesna Cuplov†¶, and Kris Thielemans*

* Institute of Nuclear Medicine, University College London, UK  
† Athinoula A. Martinos Center for Biomedical Imaging, Harvard Medical School, 02129, Boston, MA, US  
‡ Brainlab AG, 81829 Munich, Germany  
§ Department of Computer Science, University College London, UK  
¶ Laboratory of Translational Imaging in Oncology, U1288 Inserm, Institut Curie, University Paris Saclay, Orsay, France

Abstract—We present the first open-source version of STIR-GATE-Connection, a project that aims to provide an easy-to-use pipeline to simulate realistic PET data using GATE, followed by quantitative reconstruction using STIR. Monte Carlo simulations and image reconstruction are powerful research tools for emission tomography that can assist with the design of new medical imaging devices as well as the evaluation of novel image reconstruction algorithms and various correction techniques. STIR-GATE-Connection is a collection of scripts that aid with the: (i) setup of a realistic GATE simulation of a voxelised phantom using a user selected scanner configuration, (ii) conversion of the output list mode data into STIR compatible sinograms, and (iii) computation of additive and multiplicative data corrections for Poisson image reconstruction using STIR. In this work, we demonstrate example usage of these steps. A public release of STIR-GATE-Connection, licensed under the Apache 2.0 License, can be downloaded at: http://www.github.com/UCL/STIR-GATE-Connection.

Index Terms—Monte Carlo simulation, data-correction, image reconstruction

I. INTRODUCTION

Monte Carlo simulations and image reconstruction are powerful tools for the development of: new scanner designs, algorithms for image reconstruction, intrinsic resolution modelling, and partial volume modelling. However, the development of Monte Carlo simulation and reconstruction libraries are often separate, resulting in different standards and conventions. Thus, it is paramount to link these efforts for easier usage.

STIR-GATE-Connection aims to provide a simplified pipeline to progress from Monte Carlo simulation using Geant4 Application for Tomographic Emission (GATE) [1], to quantitative image reconstruction of a known true tracer distribution using Software for Tomographic Image Reconstruction (STIR) [2]. Similar efforts to this work exist, e.g. CaSTOR [3], reconstruction software capable of processing GATE data and SIMPET [4], which uses SimSET [5] as the Monte Carlo software and STIR to reconstruct the data.

In this work, we present a summary of STIR-GATE-Connection, including: GATE setup and simulation, processing output list mode files into STIR compatible sinograms, and the computation of data corrections for image reconstruction.

II. GATE SIMULATIONS

GATE simulations are configured via macro text files. STIR-GATE-Connection incorporates a modular approach with these files, which allows different scanners to be substituted into the GATE configuration. Currently there are two example scanner configurations for simulation of a Positron Emission Tomography (PET) acquisition, the GE Discovery 690 [6] (PET scanner configuration) and the Siemens mMR [7], with an additional crystal in place of the virtual crystal. However, additional scanner configurations can easily be incorporated.

STIR-GATE-Connection provides an example GATE simulation script ExampleSTIR-GATE.sh. This script can either create voxelised phantoms from parameter files or a STIR compatible voxelised phantom may be provided. The GATE simulation is set up using SetupSimulation.sh, which loads the desired scanner geometry and runs the GATE utility to create a density map from the attenuation file. The GATE executable is called and a number of GATE macro variables are computed from the voxelised phantom’s header files, e.g. the origin position, voxel size, and number of voxels. STIR-GATE-Connection also supports the running of GATE in batch array cluster jobs. SetupSimulation.sh must be run prior to launching jobs and each job will perform a GATE simulation on an independent node. Example scripts are provided for Sun Grid Engine.

III. UNLISTING

The GATE simulations output two list mode ROOT [8] files per simulation, one containing coincidence events and the other containing delayed coincidence events. UnlistROOT.sh may be used to process these files into STIR compatible interfile sinograms for the relevant scanner. A demonstration of the alignment between STIR and GATE data can be observed in Fig.1 with the alignment visualised in sinogram space.

The output ROOT data generally contains different event types, i.e. true (two photons detected in the coincidence window that originated from the same emission), scattered (one or more of the photons has undergone Compton scatter prior to detection), and random events (two photons detected in the coincidence window that did not originate from the same emission). This information is only directly ascertainable from simulation and can be useful for testing “correction”
algorithms. The unlisting of each of these types of events can be toggled using STIR-GATE-Connection. Example line profiles through the unlisted sinograms, created by GATE simulation, of an XCAT torso phantom [9] are shown in Fig. 2 (Top).

IV. DATA CORRECTION COMPUTATION

Iterative reconstruction methods incorporate the estimated contributions of both scattered and random events as well as physical and geometric factors of the scanner and attenuation factors into the acquisition model. STIR-GATE-Connection includes an example script of how to compute the normalisation as per component-based normalisation factors with crystal efficiencies and “geometric” effects. Symmetries are imposed on the latter to reduce noise. This is achieved by unlisting only the true coincidence events from a GATE simulation of a uniform cylindrical activity distribution as large as the scanner field-of-view and comparing the resulting sinogram to a STIR forward projection for the scanner using maximum likelihood computation [10]. An example of the normalisation sinogram for the GE Discovery 690 is depicted in Fig.2 (Bottom Left). Furthermore, attenuation correction may be modelled within the system matrix, see Fig.2 (Bottom Right) for the multiplicative correction factors of the XCAT torso.

The additive terms of the acquisition model are estimated using ComputePoissonDataCorrections.sh.

REFERENCES


