CASToR[1]: A Generic Data Organization and Processing Code Framework for Multi-Modal and Multi-Dimensional Tomographic Reconstruction

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Motivations for an unified tomographic image reconstruction platform

Natural differences in the dataset acquisition / organization …

- Modality (PET / SPECT / CT)
- Purpose (tracer dynamics, gated dataset)
- Data format (list-mode/histogram)

… lead to algorithms optimized for specific applications, with potential drawbacks :

- ➢ Restricted use of methodologies however compatible with other sets of conditions
- ➢ Difference in duplication of implementations
- ➢ Possibly hardly tractable code development

Additional drives for an unified platform:

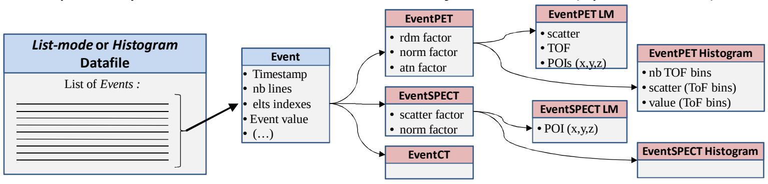
- Analogous components (projector, optimizer, ...) for PET/SPECT/CT tomographic reconstruction
- Re-emergence of iterative reconstruction in CT[2]

Proposed solution

- Unified and generic data organization and processing code framework for multi-modal and multi-dimensional tomographic reconstruction.
- Analogous data organization for list-mode/histogram
- Compromise between genericity and efficiency
- Focus on the modularity and extensibility of the platform

General data file Description

- Generic *Event* structure for all type of data (modality/data mode)
- Reconstruction framework is *Event*-based
- PET/SPECT *Event* can be of “list-mode” type (*i.e.* single detected event) or histogram type (*i.e. content of a histogram bin*).
- *Events* must contain mandatory fields: *timestamp, event value, geo localizer indices* and optionally : *TOF, scatter/random rate, norm factors, etc…* (optional fields)



Implementation

- C++ open-source platform (CASToR[1])
- 3 levels of temporal dimension :
  - Dynamic frames
  - Respiratory gating
  - Cardiac gating

➢ Events loop step equal to the number of subsets (Fig. 1)

➢ Subsets balance respected for both list-mode / histogrammed data.

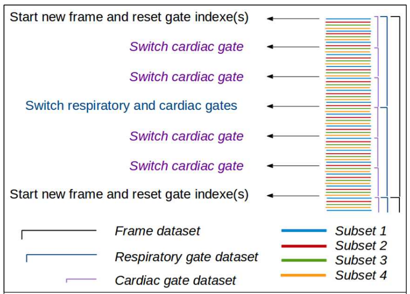


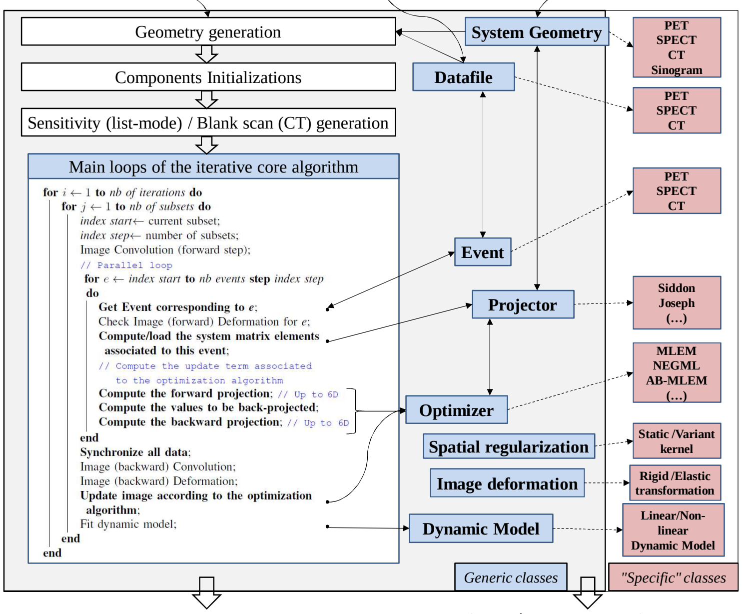
Fig.1 : Organization and processing of a 6D dataset in an OSEM framework

CASToR[1] Iterative framework

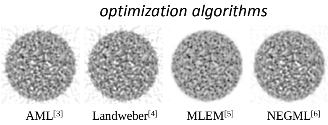
Reconstruction parameters
- Image dimensions
- Number of iterations/subsets
- Selected reconstruction components
- Components configuration parameters/files

PET/SPECT/CT datafile
- Modality
- Mode (histogram/list)
- Number of events
- System name
- Acquisition metadata
- Enabled/Disabled corrections
- Raw data

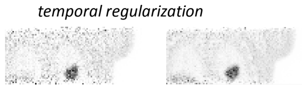
System configuration file
- Modality
- Generic geometry description
  - or -
  Scanner elements geometric cartesian coordinates
- Scanner element dimensions



Ex : Histogram reconstruction using different optimization algorithms



Ex : List-mode 4D reconstruction without (left) and with (right) temporal regularization



➢ Separation of Generic and Specific classes favors limited duplication of implementations

➢ Generic implementation of each reconstruction component allows easy integration of new methodologies

Results

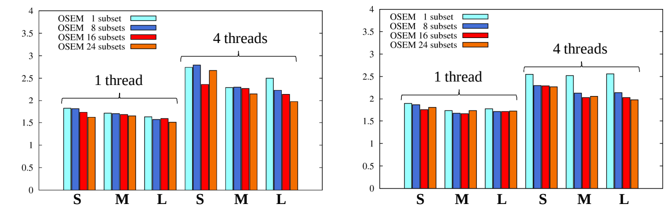


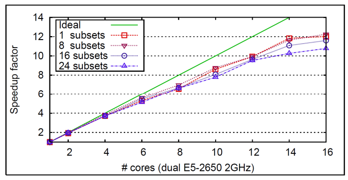
Fig.2 : Speed-up ratio of CASToR OSEM reconstructions compared to standard “2-calls to projector” implementation:

- List-mode (10M prompts) : 88x88x63 (S), 175x175x125 (M), 350x350x250 (L) 4,2,1mm³ voxels

- Histogram (45M events) : 128x128x50 (S), 256x256x100 (M), 512x512x200 (L) 4,2,1mm³ voxels

➢ Improved computational efficiency (ratios from 1.5 to 2.75) due to the separation of the computation of the system matrix elements from the actual projections

Fig.3 : Speed-up factor with respect to the number of threads for a 3D reconstruction



➢ Computing efficiency presented limited dependence on the number of subsets

Conclusions & Perspectives

- ➢ Proposed architecture handles histogram/list-mode multi-modal and multi-dimensional iterative reconstruction
- ➢ Simplified integration of new reconstruction features / methodologies, with limited duplication of implementations
- ➢ Good computing performances in its parallel execution (Unique call to the projector by event allowed a 1.5 to 2.75 increase speedup ratios on the test platform, as well as moderate cost of genericity)
- ➢ Proposed implementation will be soon available through an open-source software[1]

References

[1] http://www.castor-project.org

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[5] **L. A. Shepp and Y.Vardi**, IEEE Trans. Med. Imaging, vol. MI-1, pp. 113–122, 1982.

[6] **Katrien Van Slambrouck and al**. IEEE TMI, Jan 2015, vol. 34, pp. 126-136