GHENT
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Specialized Geant4 navigation for GATE

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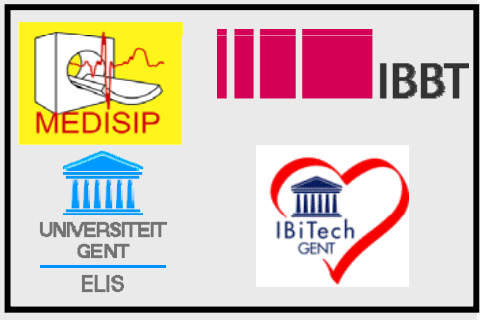


Navigation for parameterized volumes :

- What are parameterized volumes really?
- What are they used for in Gate?
- Why bother?
- How is navigation done in Geant4?
- Why is it so freaking slow?
- How to improve?
- Status

Navigation for FD/CFD

- Going a step further: FD/CFD optimized navigation
- Status

What are parameterized volumes?

- repeated volumes :
  - » one copy really exists at any given time
  - » Properties change on the fly by a parameterization
    - Material
    - Size
    - Solid type : box, sphere, trapezoid,…
  - » Very dynamic, but slower due to the parameterization
  - » Highly memory efficient!

What are they used for in GATE?

- Voxelized phantoms
- Fan beam and cone beam collimators

Why bother?

- Voxelized phantoms are widely used for realistic acquisitions in GATE
- Fan beam sims are used for brain SPECT
- Both are extremely slow when used

How is navigation done in Geant4?

Construct (1)

Close

Optimize (2)

Start run

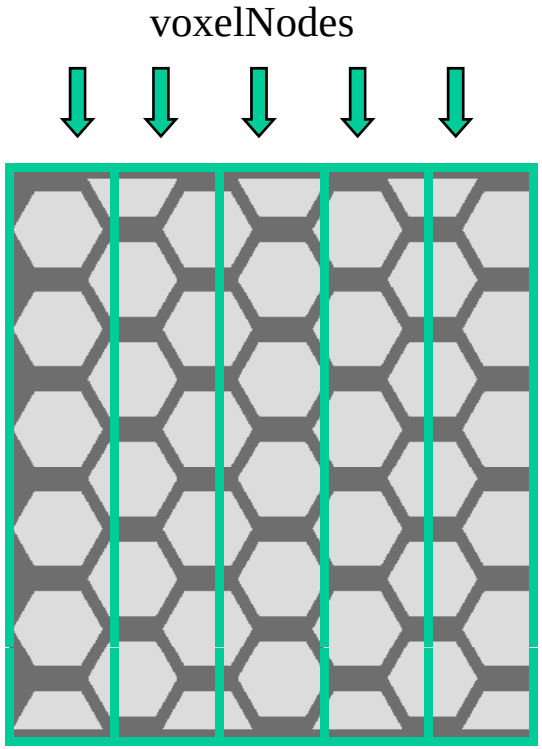
Track particles (3)

Construct (1)

- Type: single or repeated
- Parameterization
- Submit to volume store

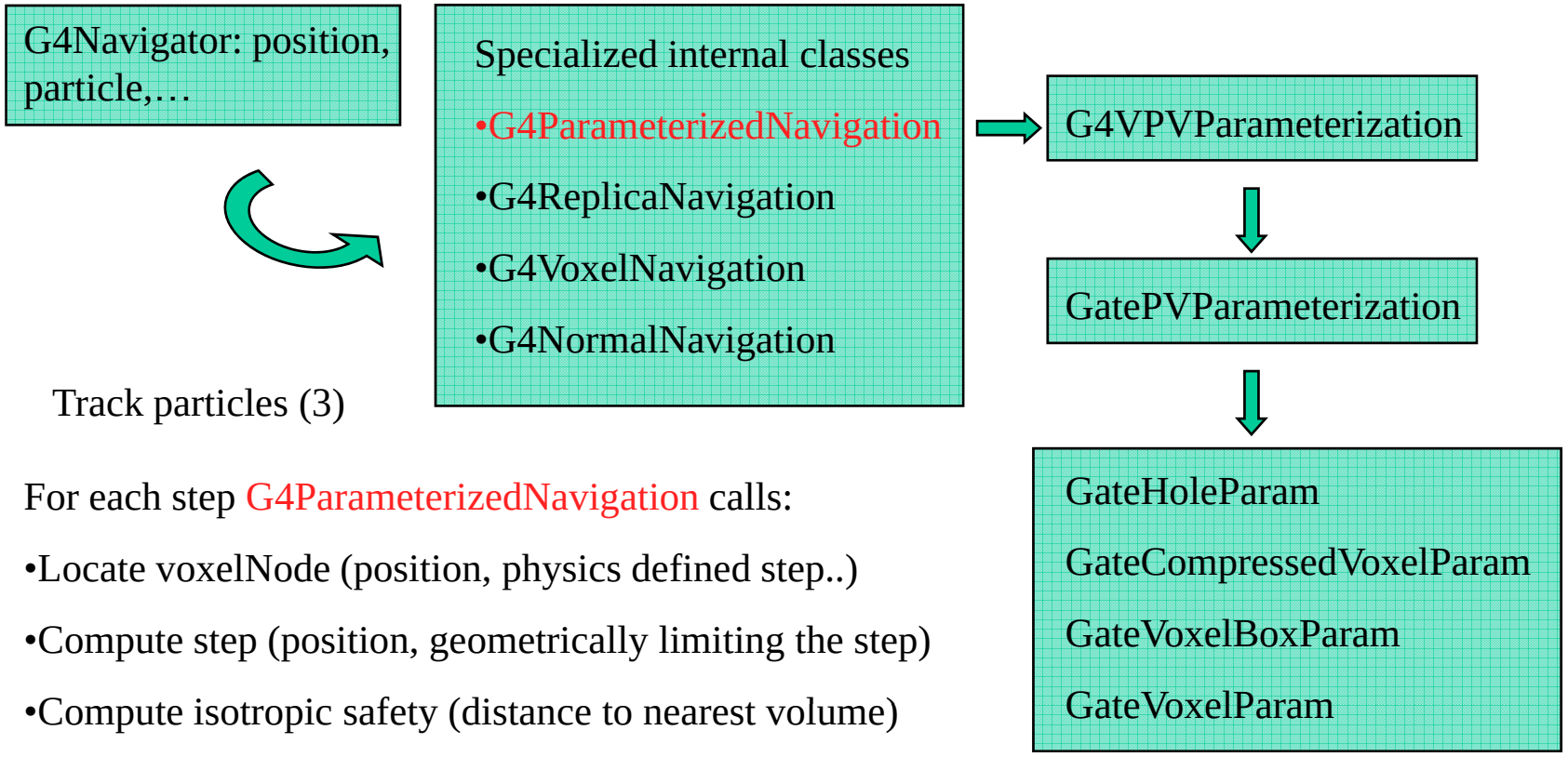
Optimize (2)

- Repeated types
- Smart voxels



- Each copy has a index number in the voxelNode it belongs to

How is navigation done in Geant4?



For each step G4ParameterizedNavigation calls:

- Locate voxelNode (position, physics defined step..)
- Compute step (position, geometrically limiting the step)
- Compute isotropic safety (distance to nearest volume)

Why is it so freaking slow?

- Locate voxelNode →
- Compute step →
- Compute isotropic safety →

Loop over copy numbers:

- compute transformation
- compute dimensions
- place it (logical, physical, solid, affine transform)
- Apply algorithm to the placement of this copy number

On average about 140 000 copies are checked to locate a particle at every single step in a fan beam collimator

What is the conceptual idea?

- The optimization is a general one
  - » Too many “wrong” volumes are placed and checked before finding the right one
  - » Navigation history is working overtime
- Make the optimization a specialized one
  - » The knowledge of the parameterization is in that class itself
  - » Exploit that to find the “right” volume (almost) directly
  - » Avoid, avoid, avoid the navigation history

How to improve?

G4Navigator: position, particle,…

-> pointer to virtual class

Virtual classes

- G4ParameterizedNavigation
- G4ReplicaNavigation
- G4VoxelNavigation
- G4NormalNavigation

GateParameterizedNavigation

- Know that the param is a GATE class: GatePVParameterization* param
- Get a param type : collimator, or voxel phantom,….
- Get a list of copies to consider
- Apply a custom algorithm for each param type

G4VPVParameterization

GatePVParameterization

- GateHoleParam
- GateCompressedVoxelParam
- GateVoxelBoxParam
- GateVoxelParam

Each parameterization class must implement

- GetCopyList
- GetParameterizationType

Status

- The above scheme has been completely implemented
- For fan beam collimators :
  - GateParameterizedNavigation
    - Calls the parameterization
    - Supplies the position of the particle
    - Asks for a list of copy numbers nearby to consider in its algorithms
    - Asks the parameterization type so a specialized algorithm can be used
  - GateHoleParameterization computes 2 copynumbers, each representing a half hole
  - Speedup : several 1000 times faster than the old fan beam collimator tracking

Status

- For voxelized phantoms :
  - The direct neighbourgs of the current voxel are used to limit the search, the 2 most probable voxels (depending on the current direction of a particle) are first in the list. Complexity dropped from O(n^3) to O(n)
  - This is combined with the compression technique that combines voxels of the same material to larger ones

- The navigation is now effectively under GATE control for parameterized volumes. This would not be required if the G4 classes would ask the parameterization classes for a specialized copy list.

Status

•Each type of parameterization can have its own “navigation algorithm” to compute the copy list, which can be much more specialized than a general optimization technique such as the smart voxels

•This anticipates the next step of Geant4 : a virtual navigator that can be customized by the user

•The new navigator code is being validated and used by all fan beam and FD/CFD simulations in Ghent and will be part of our next update to FD/CFD with fan beam collimators.

•No approximations are used in this code