OMEGA - Open-source MATLAB Emission Tomography Software

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https://github.com/villekf/OMEGA

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Contents

Motivation

- Need for software to efficiently read and reconstruct data from three different PET devices
- Efficiently read and reconstruct GATE data, including dynamic data
- Software based on MATLAB/Octave
- Several toolkits have CUDA support, but lack OpenCL support
- Easy testing of reconstruction algorithms
- Many parts of OMEGA originate from smaller projects (starting from my M.Sc. work)

Features

- Reconstruct any PET sinogram/raw list-mode data
  - Import NIfTI, Analyze, DICOM or raw format data
- Reconstruction with 10 maximum likelihood algorithms, 7 maximum a posteriori algorithms and 10 priors
  - GPU support for all but 1 prior
- Multi-GPU/device reconstruction with OSEM or MLEM
- All OpenCL reconstructions computed matrix-free
  - Non-OpenCL matrix-free computation possible for selected algorithms (OpenMP)
- Two projectors available
  - Improved version of Siddon's algorithm, with up to 5 rays
  - Orthogonal distance-based ray tracer with either 2D or 3D support

GATE features

- Easily import GATE ASCII, ROOT or LMF data into MATLAB/Octave
- Extract simultaneously prompts, trues, scatter, delays and/or (true) randoms
  - Scatter data can include Compton in phantom and/or detector and/or Rayleigh in phantom and/or detector
  - Form prompt, true, scatter, etc. sinograms
  - Reconstruct trues and/or scatter
- Obtain the true decay image
  - Obtain an image out of the source coordinates output by GATE
- Compute normalization coefficients for simulated GATE machines

Sample code

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%% MACHINE PROPERTIES %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%% R-sectors/blocks in transaxial direction
options.blocks_per_ring = (42);
%%% R-sectors/modules/blocks in axial direction (i.e. number of physical
% machine rings). Multiplying this with the below cryst_per_block should
% equal the number of crystal rings
options.linear_multip = (4);
%%% number of detectors on the side of R-sector/block/module (transaxial
%%% direction)
% (e.g. 13 if 13x13, 20 if 20x10)
options.cryst_per_block = (8);
%%% crystal pitch in x- and y-directions (mm)
options.cr_p = 2.4;
%%% crystal pitch in z-direction (mm)
options.cr_pz = 2.4;
%%% ring diameter (distance between perpendicular detectors) in mm
options.diameter = 130*2;
%%% Transaxial FOV size (mm), this is the length of the x (horizontal) side
% of the FOV
options.FOVa_x = 151;
%%% Transaxial FOV size (mm), this is the length of the y (vertical) side
% of the FOV
options.FOVa_y = options.FOVa_x;
%%% Axial FOV (mm)
options.axial_fov = floor(76.8 - options.cr_pz/10);
```

Sample code

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%% GATE SPECIFIC SETTINGS %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%% Obtain trues (true coincidences)
% If this is set to true then, in addition to the normal coincidences,
% trues are also obtained and saved
options.obtain_trues = true;
%%% Reconstruct the true coincidences
% If this is set to true, then the true coincidences will be used for
% reconstruction
% NOTE: If both this and reconstruct_scatter are set, then the trues are
% reconstructed, but not the scatter.
options.reconstruct_trues = false;
%%% Obtain scattered coincidences
% If this is set to true, then scattered coincidences are saved separately
% These events are not used for scatter correction though, but a separate
% scatter sinogram/raw data matrix will be created.
options.store_scatter = true;
%%% What scatter components are included in the scatter part
% (1 means that component is included, 0 means it is not included in the
% scatter data)
% First: Compton scattering in the phantom, second: Compton scattering in
% the detector, third: Rayleigh scattering in the phantom, fourth: Rayleigh
% scattering in the detector
% If store_scatter is set to true, at least one value has to be 1
% NOTE: LMF will always include only Compton scattering in the phantom,
% regardless of the choice below (as long as scatter is selected)
options.scatter_components = [1 1 1 1];
```

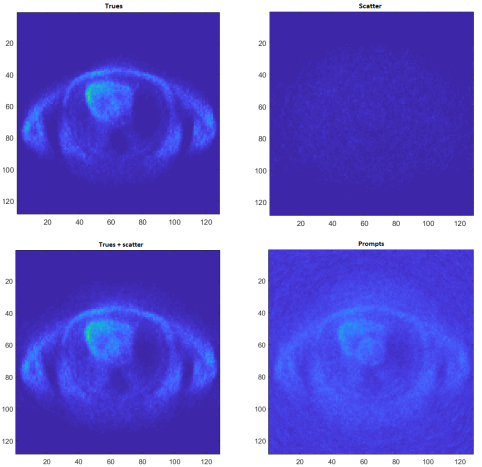
Sample code

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%% ASCII DATA FORMAT SETTINGS %%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%% Is ASCII data used (Only one data type can be used at a time)
options.use_ASCII = true;
% Copy-paste the ASCII coincidence mask used in your macro inside the
% brackets below. If no coincidence mask is used, use an empty array ([]).
options.coincidence_mask = [0 1 0 1 1 1 1 0 0 0 0 1 1 1 1 1 0 0 0 1 0 1 1 1 1 0 0 0 0 1 1 1 1 1 0 0];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

Sample code

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%% SINOGRAM PROPERTIES %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%% Span factor/axial compression
options.span = 3;
%%% Maximum ring difference
options.ring_difference = options.rings - 1;
%%% Number of angular positions (views) in sinogram
% You should primarily use the same number as the device uses
% However, if that information is not available you can use ndist_max
% function to determine potential values (see help ndist_max for usage)
options.Ndist = 200;
%%% Number of angles (tangential positions) in sinogram
% This is the final amount after possible mashing, maximum allowed is the
% number of detectors per ring/2
options.Nang = options.det_per_ring/2;
%%% Specify the amount of sinograms contained on each segment
% (this should total the total number of sinograms)
options.segment_table = [options.Nz, options.Nz - (options.span + 1):-options.span*2:max(options.Nz - options.ring_difference*2, options.span)];
if exist('OCTAVE_VERSION','builtin') == 0 && verLessThan('matlab','8.5')
    options.segment_table = [options.segment_table(1), repeat_elem(options.segment_table(2:end),2,1)];
else
    options.segment_table = [options.segment_table(1), repelem(options.segment_table(2:end),2)];
end
%%% Total number of sinograms
options.TotSinos = sum(options.segment_table);
%%% Number of sinograms used in reconstruction
options.NSinos = options.TotSinos;
```

Visualization example



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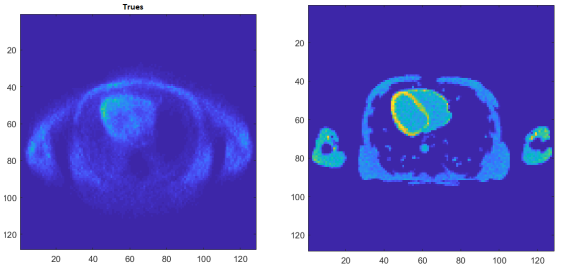

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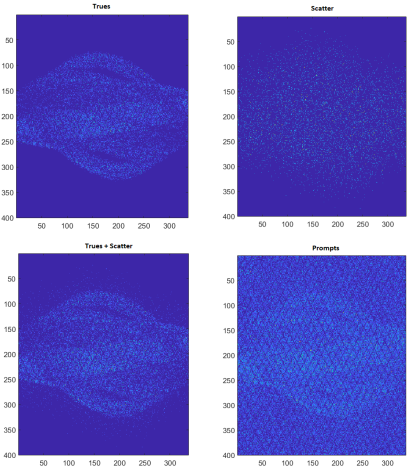
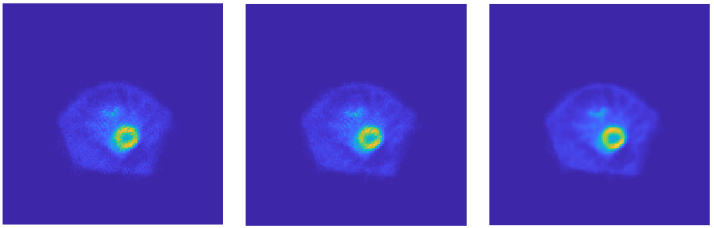


Visualization example



Improved Siddon
1 ray

Improved Siddon
5 rays

Orthogonal distance
based (3D)

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- Easily manipulate the code or any results
  - Simply extract only the GATE data
  - Or form only the sinograms
  - Or test your own reconstruction algorithms with the GATE data sinograms or list-mode data
- Export sinograms/reconstructed images easily into NIfTI, Analyze 7.5, DICOM, Interfile or raw format

Disadvantages

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- No support for GATE submodules

Future

- Support for SPECT data
- TOF support

Thank you!

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CENTRES OF EXCELLENCE IN RESEARCH