GE RDF9 Support in STIR

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GE RDF

- GE Scanner stores the PET raw data in RDF format.
- Depending on the scanner the version of RDF can change.
- For example, GE SIGNA PET/MR scanner stores data in RDF9 format, GE Discovery MI stores data in RDF 9 or 10 and GE Discovery 710 in RDF 8,9 or 10, depending on scanner software version
- STIR version 4.0 has no RDF support whereas release_4 and master branch has RDF9 with hard-wired Signa PET/MR values.
- GERDF9 branch (based on release_4) has generalise RDF9 support to other scanners.

Examples of GE RDF9 files include uncompressed sinogram, normalisation, geometric correction files and so on.

Hierarchical Data Format 5

The actual PET data stored in the GE RDF files can be extracted using HDF5 tools in C++.

HDF5 Introduction

- HDF5 is an open source file format that contains the header and data as a tree structure.
- There are tools that can be used to access the entire data or even subsets of the stored data for further manipulations.

Hierarchical Data Format 5

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HDF5 Data Access and Reading

- To open dataset the address of the data field is given.
- The data space to allocate memory is defined according to the dimensions of the data for read the data intermediately
- Finally the data is read and stored within an output buffer with a defined data space for output.

We have a dedicated class called GEHDF5Wrapper.cxx to access and read the HDF5 files for GE PET emission and correction data.

List of the Files that are Used to Read PET Data

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- Uncompressed Sinogram generally named as 'rdf.1.1'
- Uncompressed Listmode File generally named as 'LIST0000.BLF'
- Output files such as 'norm3d', 'geo3d' and 'wcc3d' files.

Singles per crystal information is extracted from the LIST0000.BLF.
Dead-time information can be extracted from LIST0000.BLF.

Overview of GE Scanner in STIR

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Scanner Parameters are included in Scanner.cxx with a list of scanner information such as:

- List of names for the scanner
- Number of rings
- Number of detectors per ring
- Maximum and Default number of arc-corrected bins
- Inner Ring Radius
- Depth of Interaction
- Ring spacing
- Bin Size
- Intrinsic tilt
- Energy resolution and so on.

This information can be available in various papers published on the Scanner as well as using the header information from the extracted files.

Overview of Incorporating the PET Acquisition Data Within STIR

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Access and Read Data From HDF5

- Access the data using address
- Initialise data space
- Read data
- Store as output

GEHDF5Wrapper.cxx

Calculate the sinograms

Read accurately stored info from HDF5 file and calculate the sinogram

Ex: SingleRates-FromGEHDF5.cxx; BinNormalisation-FromGEHDF5.cxx

Write out the acquisition data in STIR format

Use utilities to write out sinograms for inputs within reconstruction

Ex: ConstructRan-domsFrom GESingles.cxx

Example of Listmode Data Reading

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Listmode File

- Listmode Data is a list of events detected by PET crystals and is stored in RDF9.
- Read the information stored in List mode data using HDF5 functions within GEHDF5Wrapper.cxx
- Read the information that implements encoding of a "record" to crystal/ring/TOF info using classes such as CListModeDataGESigna.cxx
- Finally use utility called lm_to_projdata to get STIR projection data for the input Listmode file or use listmode reconstruction

DATA CORRECTION IN STIR

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Randoms-Correction

- Access and read single rates for each crystal per second within GEHDF5Wrapper.cxx.
- Store these for each time based slice using SingleRatesFromGEHDF5.cxx class.
- Calculate random sinograms within utility such as construct_randoms_from_GEsingles.cxx.

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Normalisation-Correction

- Read norm factors within GEHDF5Wrapper.cxx
- Calculate normalisation correction factors per detector bin as below within BinNormalisationFromGEHDF5.cxx
- Use correct_projdata to calculate STIR norm correction sino or use directly as normalisation object in your reconstruction .par file

Summary of example work-flow

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Emission Data

$$ListModeFile_{HDF5} \xrightarrow{\texttt{lm\_to\_projdata}} EmissionProjData$$

Data Corrections

- Norm File$_{\text{HDF5}}$ $\xrightarrow{\texttt{correct\_projdata}}$ Norm Sinogram
- Singles$_{\text{LMF}}$ $\xrightarrow{\texttt{construct\_randoms\_from\_GEsingles}}$ Randoms Sinogram
- Rotated MRAC Image $\xrightarrow{\texttt{calculate\_attenuation\_coefficients}}$ Attenuation Sinogram
- Scatter Correction: TOF scatter correction not implemented. Scatter correction carried out using Single Scatter Simulation

Example of Sinogram Comparisons

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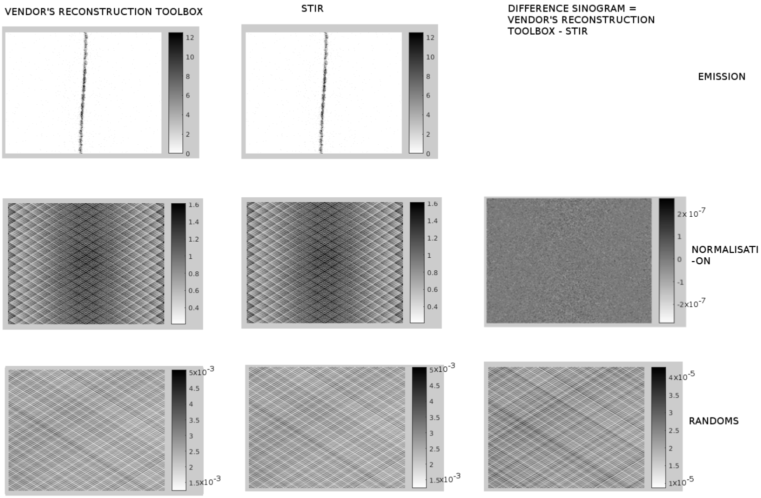

List for GE RDF9 During Hackathon

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Tasks:

- Reading Geometric Factor within BinNormalisationFromGEHDF5.
- Test current implementation of randoms correction
- Upload test raw data from scanner on Zenodo
- Upload emission and norm sinogram converted into STIR interfiles seperately on Zenodo or Github
- Incorporate simple tests to compare number of counts in sinograms, compare with singles array, some basic number comparisons on norm
- Compare the uploaded sinograms with the calculated ones using the code.

Test Data For GE SIGNA PET/MR

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- VQC phantom datasets with descriptions.

This datasets will consist of:
1. Listmode file in HDF5 file format collected at the end of the scan from the scanner console.
2. MR images extracted from the scanner after acquisition. This consists a series of 'MRDC' images acquired using MR sequences.
3. PET reconstructed image: The reconstructions are fully 3D time-of-flight (ToF) iterative reconstructions and images are reconstructed with 28 subsets over 2 full iterations.
4. Raw PET datasets in 'RPDC' format. RPDC files consist of compressed sinogram raw data file (RDF) along with calibration information including normalisation and well counter.

Test Data

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- Extracted Emission and Data Correction Sinograms From Accurate Version of Implementations within STIR to be uploaded as Test Data
- 1 phantom dataset for the Discovery MI in RDF9

Test the Unlister in STIR

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- Creating a test to check the emission sinogram is unlisted accurately with STIR.

Suggested Approach: In order to test the unlister, these steps can be used:

- Unlist the Listmode file in format '.BLF' into STIR sinogram.
  Unlist Listmode Data with STIR → `lm_to_projdata`
  Output STIR sinogram
- Initial test: Comparing the total number of counts
- Compare this sinogram with the one uploaded as test on Zenodo.

Similar tests for randoms and normalisation.