Fully Bayesian Image Estimation Software for GATE Simulations

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What?

We have developed a **simple** and useful **tool** to **reconstruct images** from the output **ROOT files** of Monte Carlo simulations of PET acquisitions obtained with **GATE.**

1) PET Scanner Model
2) Phantom
   - Material Distribution
   - Source Activity Distribution
3) GATE Simulation
4) Image Reconstruction

Why?

- ROOT files need post-processing to convert them into the appropriate formats required by the available open-source reconstruction codes (e.g. STIR):
  - Generation of sinograms
  - Sinogram Rebinning / Mashing
  - Normalization
- Significant amount of knowledge about PET data processing and tomographic image reconstruction required.
- A simple reconstruction tool for GATE is needed.

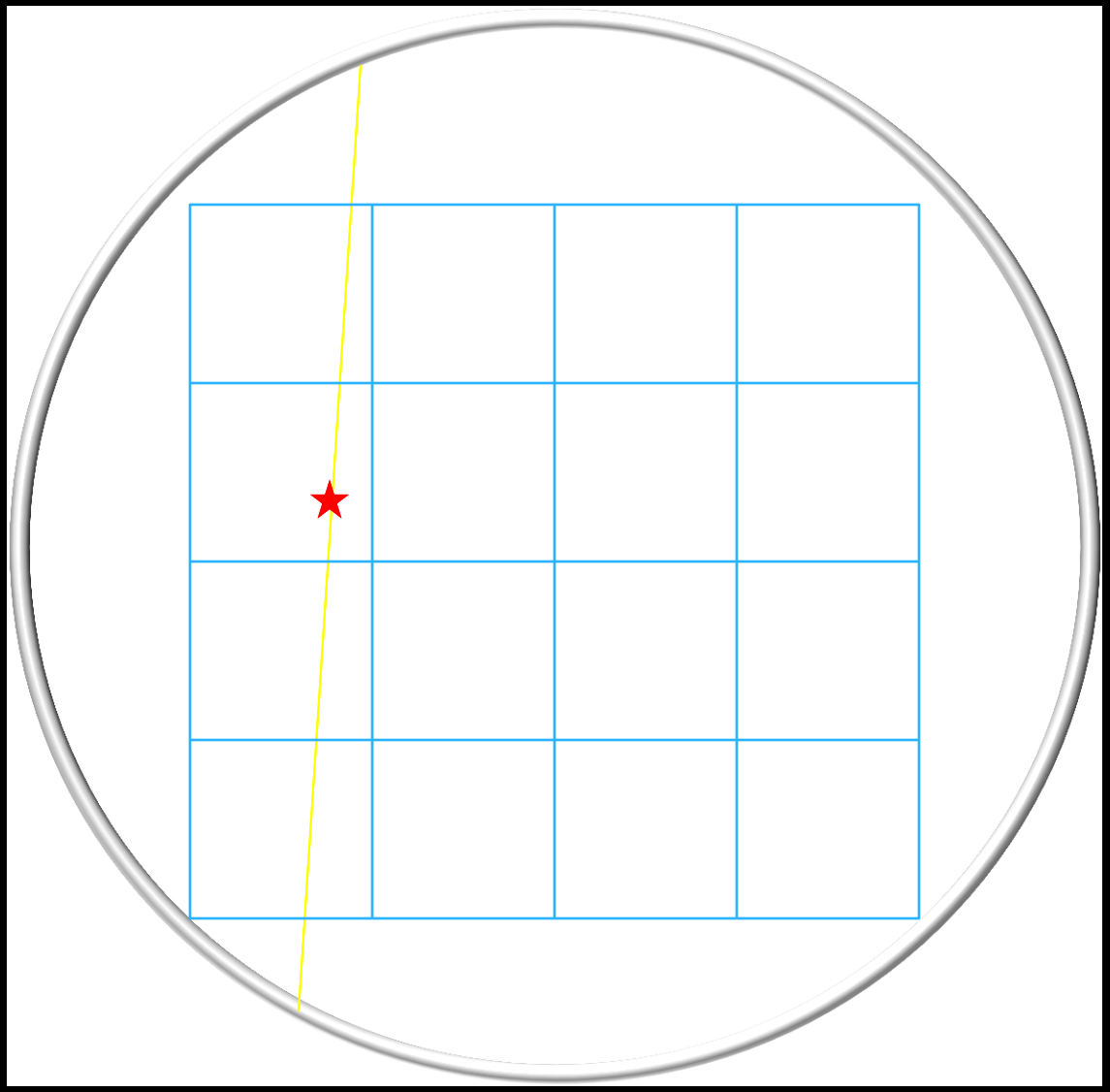
How? (I)

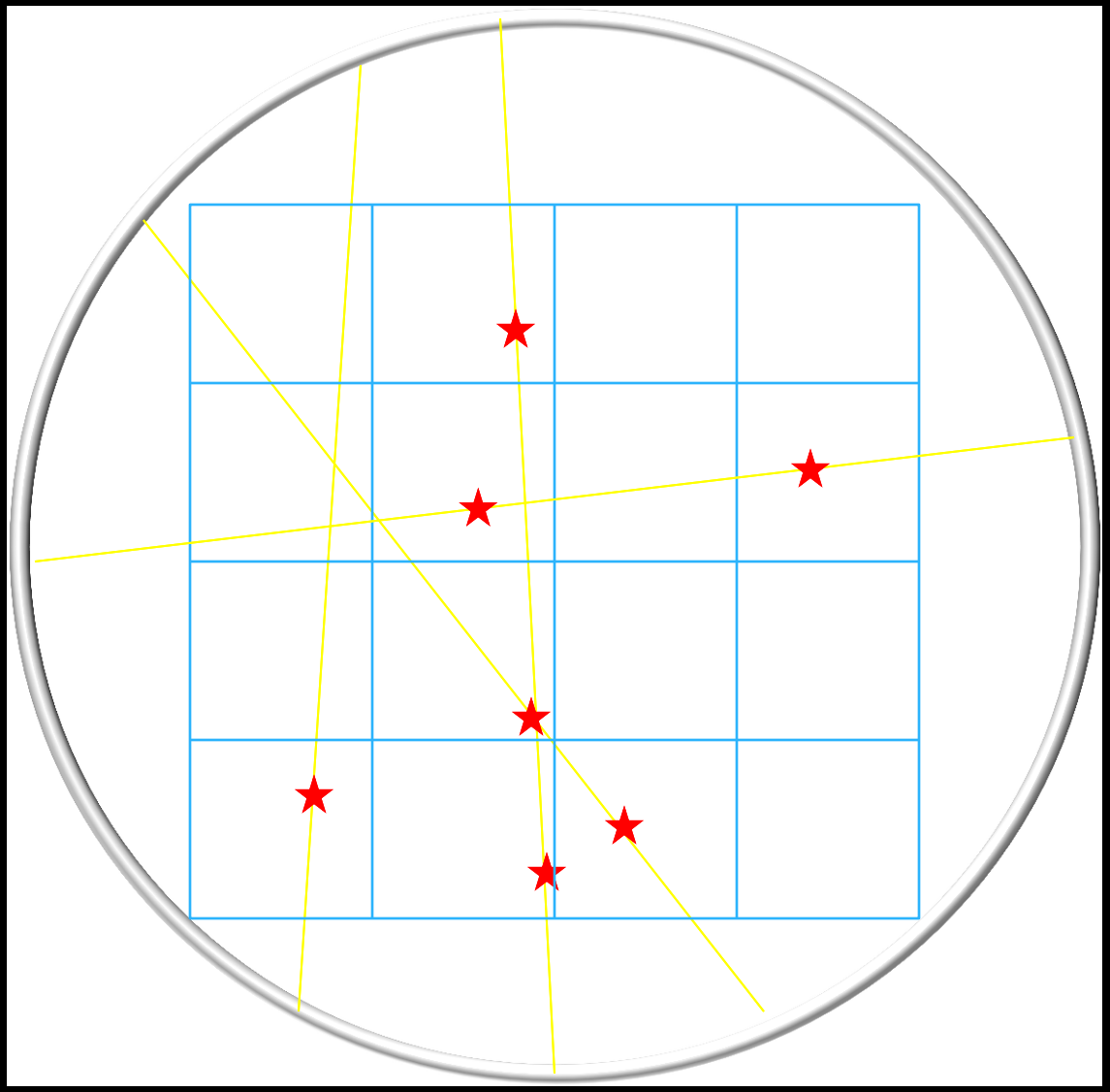
Fully Bayesian Image 3D Estimation (FBI3D) implements the Origin Ensemble (OE) algorithm, proposed by A. Sitek.

A. Sitek - Phys. Med. Biol. 53, 3201-3216 (2008)
A. Sitek - Phys. Med. Biol. 57 (21), 6779 (2012)

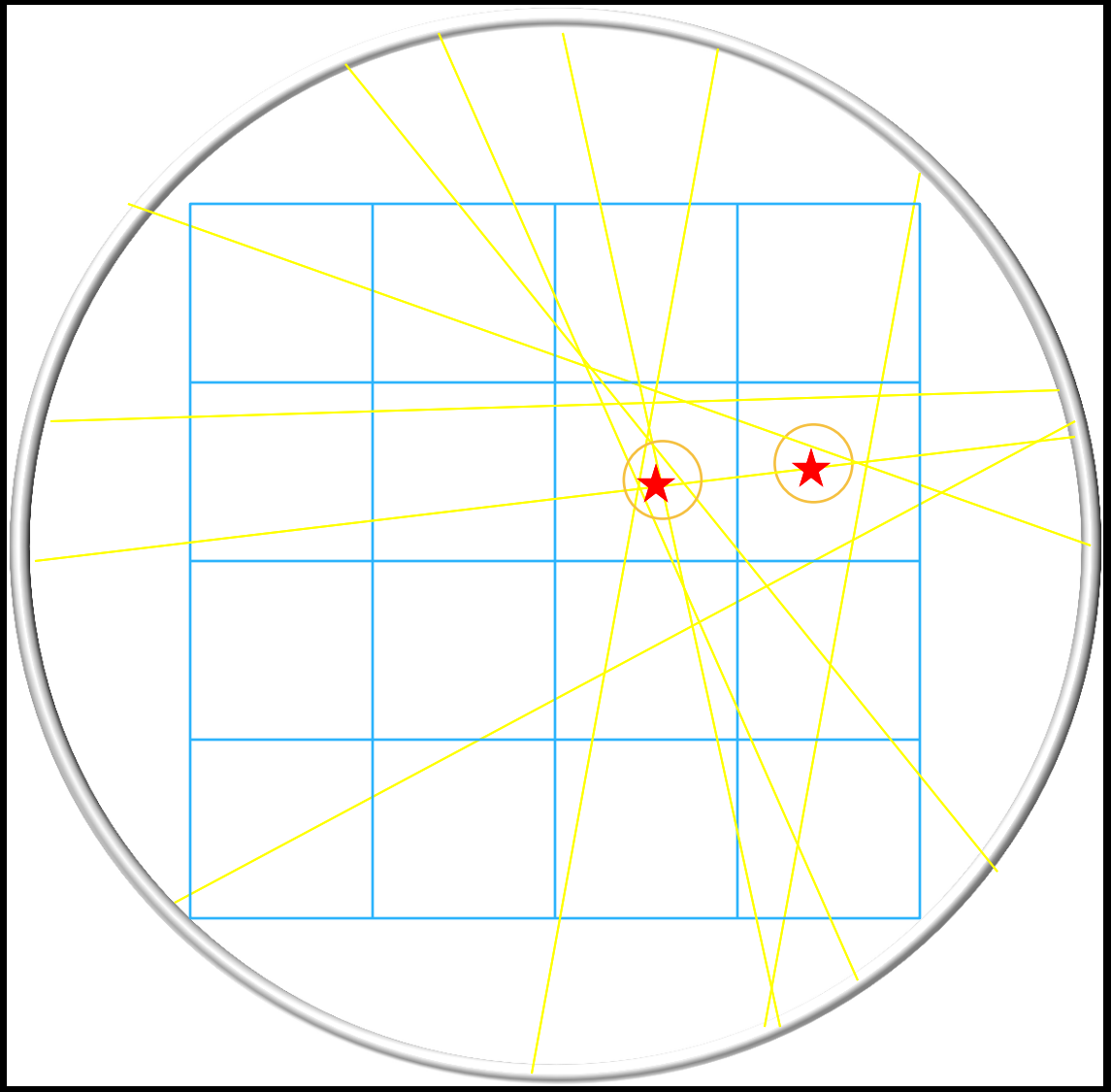
This algorithm iteratively locate each detected count in its most likely position along the LOR based on the information obtained from the other coincidences.

It is simple and provides not only an estimated image, but also information about its uncertainty.

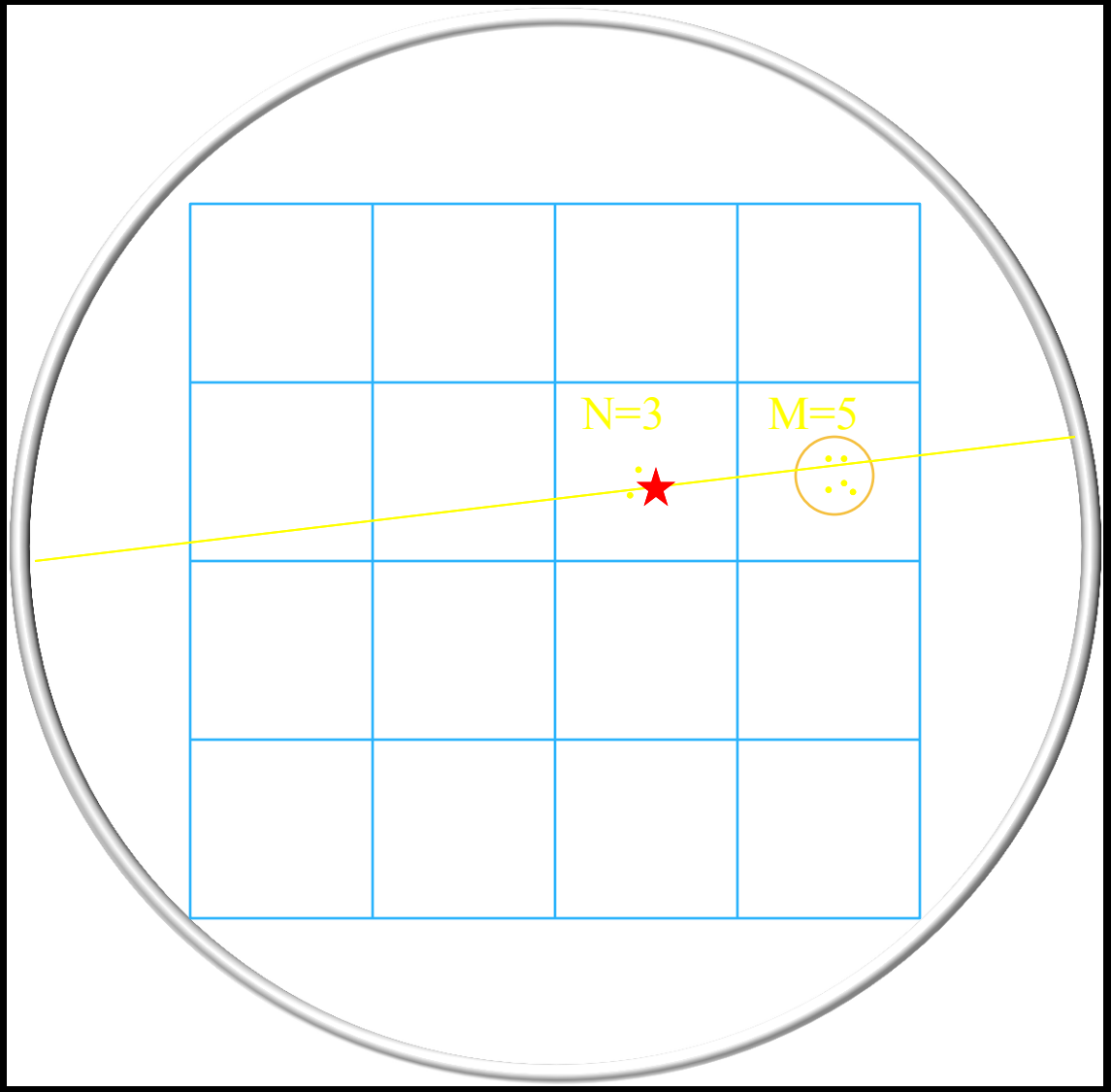




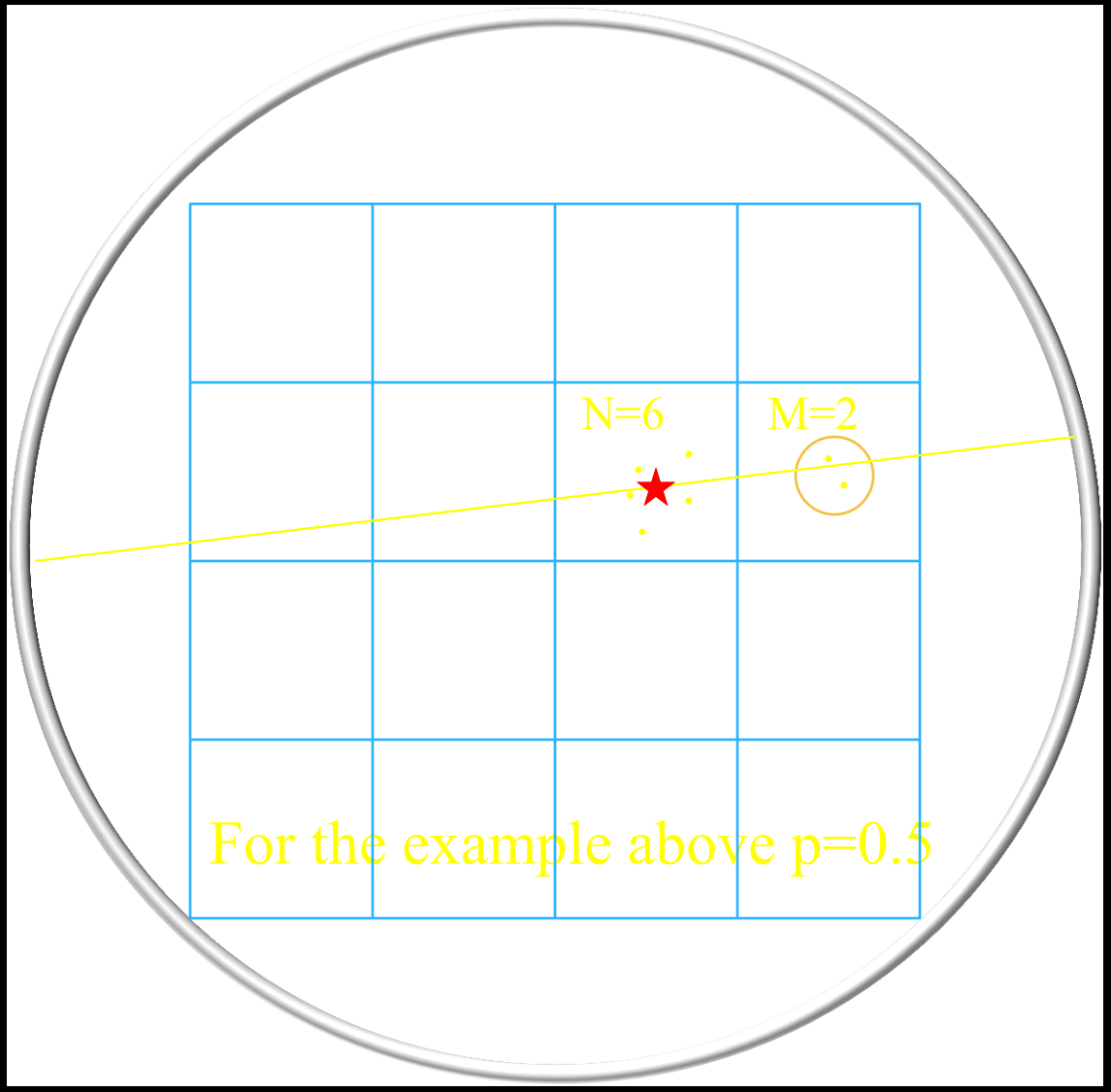
To move or not to move…



Rules of “traffic”



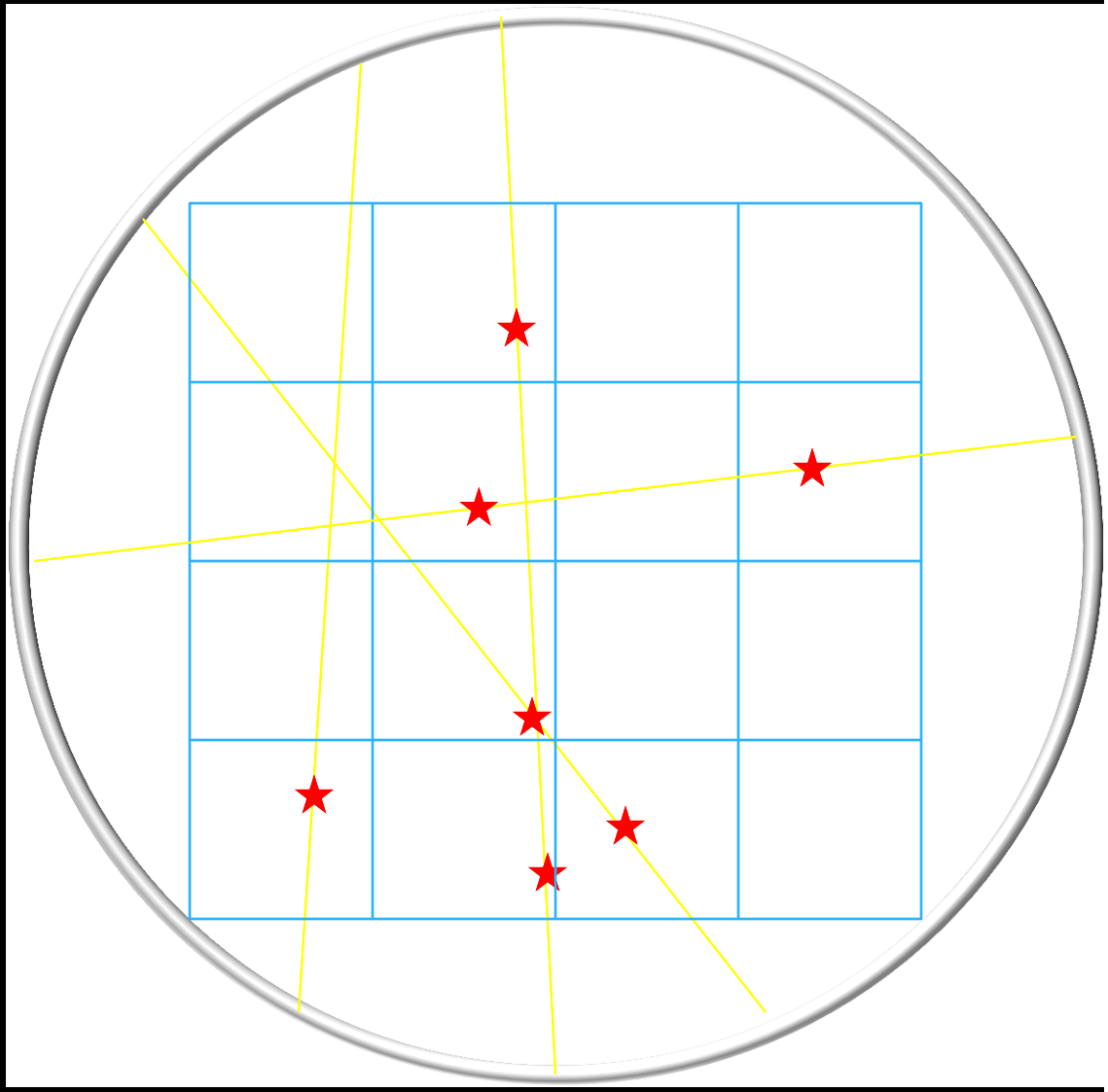
Rules of “traffic”



1. Put origin of each event at random location in ROR
2. Randomly select an origin and chose a new location for it
3. Accept/Reject new location depending on (M+1)/N ratio
4. Go to 2.

Looks like a heuristic
and naïve algorithm

Simplicity is overwhelming …



How? (II)

It contains a set of simple functions:

1) Read ROOT file
2) Place initially each Coincidence in a voxel
3) Reallocate Coincidences iteratively
   (Along their LOR based on probabilistic rules)
4) Final image corrected by sensitivity

How? (III)

FBI3D code is written in C++

It can be executed within the ROOT CINT interpreter, or compiled and executed as a standalone tool.

```
root

root [0]  .x FBI3D.C+("file.root", "norm.root")
```

```
g++ -w -Wl,--no-as-needed FBI3D.C -o FBI3D.x `root-config --cflags --glibs`

./FBI3D.x  file.root  norm.root
```

where root-config is a small utility in $ROOTSYS/bin that knows the right compiler/linker sequence for your machine.

When?

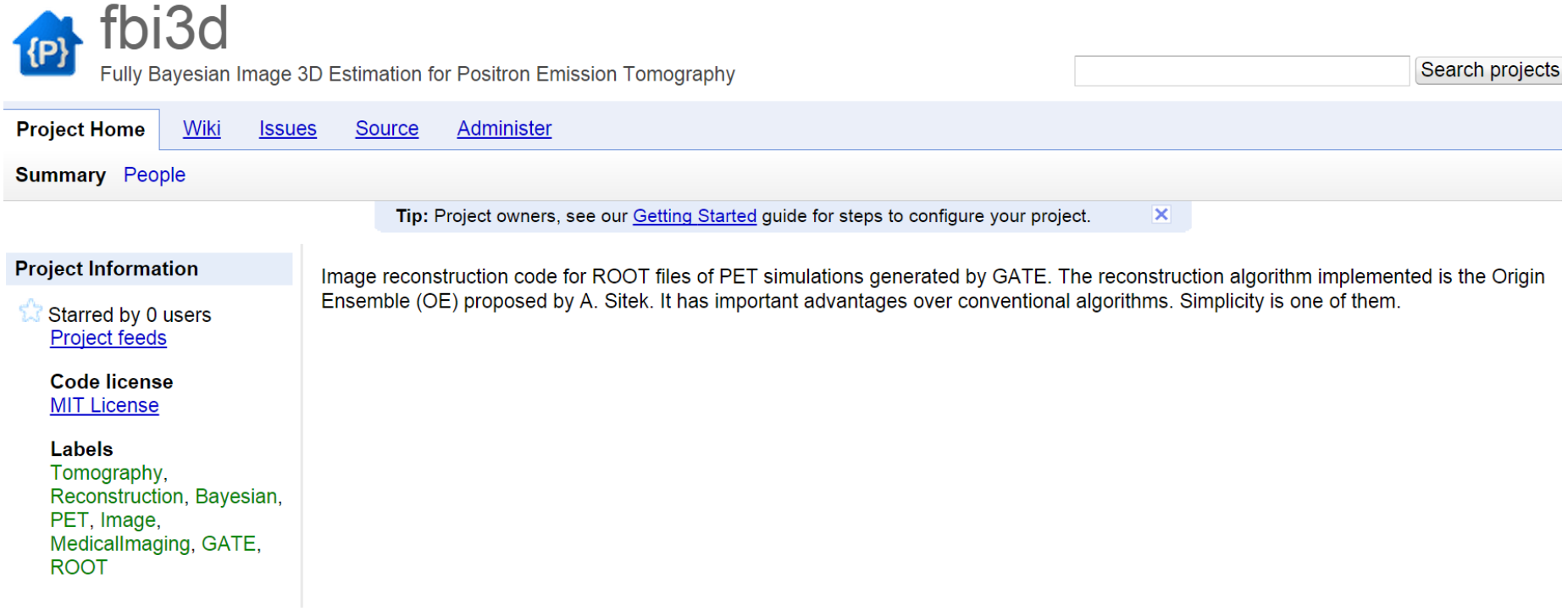
- FBI3D currently has only a basic set of features but it will be expanded in the future:
  - Attenuation and scatter corrections
  - Speed-up of the code based on a parallelization of the algorithm.

- It can be easily adapted to incorporate customizable tools.

Who?

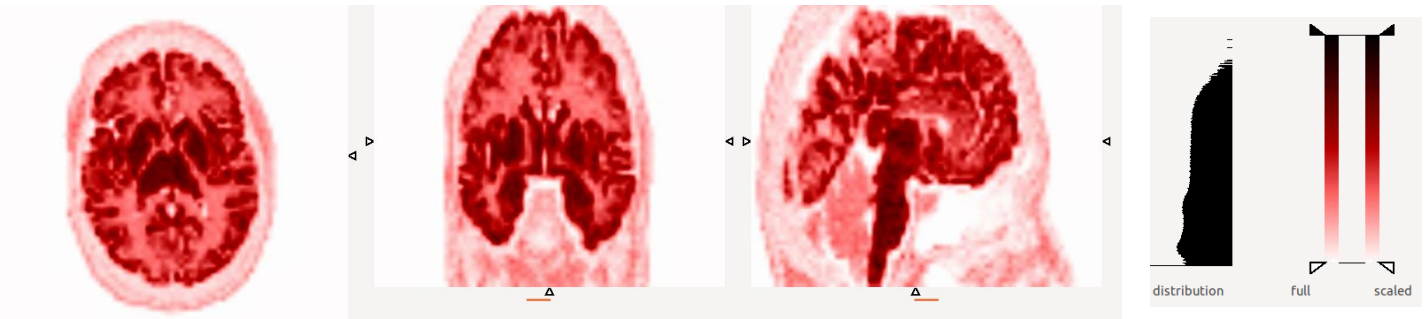
We expect FBI3D to be a useful tool for the large community of GATE users.

https://code.google.com/p/fbi3d



Example: Gate Simulations (I)

- ECAT PET System (Example folder in GATE v7.0)
- Voxelized brain phantom with 10 segmented tissues assuming a standard FDG distribution.
- Simulated for 3 min filled with a back-to-back 511keV gamma source within air. The simulation took 5.6 hours in 1 CPU (Intel(R) Core(TM) i7-3770K @ 3.5GHz).
- The generated 1.1GB ROOT file of the brain phantom contained 6.0 x 106 coincidences.



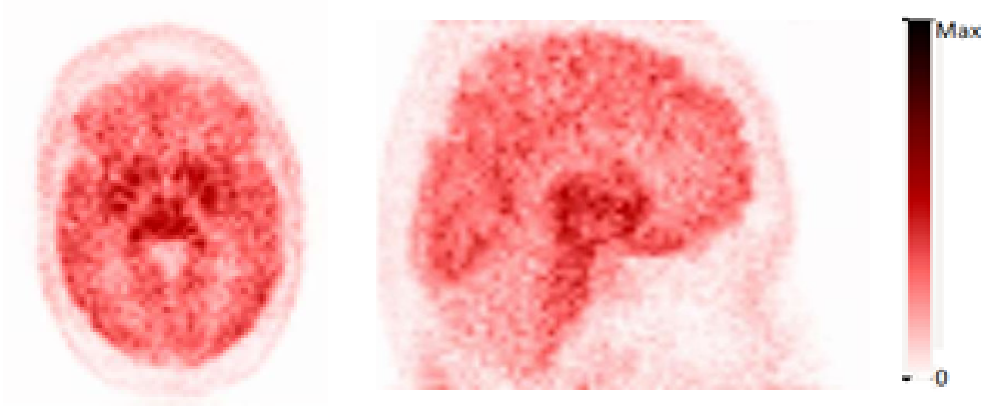
Example: Gate Simulations (II)

Normalization simulation

- Uniform activity distribution in the FOV
- 6 μCi of a back-to-back source within air
- We simulated a 3h acquisition
- Used for obtaining the sensitivity distribution (based on the detected coincidences coming from each point vs the number of decays simulated)
- Used also for obtaining the scanner's geometry

Example: FBI3D

- Estimated image with 75x75x61 voxels
- 150 iterations
- The reconstruction time was 30 min using 1 CPU.
- No attenuation or scatter correction was used.
- The only two inputs required for FBI3D were the data and normalization ROOT files.



Transverse and Sagittal views of the reconstructed image with FBI3D of the brain phantom from the GATE-simulated data.

Discussion & Conclusion

- We have developed a simple, user friendly method for reconstructing 3D PET images from GATE simulation ROOT files.
- No conversion of ROOT files into any specific sinogram or LOR histogram formats is required.
- As it uses the information in the normalization acquisition for obtaining the appropriate parameters of the scanner and the FOV, no additional input is necessary.
- We expect FBI3D to be a useful tool for the large community of GATE users.

Acknowledgements

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