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The ASTRA Tomography Toolbox

5 April 2016

Introduction

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Today

- **Introduction to ASTRA**
- Exercises
- More on ASTRA usage
- Exercises
- Extra topics
- Hands-on, questions, discussion

About Me

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Center for Mathematics & Computer Science (CWI), Amsterdam

Lead developer on ASTRA Toolbox

History

- 2007: Toolbox started at U. Antwerp (Vision Lab)
  - Initial goal: reduced implementation work for internal PhD projects
- 2012: First open source release
- 2014: Now developed jointly by CWI and Vision Lab
- Dec 2015: Release 1.7

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What, exactly, is ASTRA?

ASTRA is a modular toolbox for tomographic reconstruction, with a focus on research.

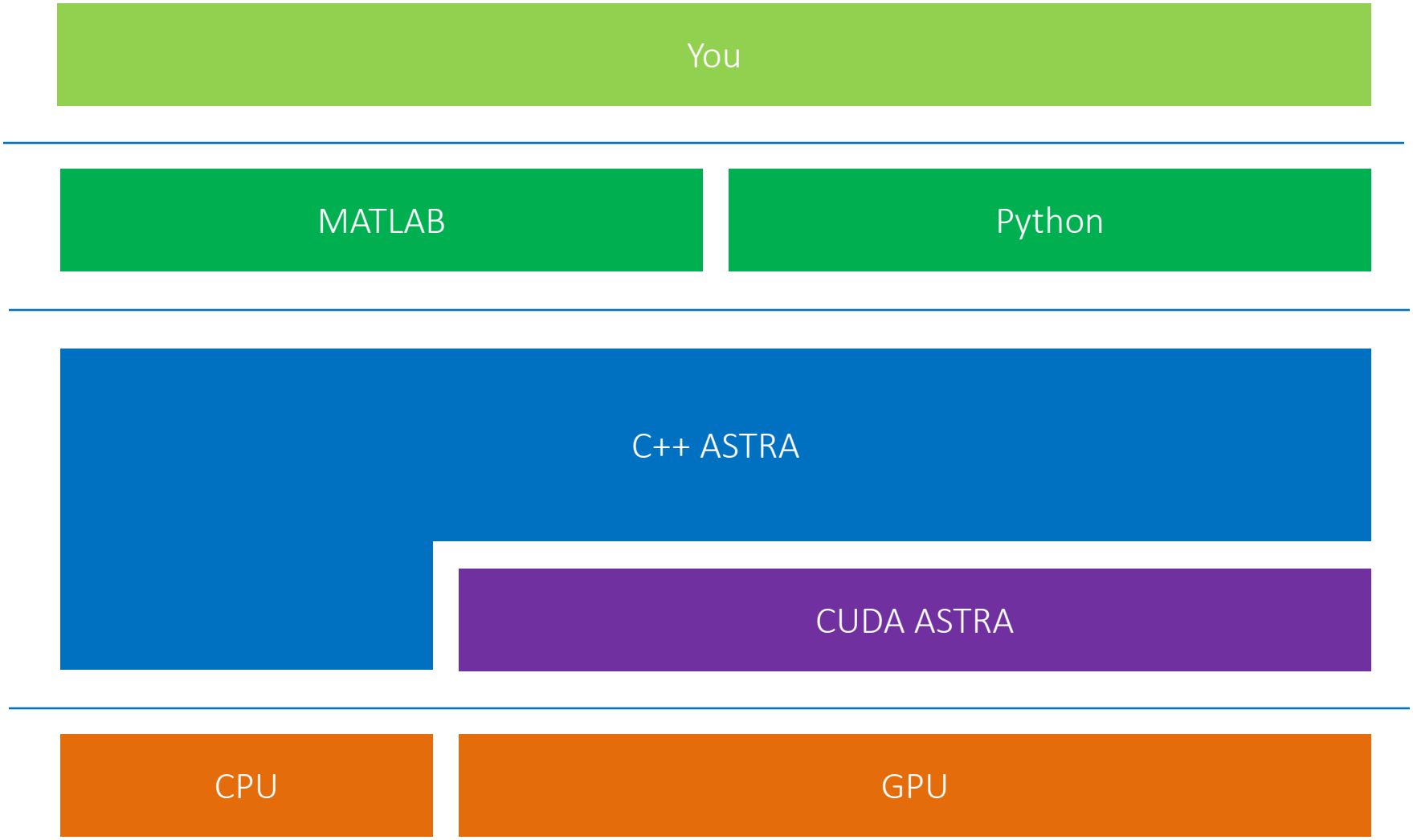
Broad support
algorithms and geometries

Powerful
C++ and CUDA

Easy to use
Interface to Matlab and Python

Flexible
Building block for custom algorithms

Toolbox organization



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Scope of today

ASTRA can be used for:

- 2D tomography using CPU
- 2D tomography using GPU
- 3D tomography using GPU
- All from Matlab and Python

The exercise sessions today will focus on Matlab+2D/CPU, but most topics will generalize readily to 3D and/or GPU usage.

The last lecture today will also explicitly cover 3D and GPU topics.

Toolbox concepts

volume geometry

- volume size
- number of pixels/voxels

options: 2D and 3D

limitation: pixel size should be 1x1, volume centred around origin

---

volume geometry

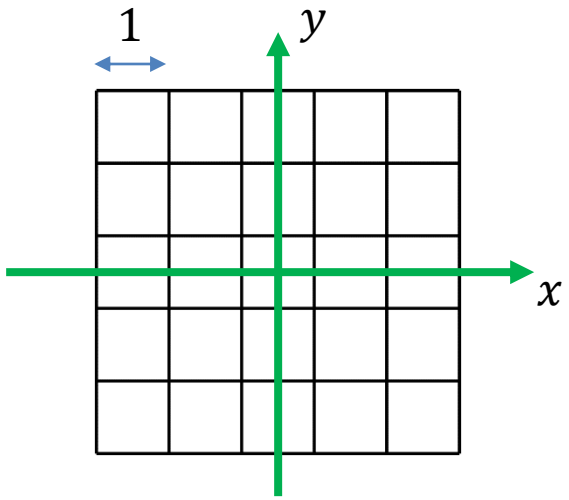
Toolbox concepts

volume geometry (2D)

number of columns (x)

number of rows (y)

```
vol_geom = astra_create_vol_geom(5, 5);
```



volume geometry

Toolbox concepts

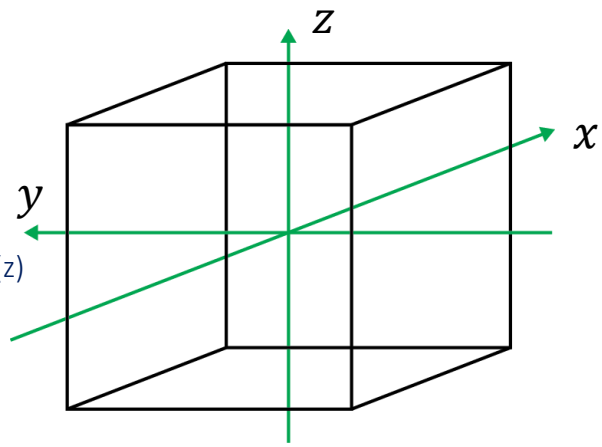
volume geometry (3D)

number of rows (y)

number of columns (x)

number of slices (z)

```
vol_geom = astra_create_vol_geom(5, 5, 5);
```

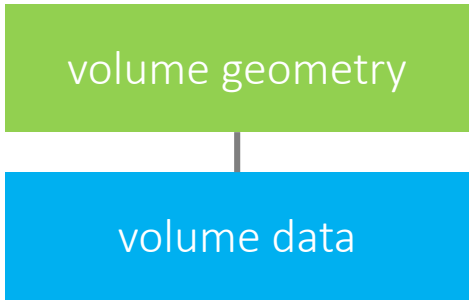


volume geometry

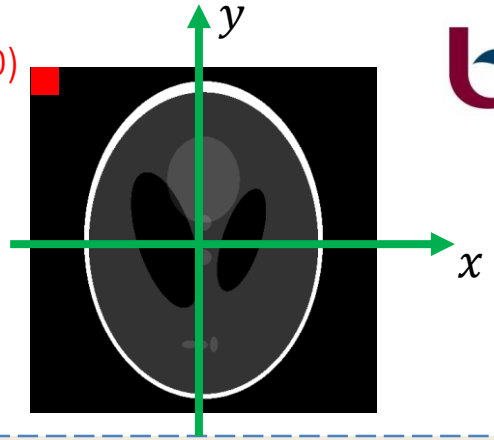
Toolbox concepts

volume data

- place to store data (e.g. reconstruction)
  - In C++: float*
  - In MATLAB/Python: id
- links to volume geometry



Toolbox concepts



row: x-axis

column: inverse y-axis

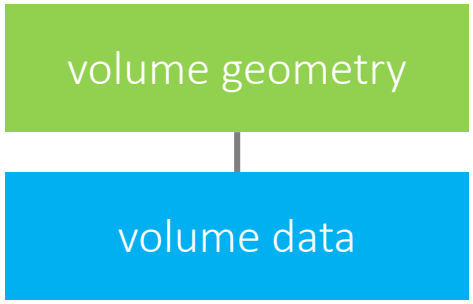
volume data (2D)

```
reconstruction_id = astra_mex_data2d('create', '-vol', vol_geom);
reconstruction_id = astra_mex_data2d('create', '-vol', vol_geom, 0);
reconstruction_id = astra_mex_data2d('create', '-vol', vol_geom, V);
```

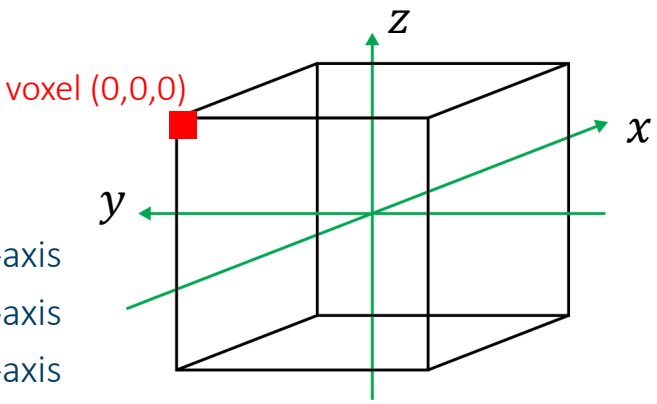
```
astra_mex_data2d('store', reconstruction_id , 0);
astra_mex_data2d('store', reconstruction_id , V);
```

```
reconstruction = astra_mex_data2d('get', reconstruction_id );
```

```
astra_mex_data2d('delete', reconstruction_id);
```



Toolbox concepts



row: x-axis

column: inverse y-axis

Slice: inverse z-axis

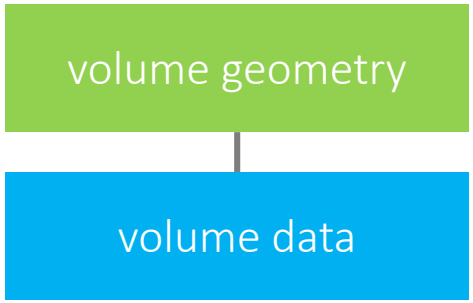
volume data (3D)

```
reconstruction_id = astra_mex_data3d('create', '-vol', vol_geom);
reconstruction_id = astra_mex_data3d('create', '-vol', vol_geom, 0);
reconstruction_id = astra_mex_data3d('create', '-vol', vol_geom, V);
```

```
astra_mex_data3d('store', reconstruction_id , 0);
astra_mex_data3d('store', reconstruction_id , V);
```

```
reconstruction = astra_mex_data3d('get', reconstruction_id );
```

```
astra_mex_data3d('delete', reconstruction_id);
```



Toolbox concepts

projection geometry

- trajectory of source and detector plane
- number of detectors
- detector size

options: 2D: parallel-beam, fan-beam; 3D: parallel-beam, cone-beam; vector based geometries

limitations: detectors must be square and central detector must cast ray through origin

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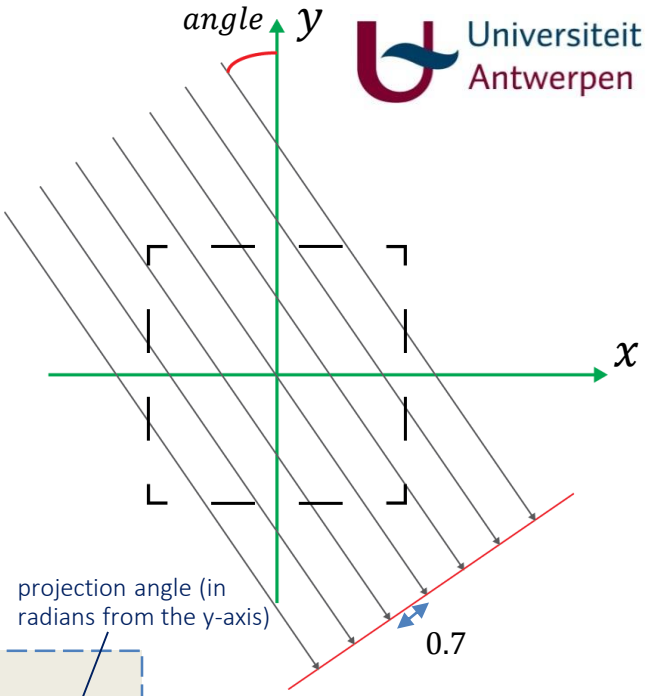
projection geometry

volume geometry

volume data

Toolbox concepts

projection geometry (2D parallel)



detector width

detector count (per projection)

projection angle (in radians from the y-axis)

```
angles = linspace2(0,pi,180);
proj_geom = astra_create_proj_geom('parallel', 0.7, 7, angles);
```

projection geometry

volume geometry

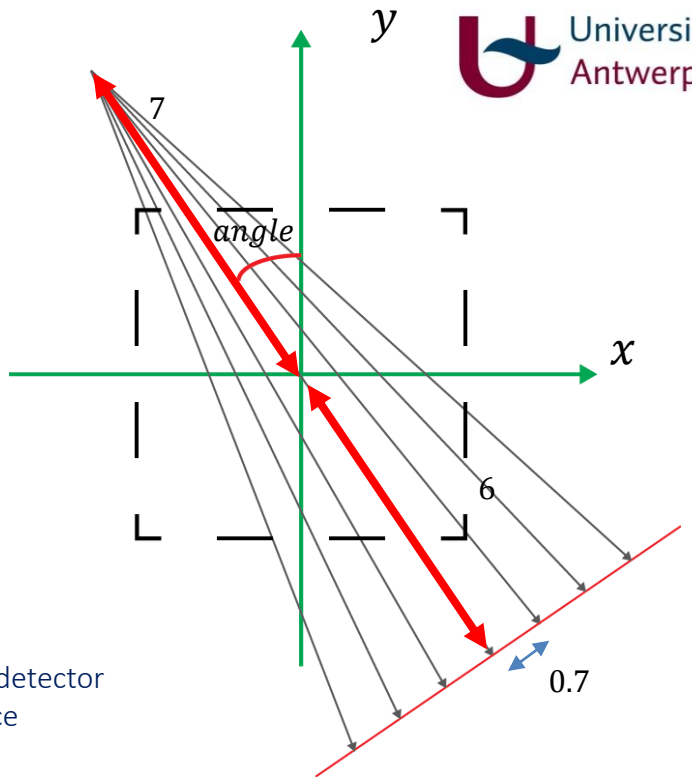
volume data

Toolbox concepts

projection geometry (2D fan-beam)

```
angles = linspace2(0,pi,180);
proj_geom = astra_create_proj_geom(
  'fanflat', 0.7, 7, angles, 7, 6);
```

- detector width
- detector count (per projection)
- projection angle (in radians from the y-axis)
- source-origin distance
- origin-detector distance



projection geometry

volume geometry

volume data

Toolbox concepts

projection geometry (3D cone-beam)

```
angles = linspace2(0,pi,180);
proj_geom = astra_create_proj_geom('cone', 0.7, 0.7, 7, 7, angles, 7, 6);
```

detector width

detector height

projection angle (in radians from the y-axis)

origin-detector distance

detector row count (per projection)

detector col count (per projection)

source-origin distance

---

projection geometry

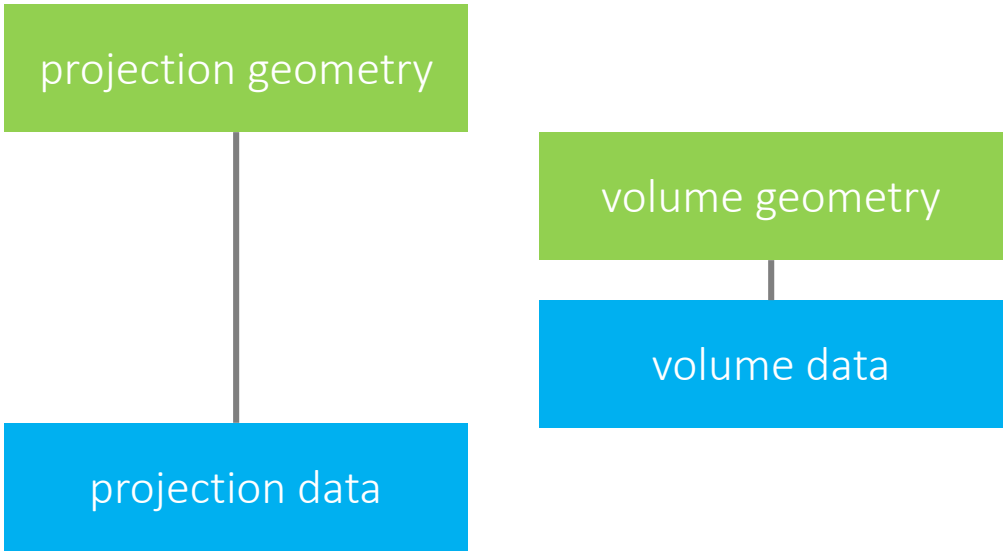
volume geometry

volume data

Toolbox concepts

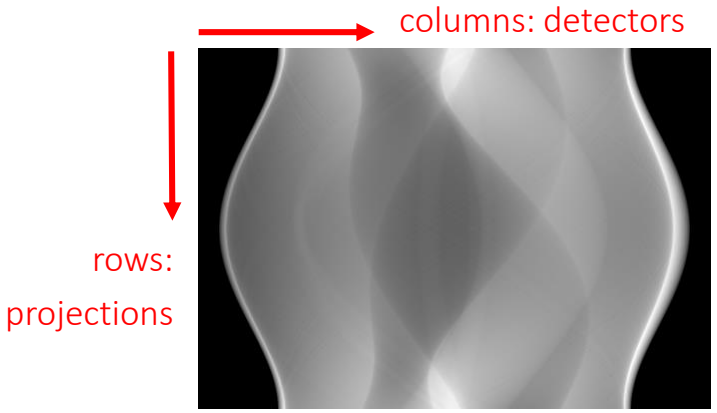
projection data

- place to store projection (e.g. sinogram)
  - similar to volume data
- links to projection geometry

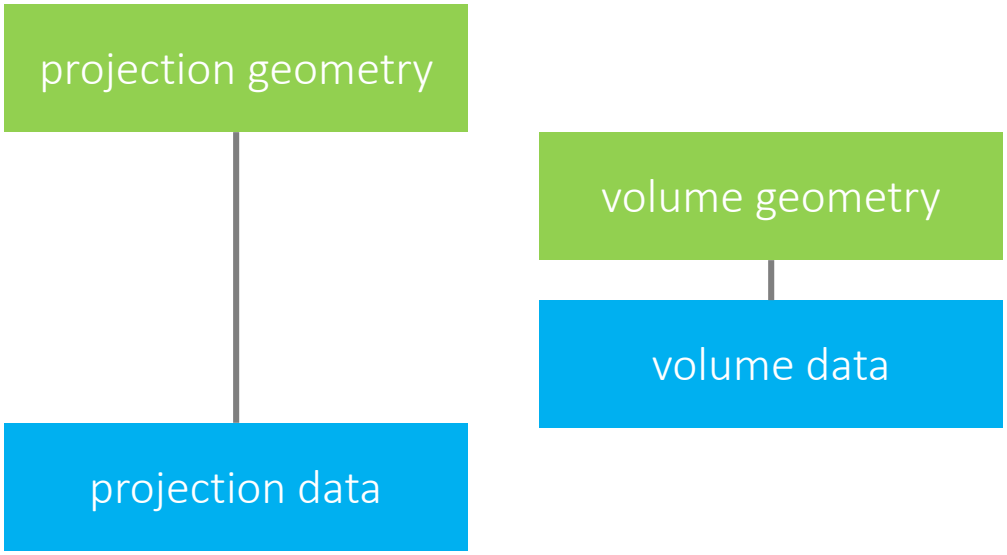


Toolbox concepts

projection data (2D)

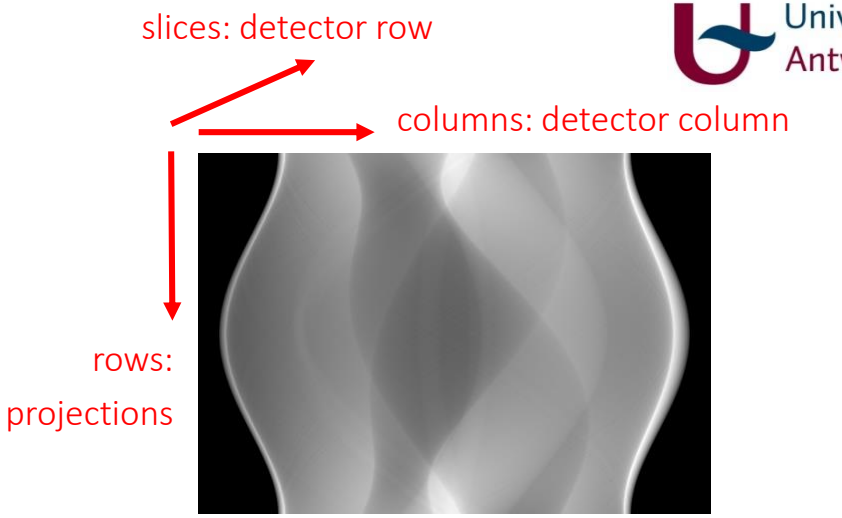



```
projection_id = astra_mex_data2d('create', '-sino', proj_geom);
projection_id = astra_mex_data2d('create', '-sino', proj_geom, 0);
projection_id = astra_mex_data2d('create', '-sino', proj_geom, V);
```

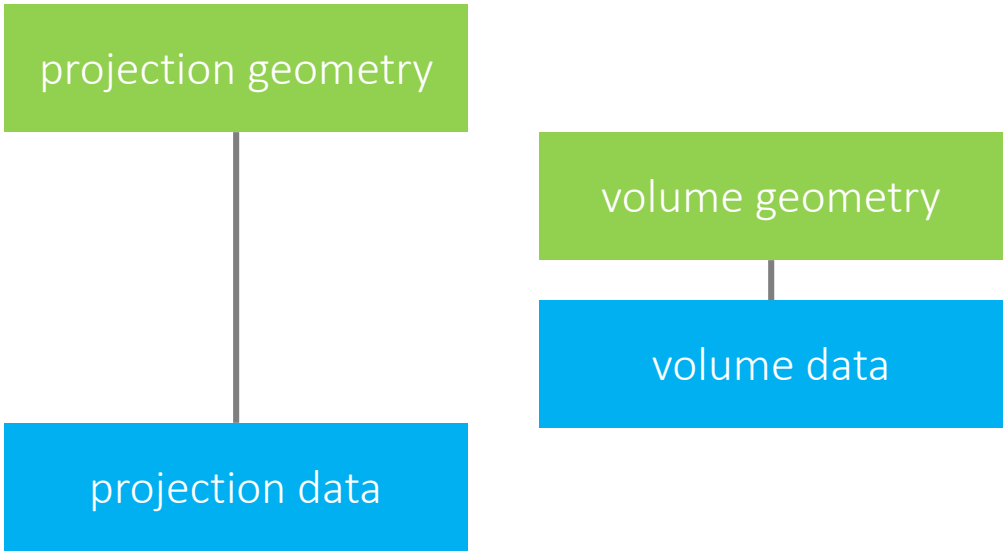


Toolbox concepts

projection data (3D)



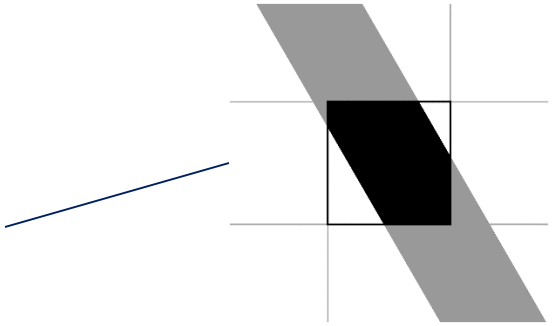

```
projection_id = astra_mex_data3d('create', '-sino', proj_geom);
projection_id = astra_mex_data3d('create', '-sino', proj_geom, 0);
projection_id = astra_mex_data3d('create', '-sino', proj_geom, V);
```



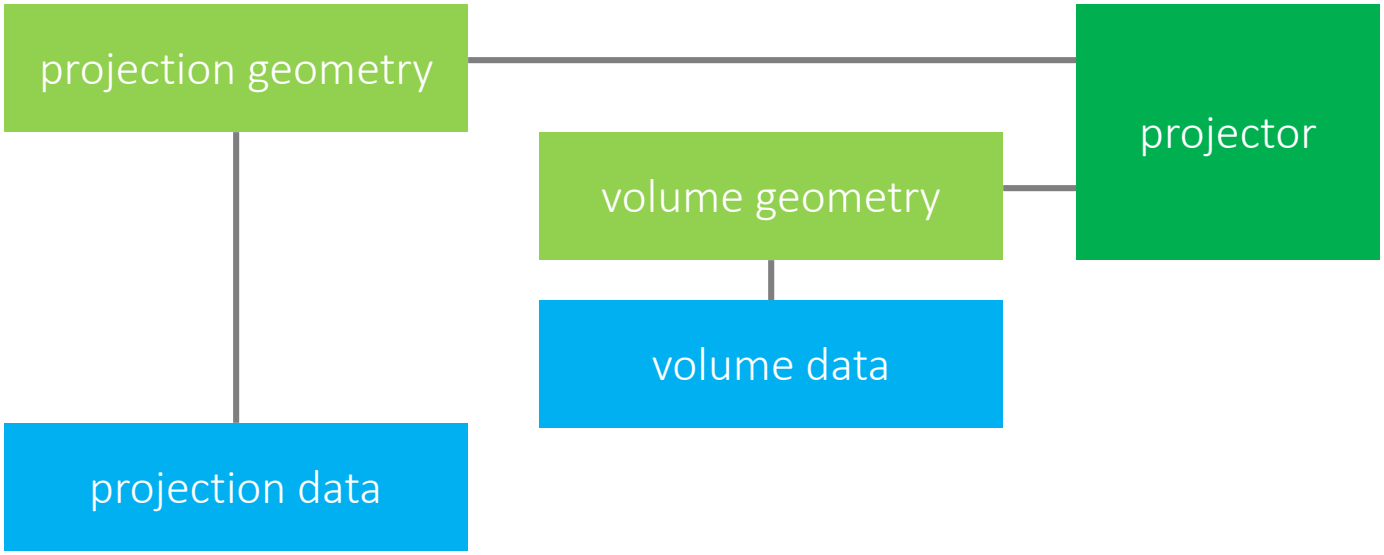
Toolbox concepts

Projector

- links volume geometry to projection geometry
- only for CPU algorithms
- in matlab/python: stored by id



options 2D parallel-beam: line, josephs kernel ('linear'), strip
2D fan-beam: line, strip
3D cone-beam: josephs kernel ('linear')

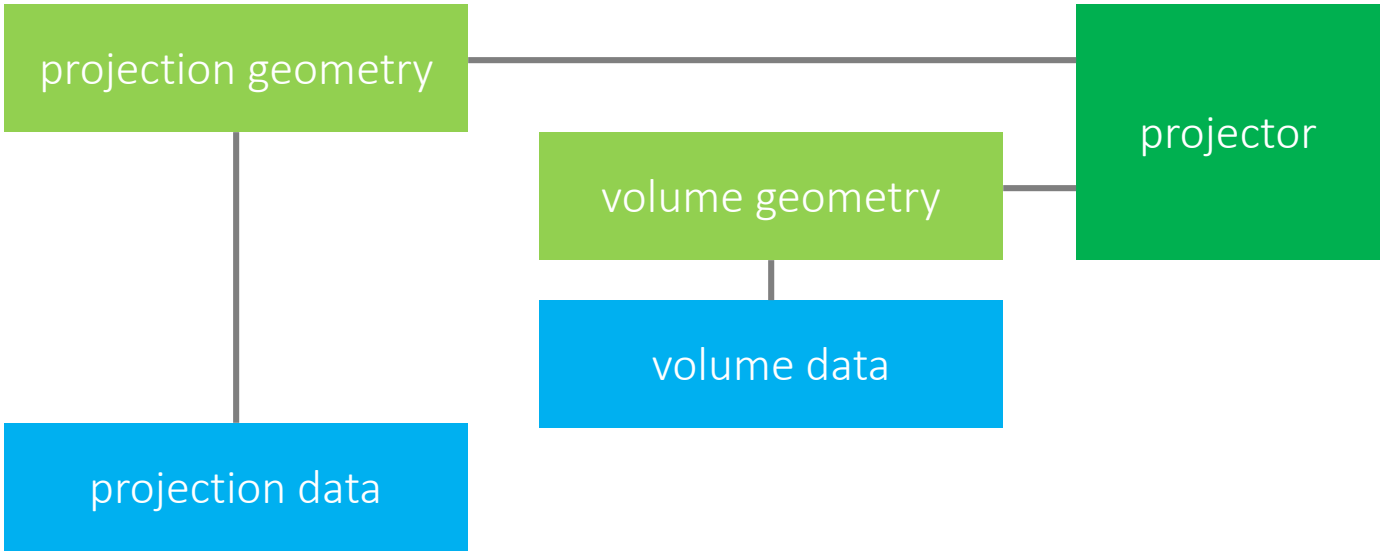


Toolbox concepts

Projector

```
projector_id = astra_create_projector('strip', proj_geom, vol_geom);
```

```
astra_mex_projector('delete', projector_id );
```



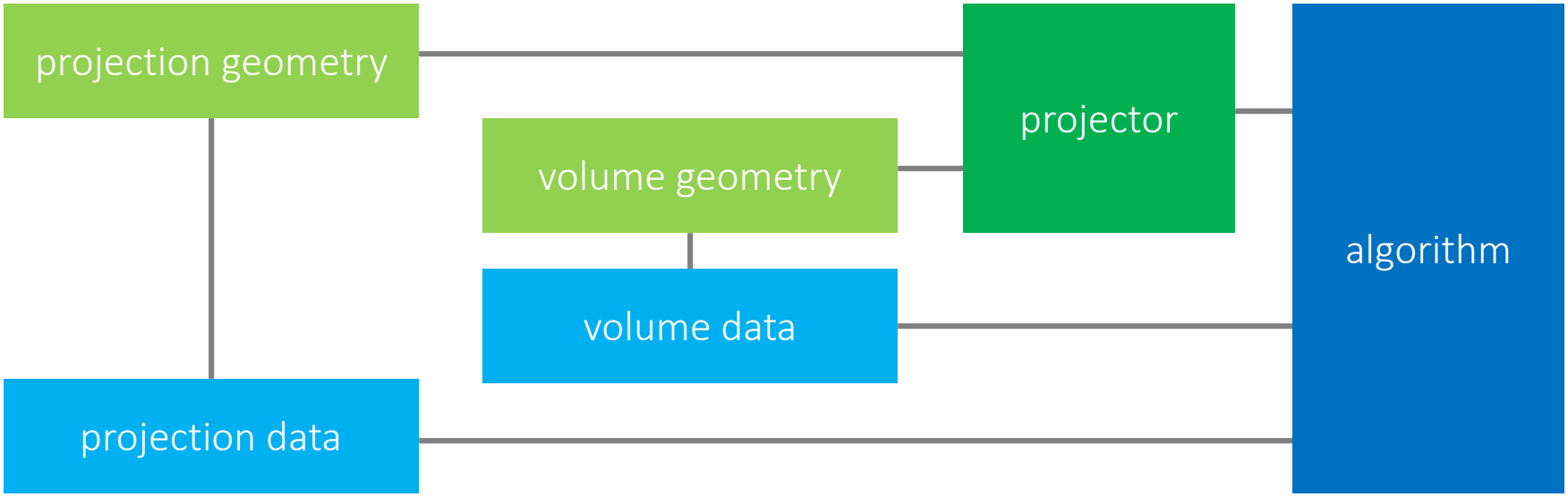
Toolbox concepts

Algorithm

- Where the computations happen
- Configured with matlab structs / python dicts
- Stored by id

Options, CPU: FBP, ART, SART, SIRT, CGLS, FP, BP

GPU: FBP, FDK, SIRT, CGLS, FP, BP



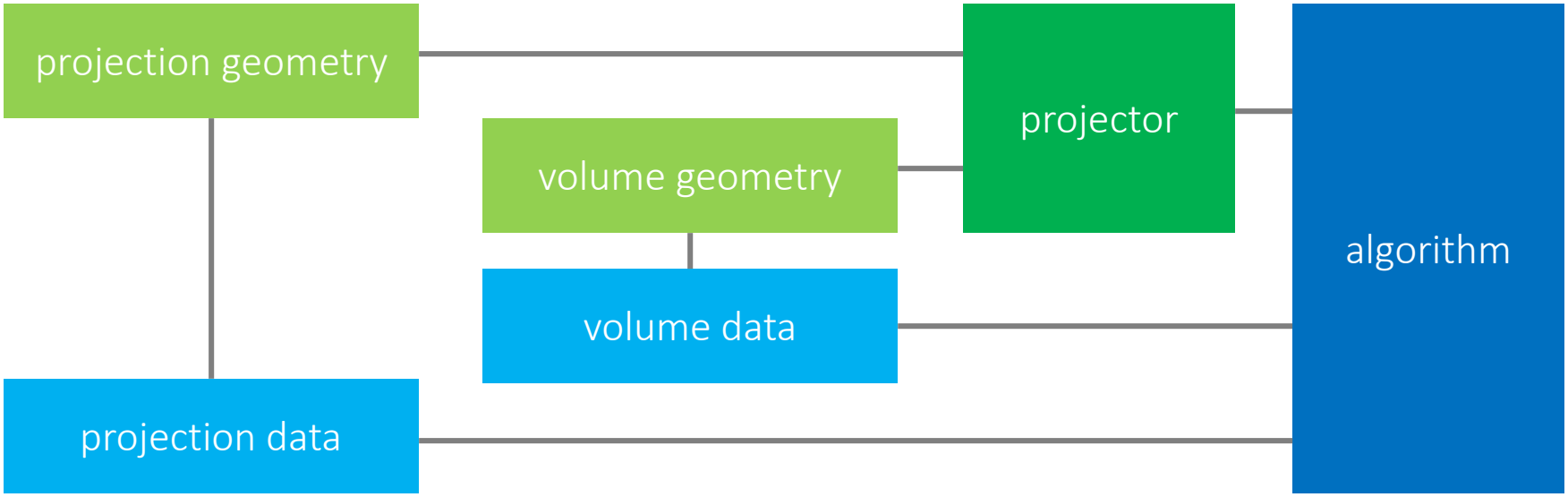
Toolbox concepts

Algorithm (CPU)

```
cfg = astra_struct('SIRT');
cfg.ProjectionDataId = projection_id;
cfg.ReconstructionDataId = reconstruction_id;
cfg.ProjectorId = projector_id;
alg_id = astra_mex_algorithm('create', cfg);
```

```
astra_mex_algorithm('iterate', alg_id, 50);
```

```
astra_mex_algorithm('delete', alg_id);
```



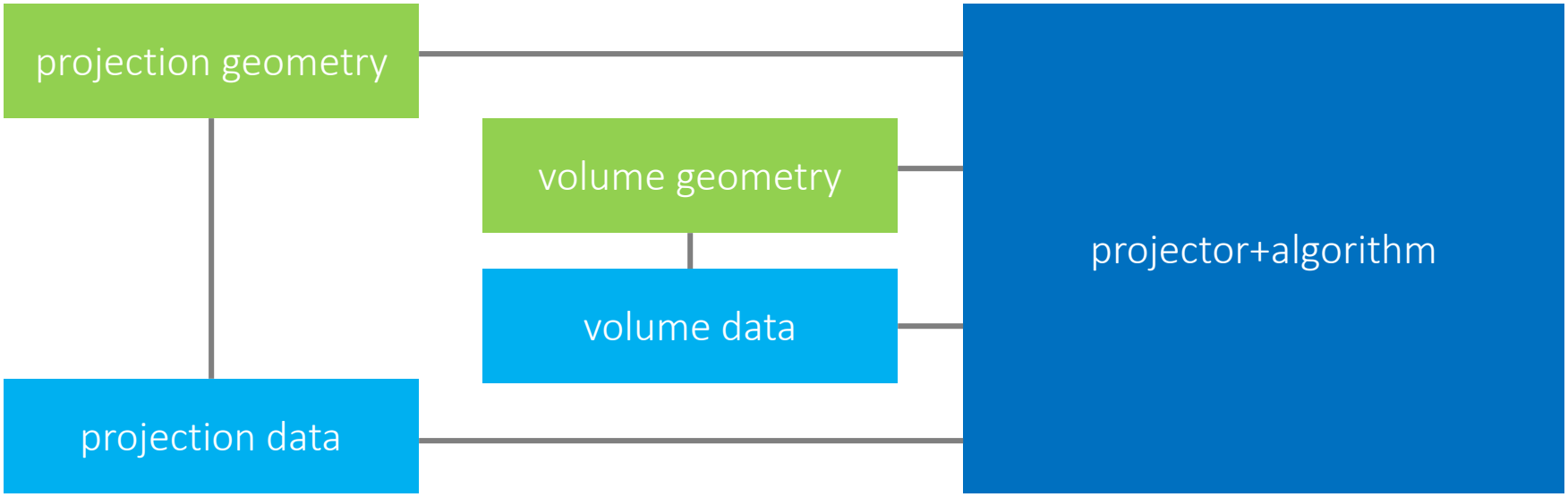
Toolbox concepts

Algorithm (GPU)

```
cfg = astra_struct('SIRT_CUDA');
cfg.ProjectionDataId = projection_id;
cfg.ReconstructionDataId = reconstruction_id;
alg_id = astra_mex_algorithm('create', cfg);
```

```
astra_mex_algorithm('iterate', alg_id, 50);
```

```
astra_mex_algorithm('delete', alg_id);
```



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Intermediate results

With most iterative algorithms, it is possible to continue iterating after a set of iterations.

```
for i = 1:10
    astra_mex_algorithm('iterate', alg_id, 10);
    r = astra_mex_data2d('get', rec_id);
    % (process or display r)
end
```

Note: with CGLS the output will be different than doing 100 iterations at once, since that resets with each run. For SART, SIRT the output will be the same.

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Tools of the toolbox

- Create a forward projection

```
[fp_id, fp] = astra_create_sino(volume, projector_id);
```

- Create a backprojection

```
[bp_id, bp] = astra_create_backprojection(fp, projector_id);
```

- Delete all astra objects

```
astra_clear;
```

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More information

Where to find information?

- These slides (see workshop webpage for PDF)
- Docs: http://www.astra-toolbox.com/
- Samples: <astra_root>/samples/

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Today

- Introduction to ASTRA
- **Exercises (see workshop webpage for PDF, part 1)**
- More on ASTRA usage
- Exercises
- Extra topics
- Hands-on, questions, discussion

Practical issues

For the exercises, you need:

- Either, have ASTRA installed in Matlab on your laptop.
  Later today, you'll also need SPOT:
  http://www.cs.ubc.ca/labs/scl/spot

- Or, use thinlinc to access the DTU server.
  Start Matlab using Applications->DTU->Mathematics->ASTRA
  Add ASTRA to your matlab path:

```
addpath('/appl/astra/1.7.1beta/matlab/mex');
addpath('/appl/astra/1.7.1beta/matlab/tools');
```

  Samples are in /appl/astra/1.7.1beta/samples/matlab