Common Geometry Primitives (Unified Solids)

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Motivations for a common solids library

- Optimize and guarantee better long-term maintenance of Root and Gean4 solids libraries
  - A rough estimation indicates that about 70-80% of code investment for the geometry modeler concerns solids, to guarantee the required precision and efficiency in a huge variety of combinations
- Create a single library of high quality implementations
  - Starting from what exists today in Geant4 and Root
  - Adopt a single type for each shape
  - Create a new Multi-Union solid
  - Aims to replace solid libraries in Geant4 and Root
  - Allowing to reach complete conformance to GDML solids schema
- Optimize, extend and rationalize the testing suite

Strategy and current status

- Stage ONE: Startup (completed)
- ✓ Types and USolid interface are defined
- ✓ Bridge classes defined and implemented for both Geant4 and Root
- ✓ First solid (box) implemented and tested
- ✓ Testing suite defined and deployed
- ✓ Implementation of "Multi-Union" solid completed and performance optimized

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- Stage TWO: Migration (current)
- **Evaluate weaknesses of solids for priority**
- **Implement migration of each solid according to priority**
- ✓ Started implementation of primitives:
  - ✓ First implementation of Orb (simple full sphere) and Trd (simple trapezoid)
  - ✓ Testing suite extended with Data Analysis and Performance tests with direct comparisons with Geant4 and Root implementations

Current resources

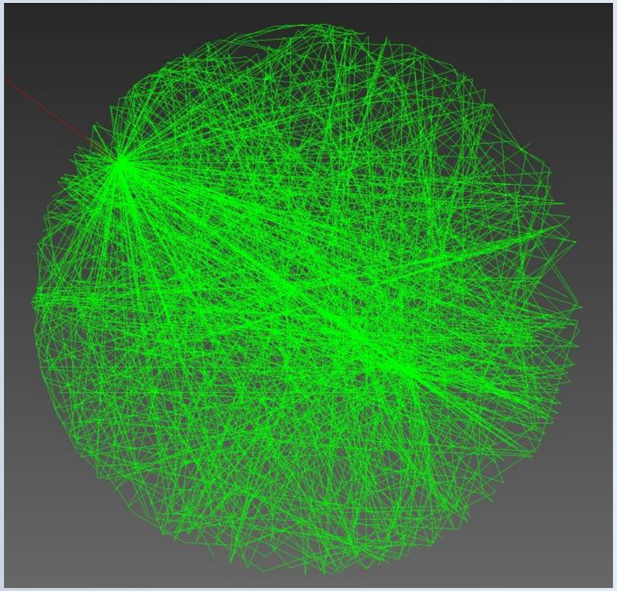
- Contributions from:
  - John Apostolakis (PH/SFT)
  - Gabriele Cosmo (PH/SFT)
  - Marek Gayer (PH/SFT, Fellow from 1/7/2011)
  - Andrei Gheata (ALICE)
  - Jean-Marie Guyader (CERN Summer Student until 31/8/2011)
  - Tatiana Nikitina (PH/SFT)
- Current resources sums up to ~1.4 FTE

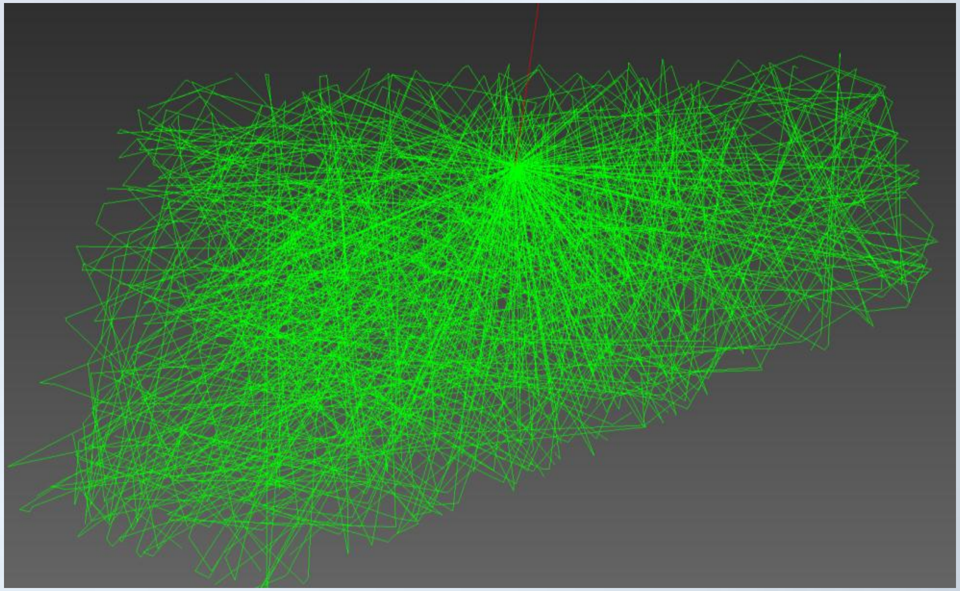
Testing Suite

- Solid Batch Test
- Optical Escape
- Data analysis and performance (SBT DAP)
- Specialized tests (e.g. quick performance scalability test for multi-union)

Optical Escape Test

- Optical photons are generated inside a solid
- Repeatedly bounce on the reflecting inner surface
- Particles must not escape the solid





Solids Batch Test (SBT)

- Points and vectors test
  - Generating groups of inside, outside and surface points
  - Testing all distance methods with numerous checks
    - E.g. for each inside random point *p*, *SafetyFromInside(p)* must be > 0
- Voxels tests
  - Randomly sized voxels with random inside points
- Scriptable application, creates logs
- Extendible C++ framework
  - Allowing easy addition of new tests

Data Analysis and Performance (DAP)

DAP features

- Extension of the SBT framework
- Centred around testing USolids together with existing Geant4 and Root solids
- Values and their differences from different codes can be compared
- Constrain: similar or better performance required for each method
- The core part of USolids testing
- Portable: Windows, Linux, Mac
- Two phases
    - Sampling phase (generation of data sets, implemented as C++ app.)
    - Analysis phase (data post-processing, implemented as MATLAB scripts)

DAP - Sampling phase

- Tests with solids from three libraries: Geant4, Root and USolids
- Tests with pre-calculated, randomly generated sets of points and vectors
- Storing of results data sets to disk
- Measurement of performance
- Support for batch scripting
  - Detailed configuration of conditions in the tests
  - Invoking several tests sequentially
- Rich debugging possibilities in Visual Studio

DAP - Analysis phase

- Visualization of scalar and vector data sets and shapes
- Visual analysis of differences
- Graphs with comparison of performance and scalability
- Inspection of values and differences of data sets

Visualization of scalar and vector data sets

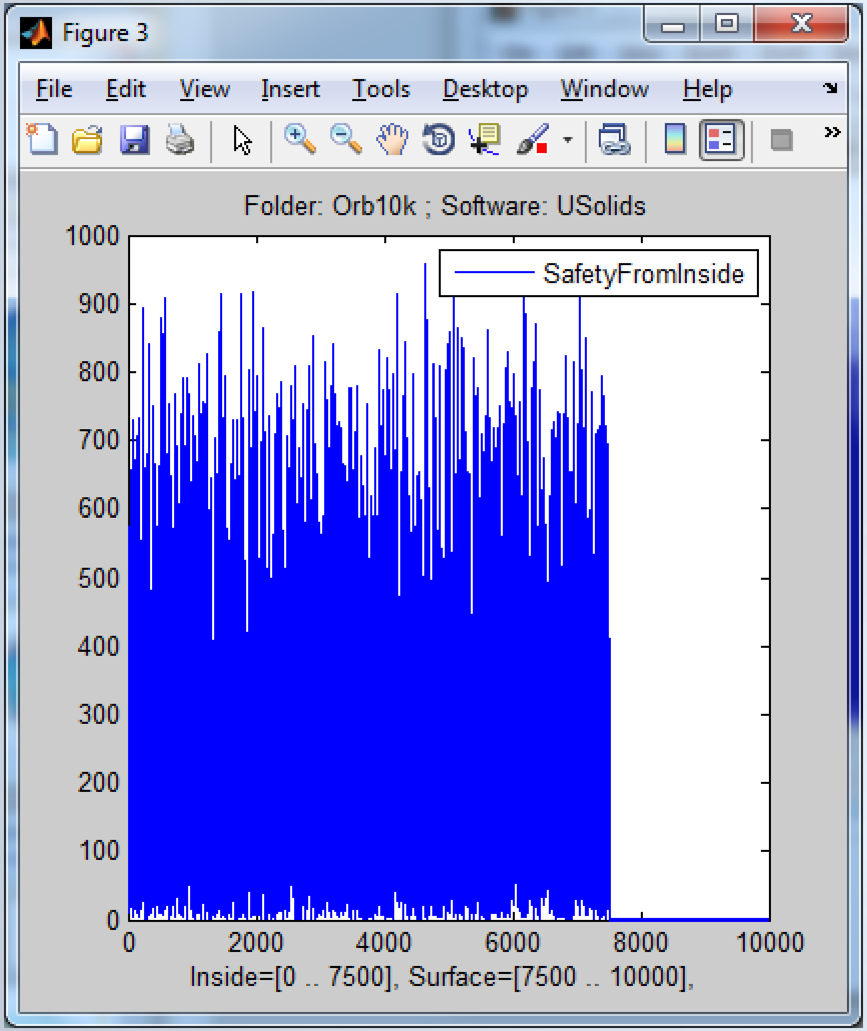
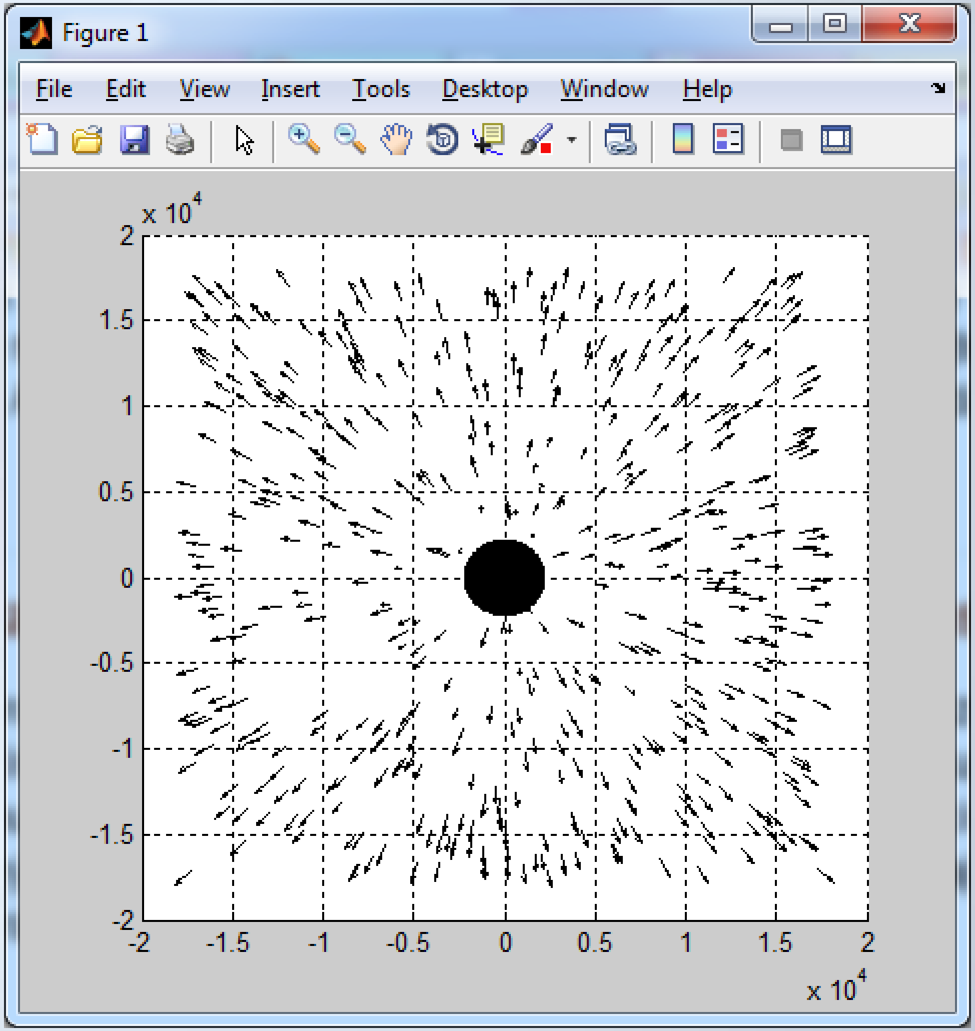
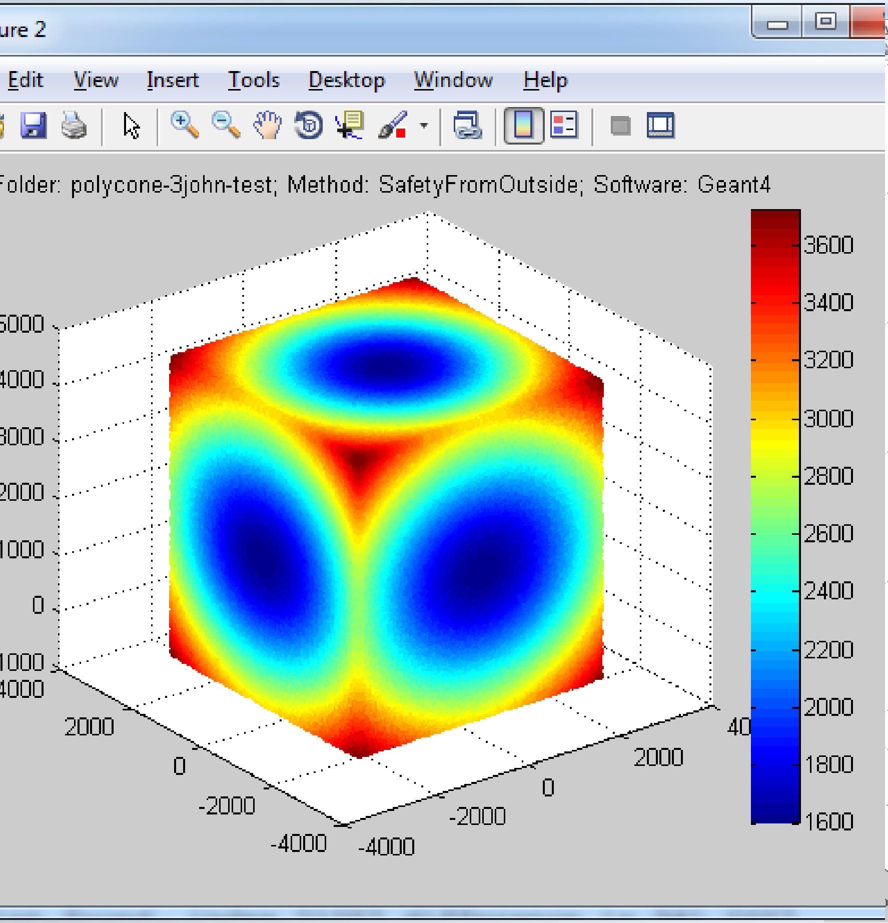


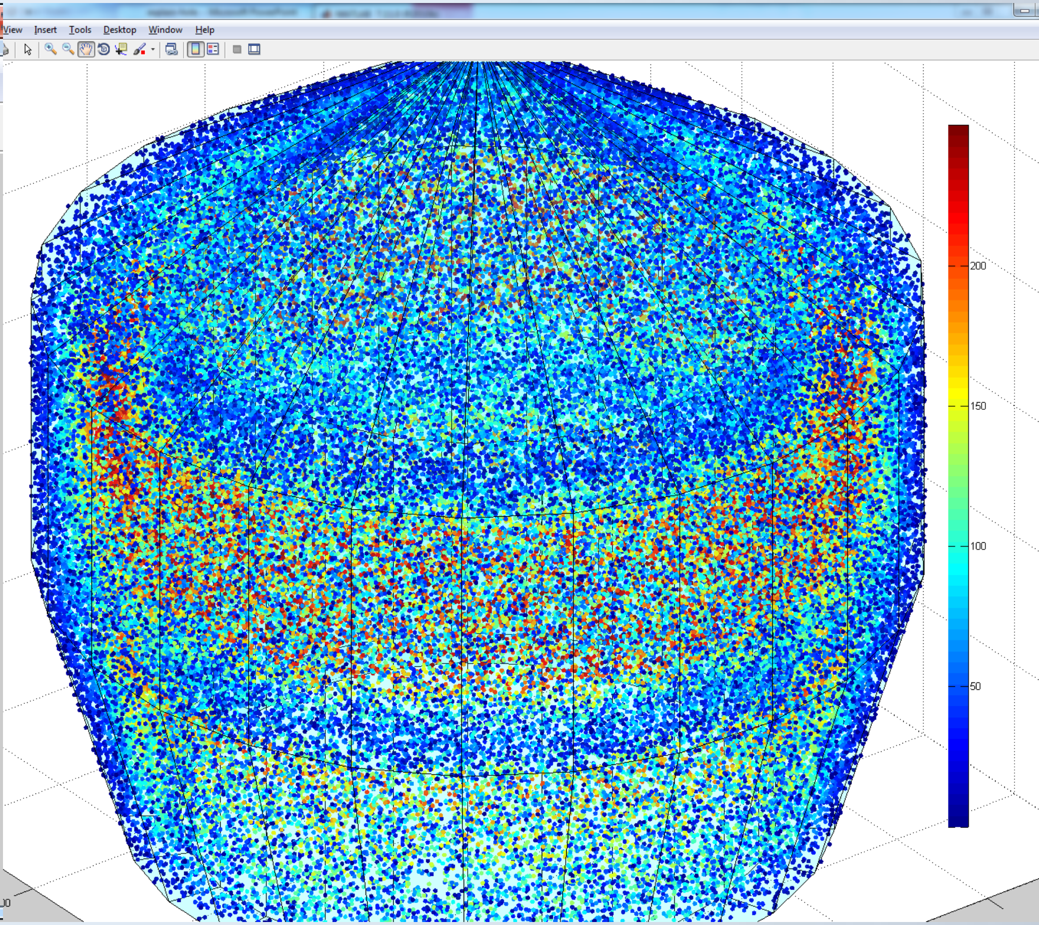
Figure 3
File Edit View Insert Tools Desktop Window Help
Folder: Orb10k ; Software: USolids
SafetyFromInside
1000
900
800
700
600
500
400
300
200
100
0
0
2000
4000
6000
8000
10000
Inside=[0 .. 7500], Surface=[7500 .. 10000],



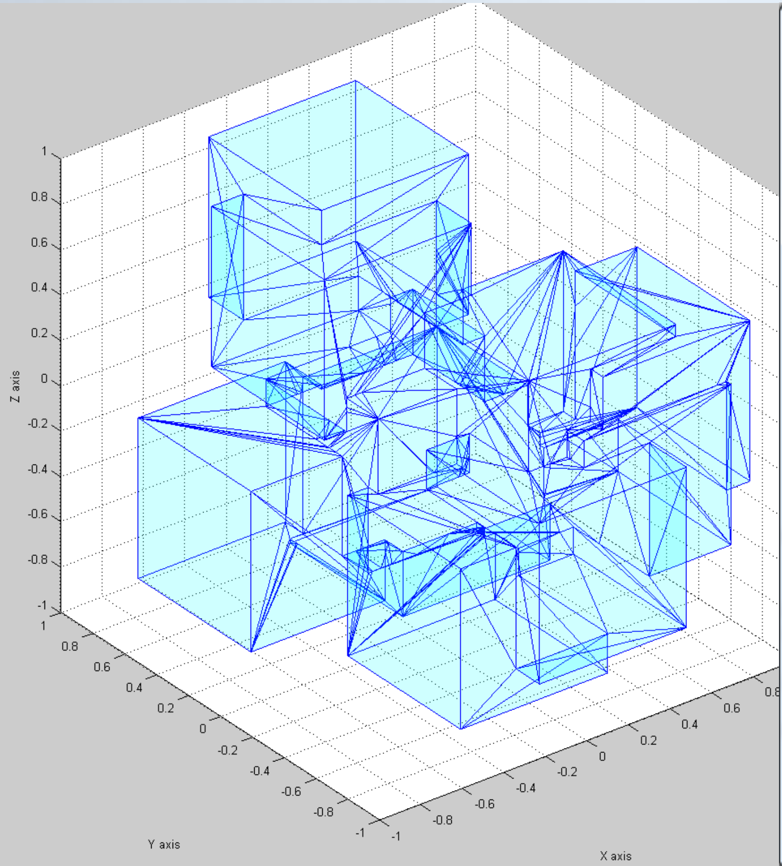
3D plots allowing to overview data sets

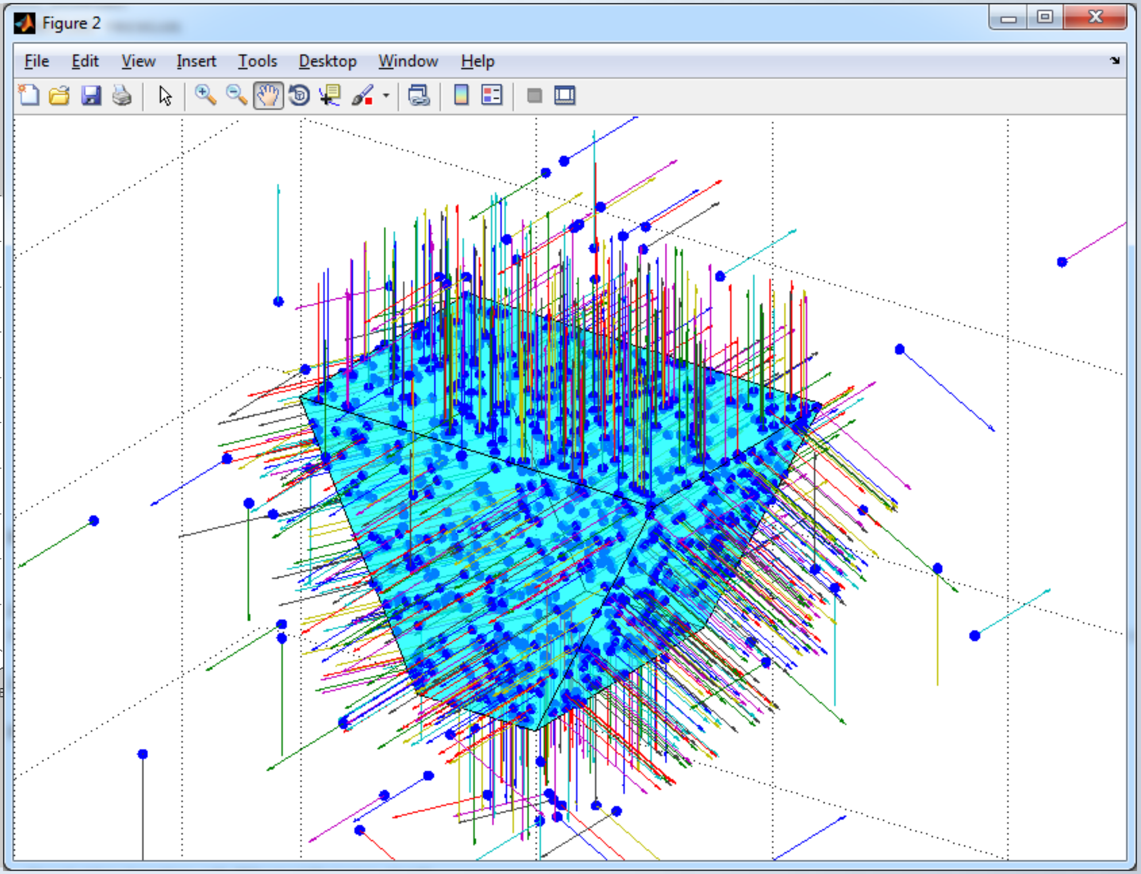


Folder: polycone-3john-test; Method: SafetyFromOutside; Software: Geant4

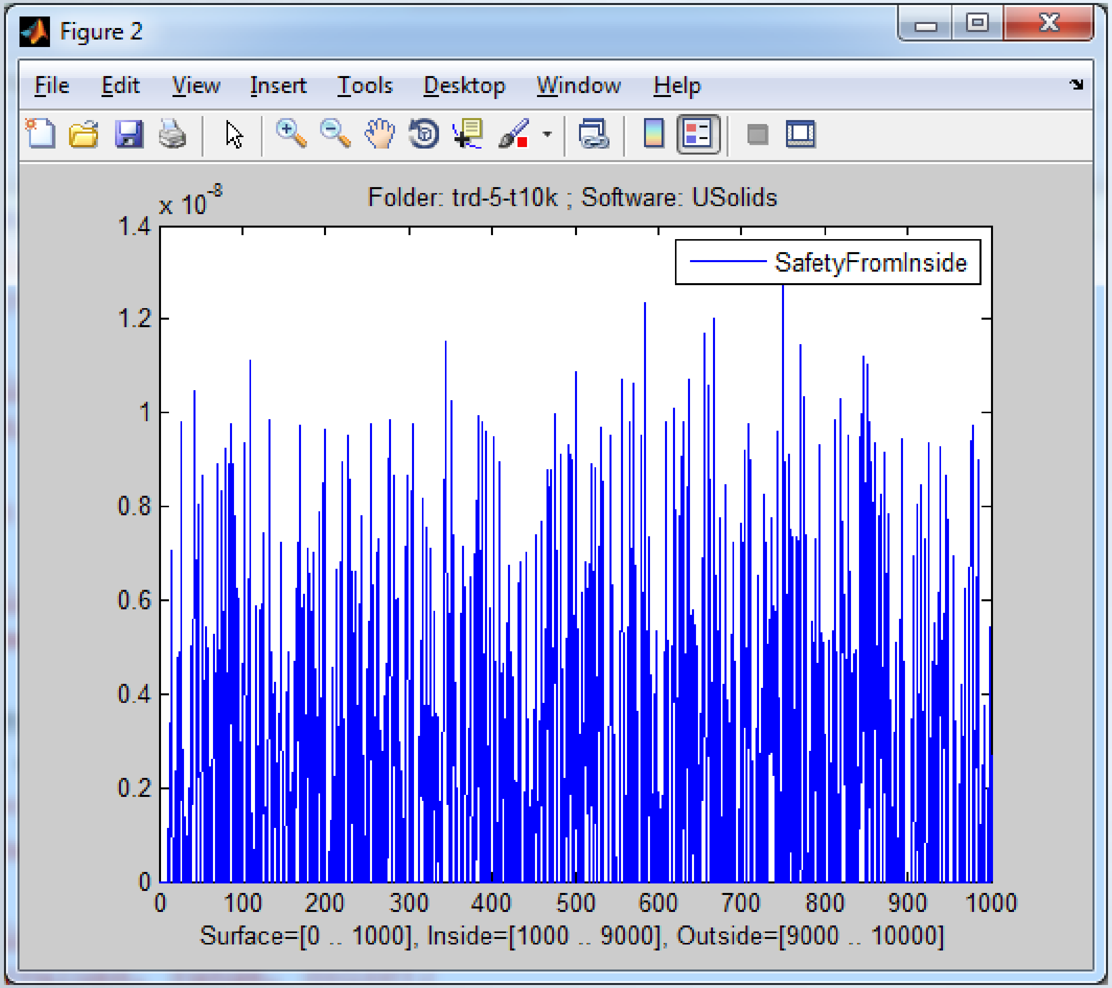


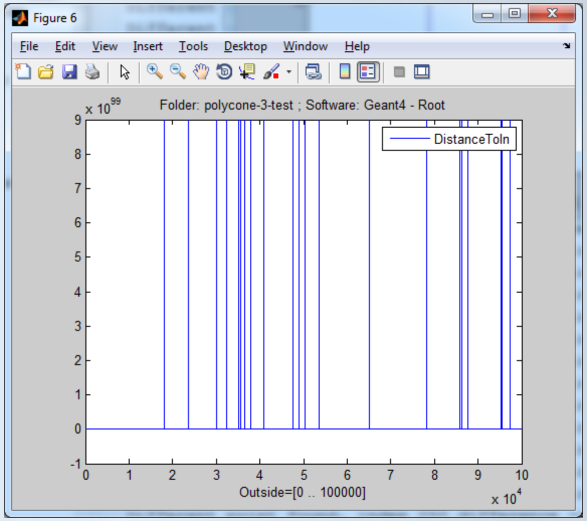
3D visualization of investigated shapes

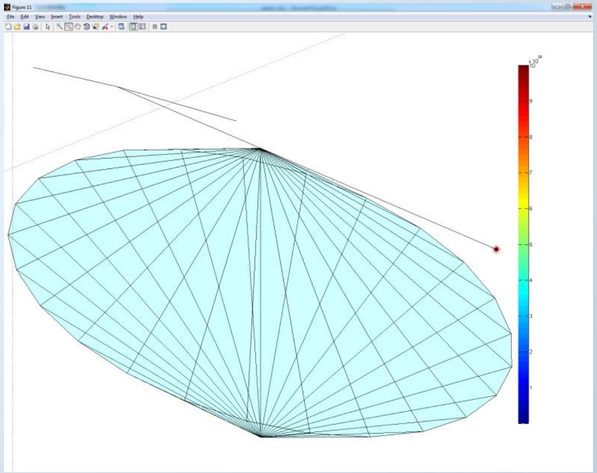




Support for regions of data, focusing on sub-parts







Visual analysis of differences

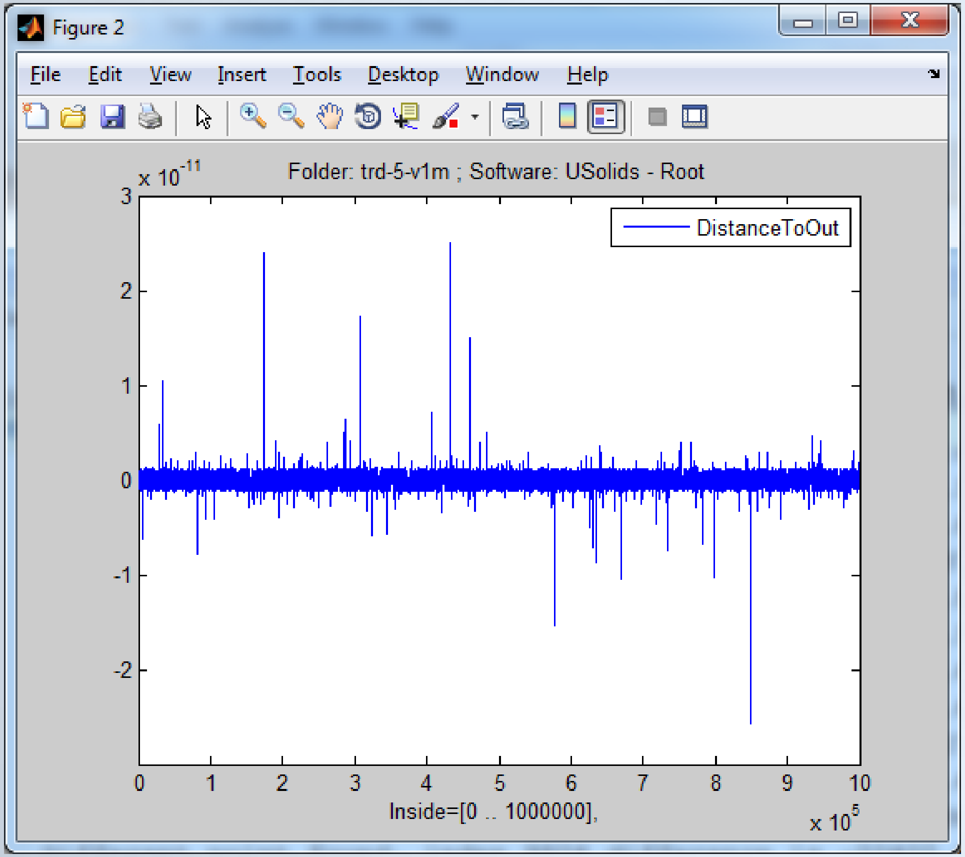
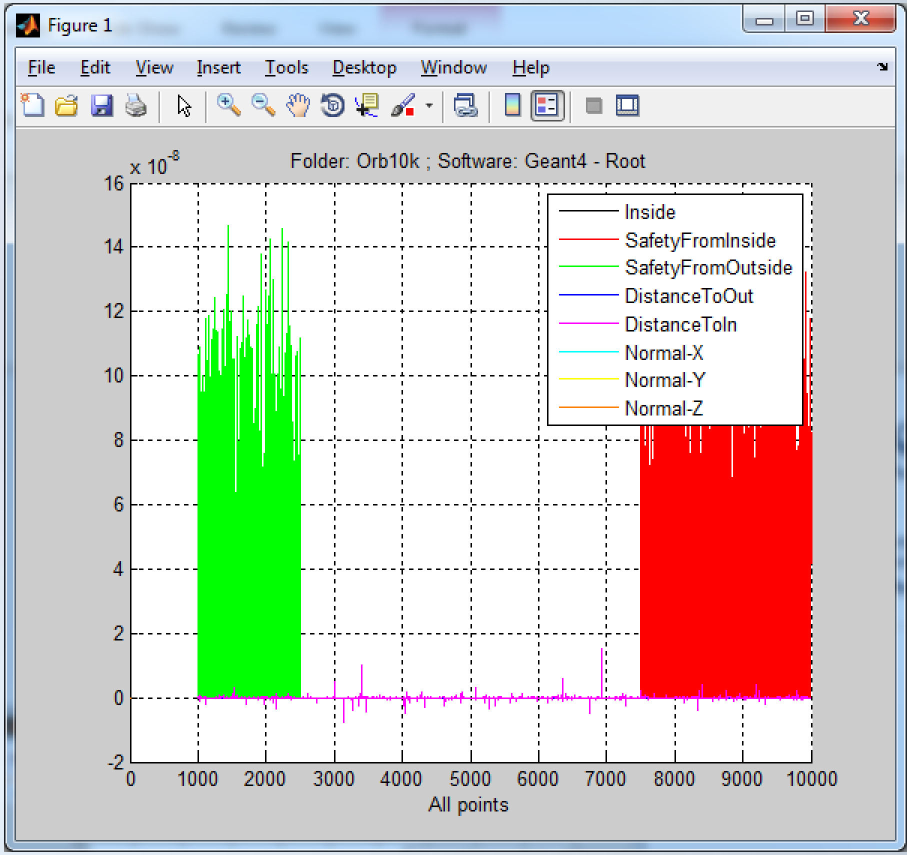
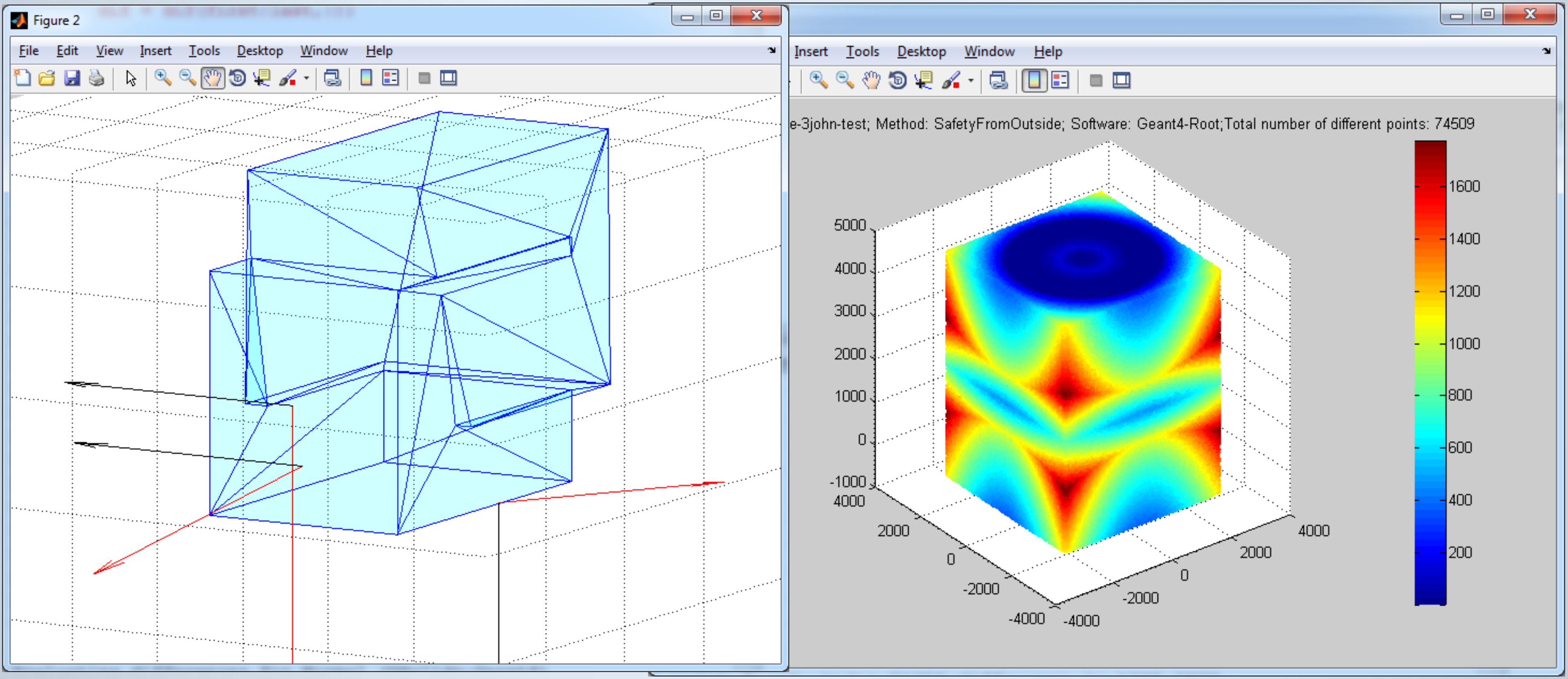


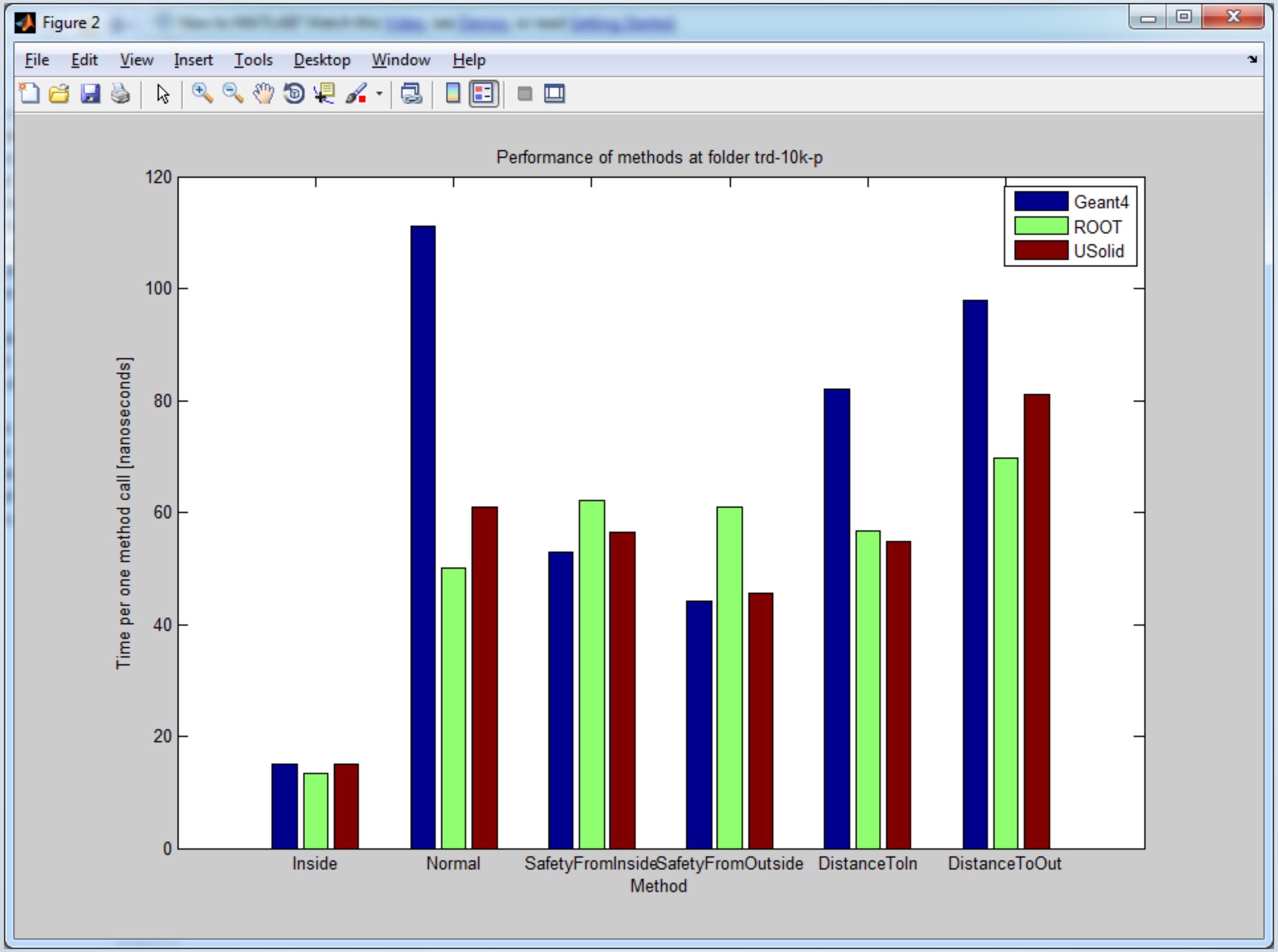
Figure 2
File Edit View Insert Tools Desktop Window Help
Folder: trd-5-v1m ; Software: USolids - Root
x 10^-11
3
2
1
0
-1
-2
DistanceToOut
0 1 2 3 4 5 6 7 8 9 10
Inside=[0 .. 1000000],
x 10^5



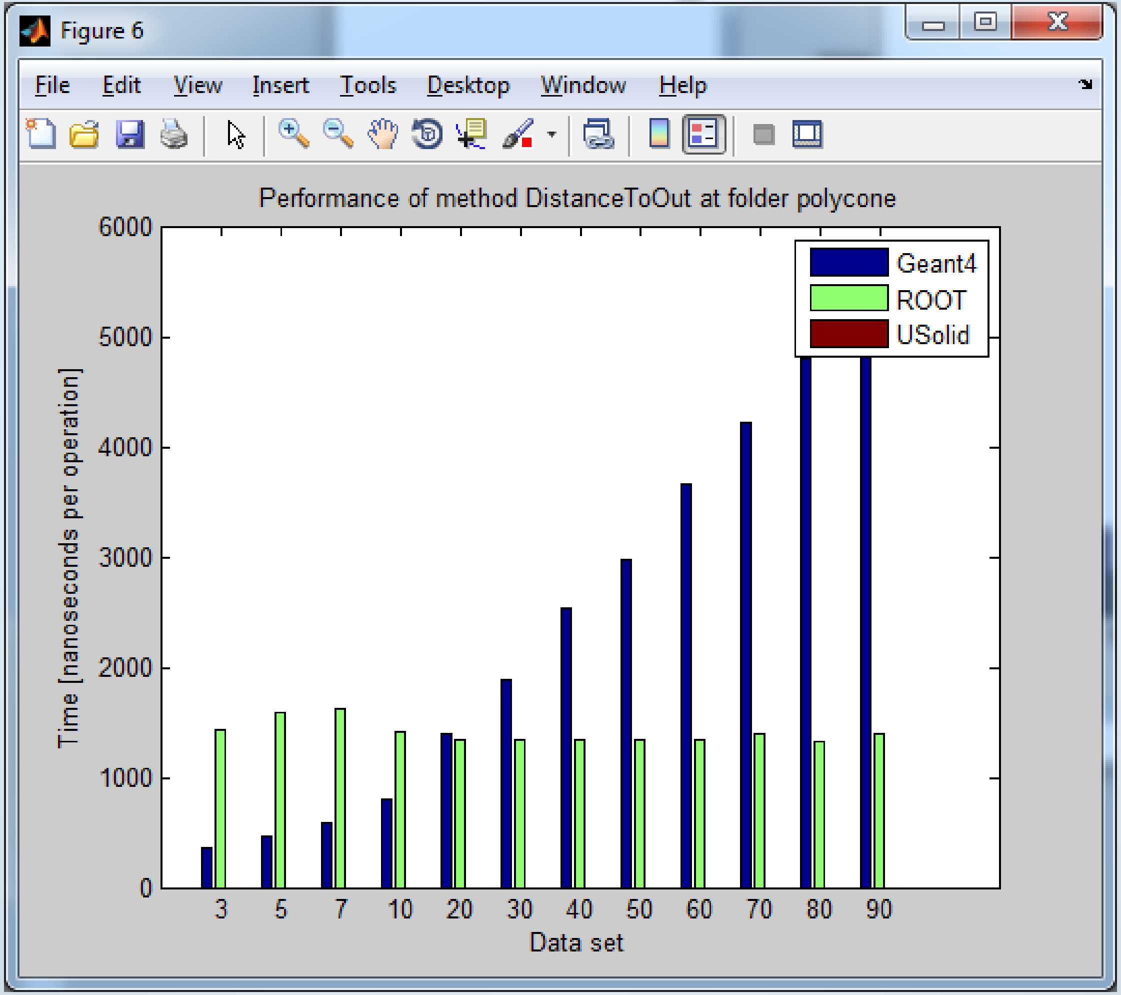
Visual analysis of differences in 3D


e-3john-test; Method: SafetyFromOutside; Software: Geant4-Root;Total number of different points: 74509

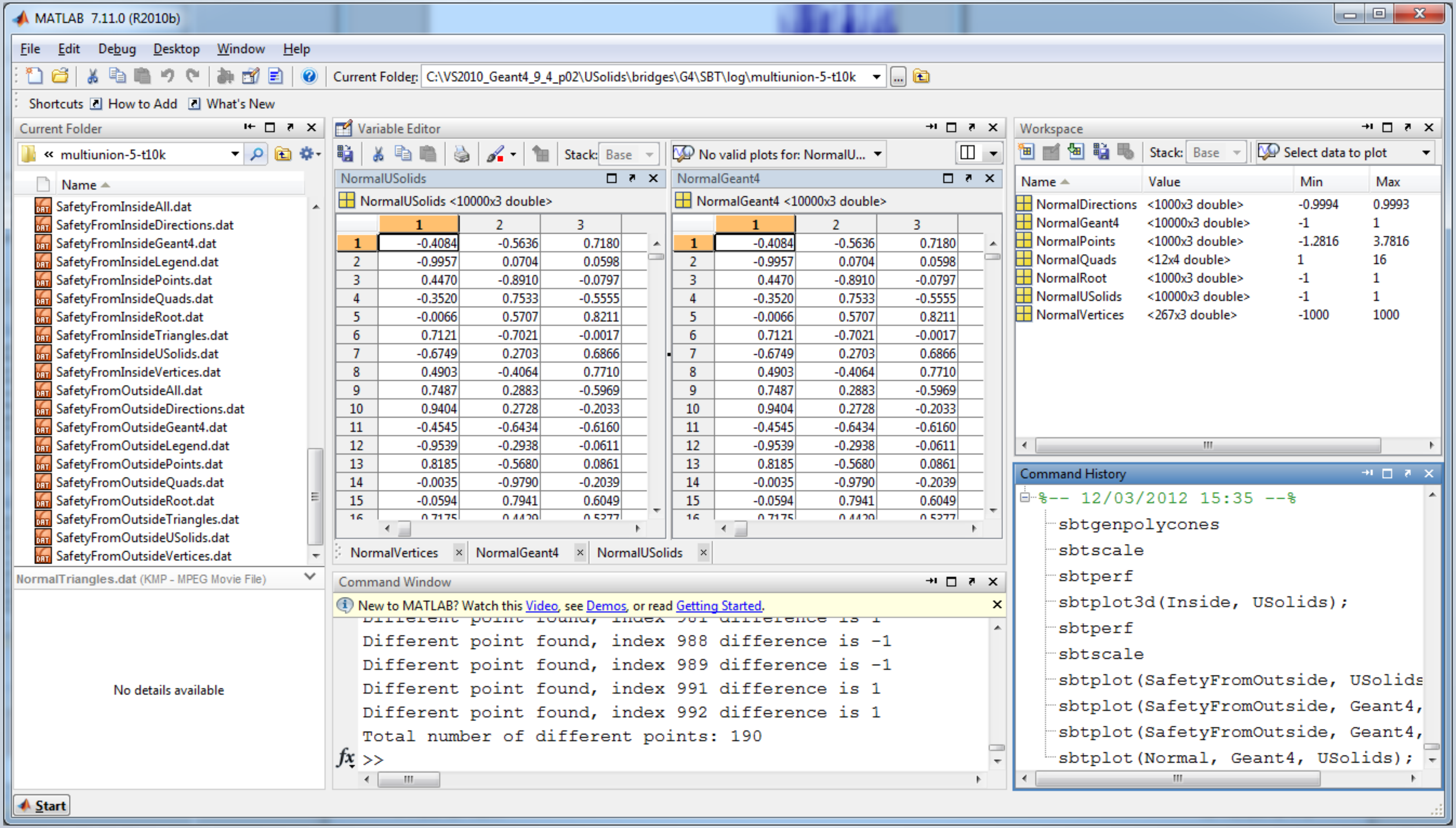
Graphs with comparison of performance



Visualization of scalability performance for specific solids



Inspection of values and differences of scalar and vector data sets



MATLAB 7.11.0 (R2010b)

Current Folder: C:\VS2010_Geant4_9_4_p02\USolids\bridges\G4\SBT\log\multiunion-5-t10k

Current Folder: multiunion-5-t10k

- SafetyFromInsideAll.dat
- SafetyFromInsideDirections.dat
- SafetyFromInsideGeant4.dat
- SafetyFromInsideLegend.dat
- SafetyFromInsidePoints.dat
- SafetyFromInsideQuads.dat
- SafetyFromInsideRoot.dat
- SafetyFromInsideTriangles.dat
- SafetyFromInsideUSolids.dat
- SafetyFromInsideVertices.dat
- SafetyFromOutsideAll.dat
- SafetyFromOutsideDirections.dat
- SafetyFromOutsideGeant4.dat
- SafetyFromOutsideLegend.dat
- SafetyFromOutsidePoints.dat
- SafetyFromOutsideQuads.dat
- SafetyFromOutsideRoot.dat
- SafetyFromOutsideTriangles.dat
- SafetyFromOutsideUSolids.dat
- SafetyFromOutsideVertices.dat

NormalTriangles.dat (KMP - MPEG Movie File)

No details available

Variable Editor – NormalUSolids <10000x3 double>

	1	2	3
1	-0.4084	-0.5636	0.7180
2	-0.9957	0.0704	0.0598
3	0.4470	-0.8910	-0.0797
4	-0.3520	0.7533	-0.5555
5	-0.0066	0.5707	0.8211
6	0.7121	-0.7021	-0.0017
7	-0.6749	0.2703	0.6866
8	0.4903	-0.4064	0.7710
9	0.7487	0.2883	-0.5969
10	0.9404	0.2728	-0.2033
11	-0.4545	-0.6434	-0.6160
12	-0.9539	-0.2938	-0.0611
13	0.8185	-0.5680	0.0861
14	-0.0035	-0.9790	-0.2039
15	-0.0594	0.7941	0.6049

Variable Editor – NormalGeant4 <10000x3 double>

	1	2	3
1	-0.4084	-0.5636	0.7180
2	-0.9957	0.0704	0.0598
3	0.4470	-0.8910	-0.0797
4	-0.3520	0.7533	-0.5555
5	-0.0066	0.5707	0.8211
6	0.7121	-0.7021	-0.0017
7	-0.6749	0.2703	0.6866
8	0.4903	-0.4064	0.7710
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10	0.9404	0.2728	-0.2033
11	-0.4545	-0.6434	-0.6160
12	-0.9539	-0.2938	-0.0611
13	0.8185	-0.5680	0.0861
14	-0.0035	-0.9790	-0.2039
15	-0.0594	0.7941	0.6049

NormalVertices | NormalGeant4 | NormalUSolids

Workspace

Name	Value	Min	Max
NormalDirections	<1000x3 double>	-0.9994	0.9993
NormalGeant4	<10000x3 double>	-1	1
NormalPoints	<1000x3 double>	-1.2816	3.7816
NormalQuads	<12x4 double>	1	16
NormalRoot	<1000x3 double>	-1	1
NormalUSolids	<10000x3 double>	-1	1
NormalVertices	<267x3 double>	-1000	1000

Command Window

New to MATLAB? Watch this Video, see Demos, or read Getting Started.

```
Different point found, index 988 difference is -1
Different point found, index 989 difference is -1
Different point found, index 991 difference is 1
Different point found, index 992 difference is 1
Total number of different points: 190
>>
```

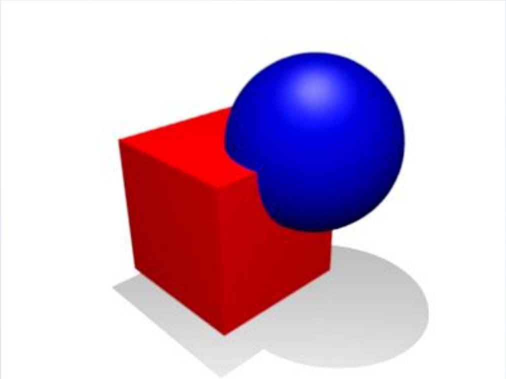
Command History

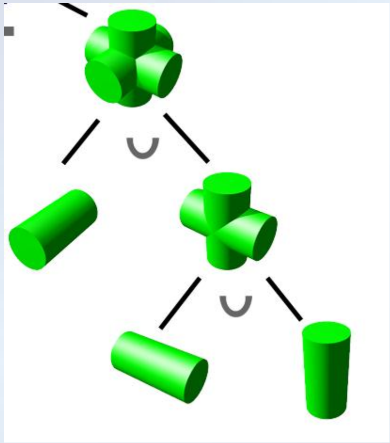
```
%-- 12/03/2012 15:35 --%
sbtgenpolycones
sbtscale
sbtperf
sbtplot3d(Inside, USolids);
sbtperf
sbtscale
sbtplot(SafetyFromOutside, USolids
sbtplot(SafetyFromOutside, Geant4,
sbtplot(SafetyFromOutside, Geant4,
sbtplot(Normal, Geant4, USolids);
```

New Multi-Union solid

Boolean Union solids

- Existing CSG Boolean solids (Root and Geant4) represented as binary trees
  - To solve navigation requests, most of the solids composing a complex one have to be checked
  - Scalability is typically linear => low performance for solids of many parts



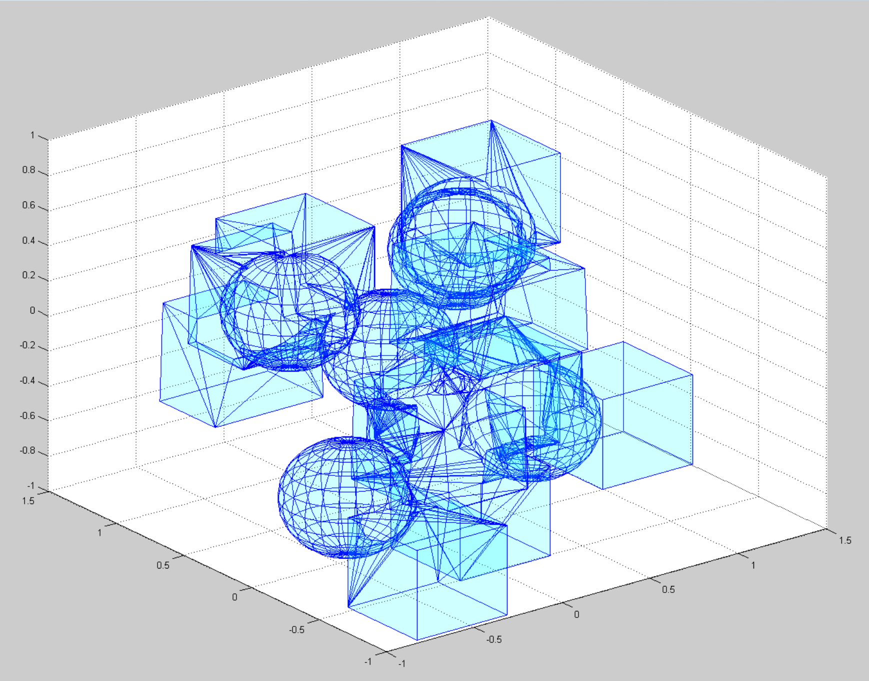


[Images source: wikipedia.org]

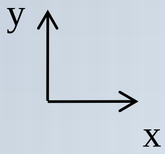
Boolean Union solid:
is composite of two solids, either primitive or Boolean

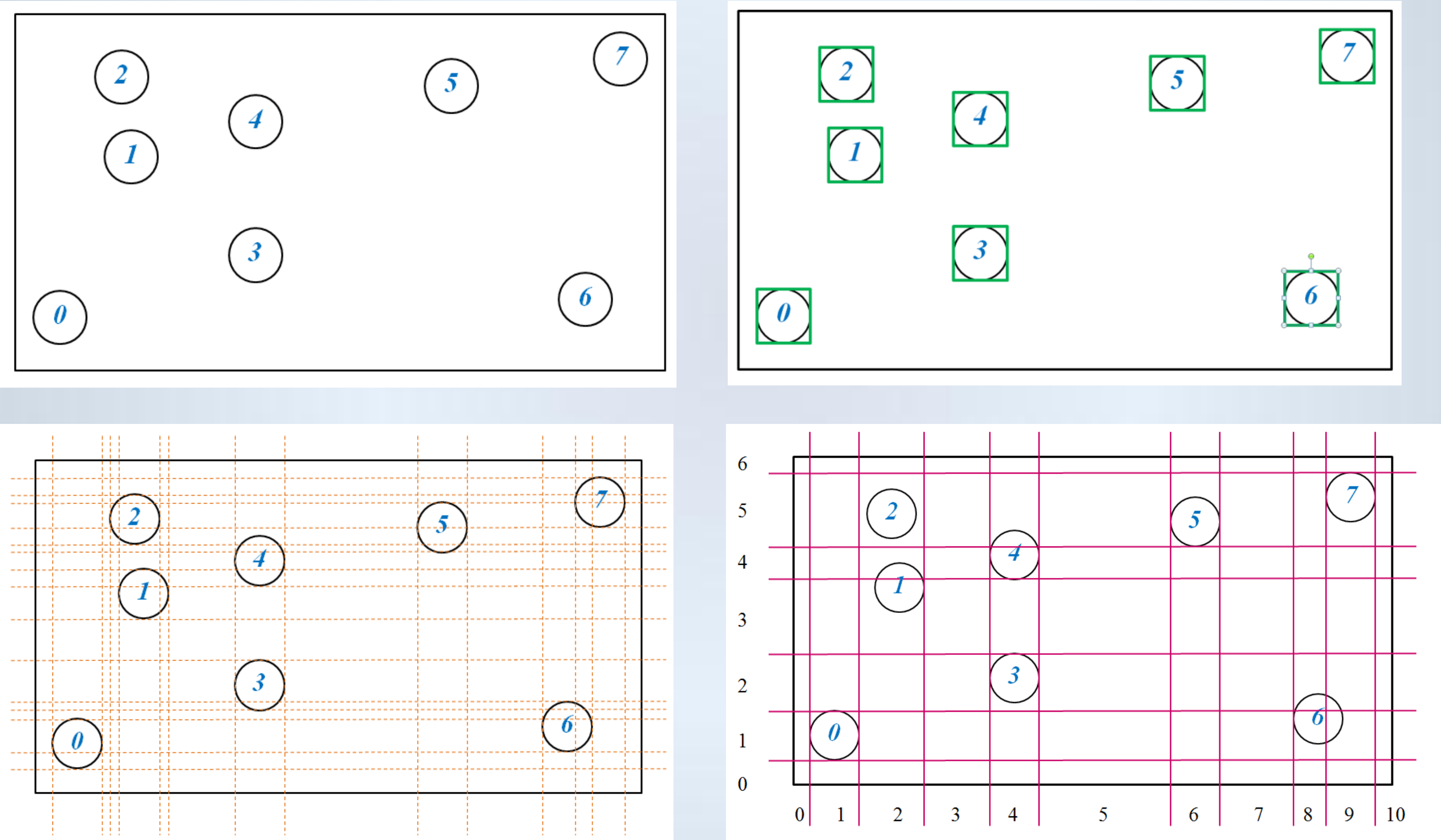
Multi-Union solid

- We implemented a new solid as a union of many solids using voxelization techniques to optimize the speed
  - 3D space partition for fast localization of components
  - Aiming for a log(n) scalability
- Useful also for several complex composites made of many solids with regular patterns

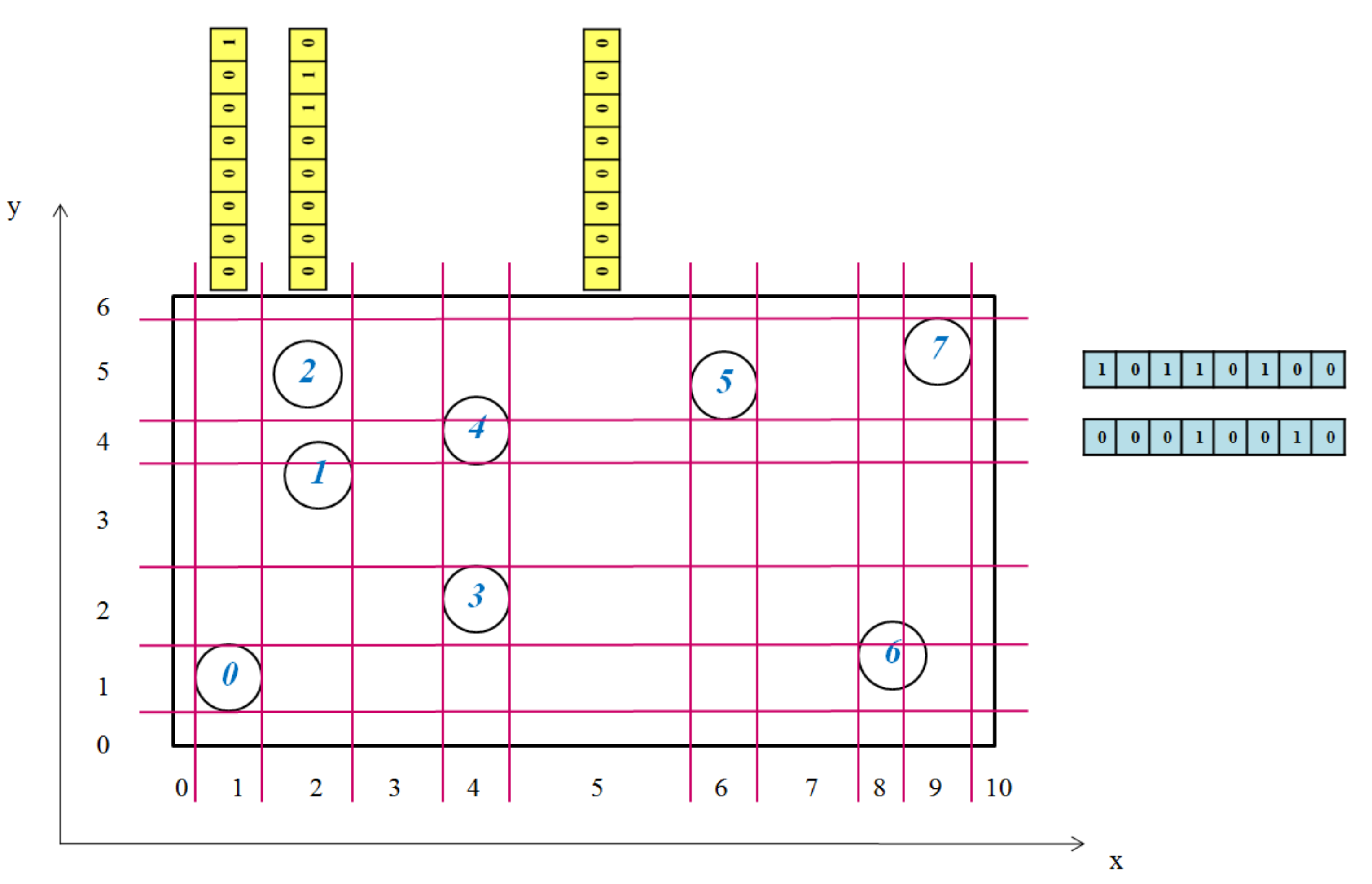


1. Create voxel space (2D simplification)

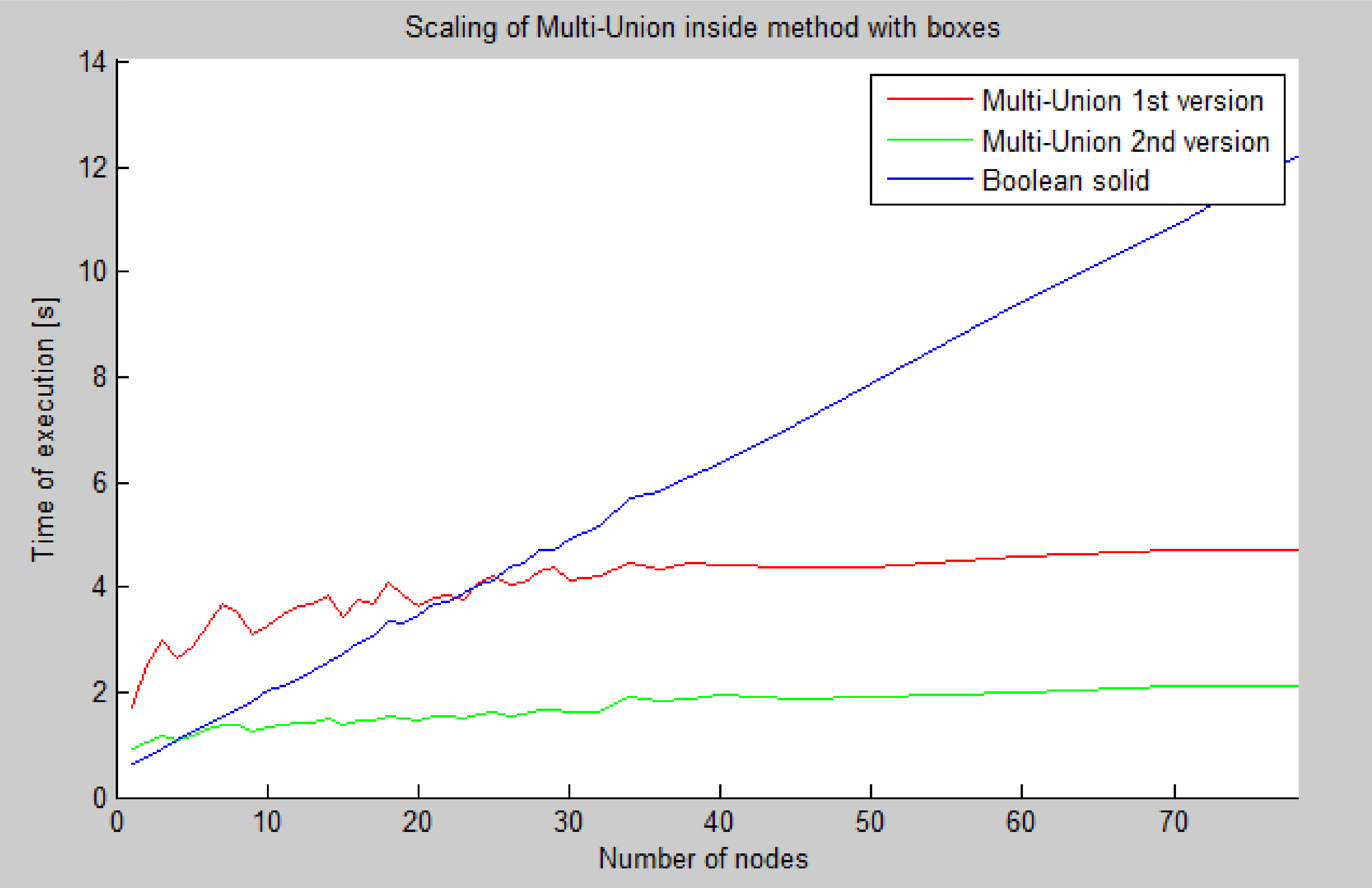




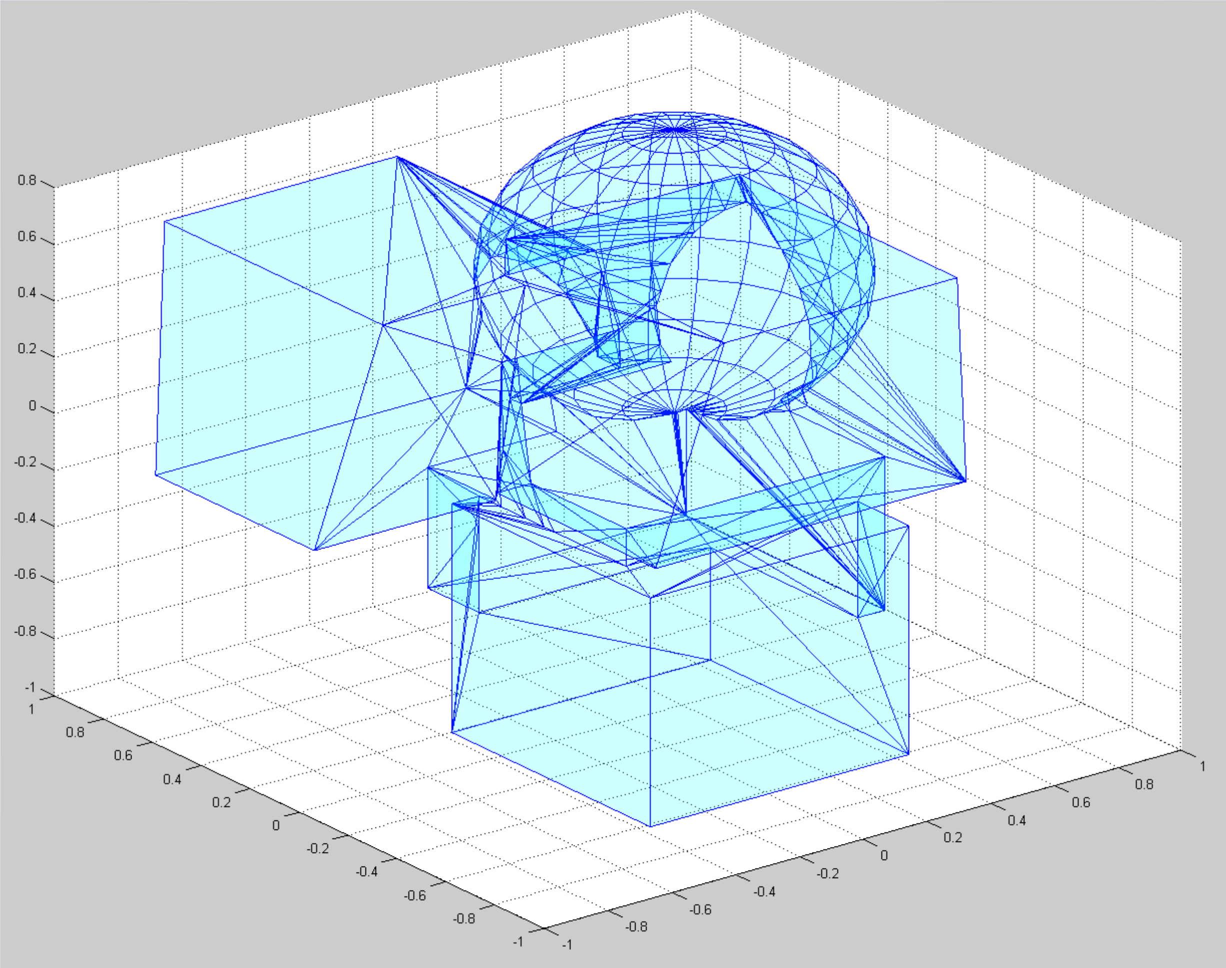
2. Usage of bit masks for storing voxels



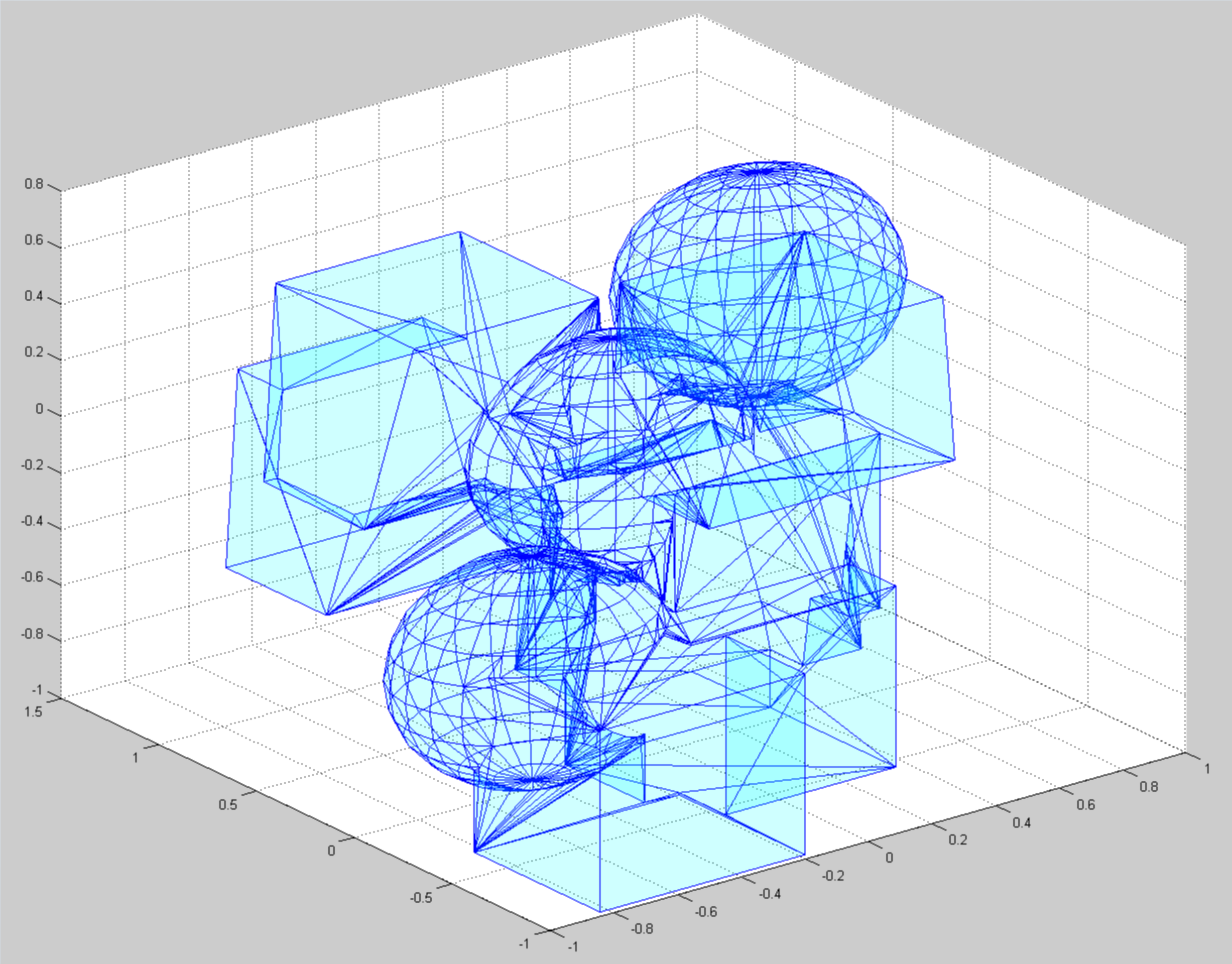
Scaling of Multi-Union vs. Boolean solid



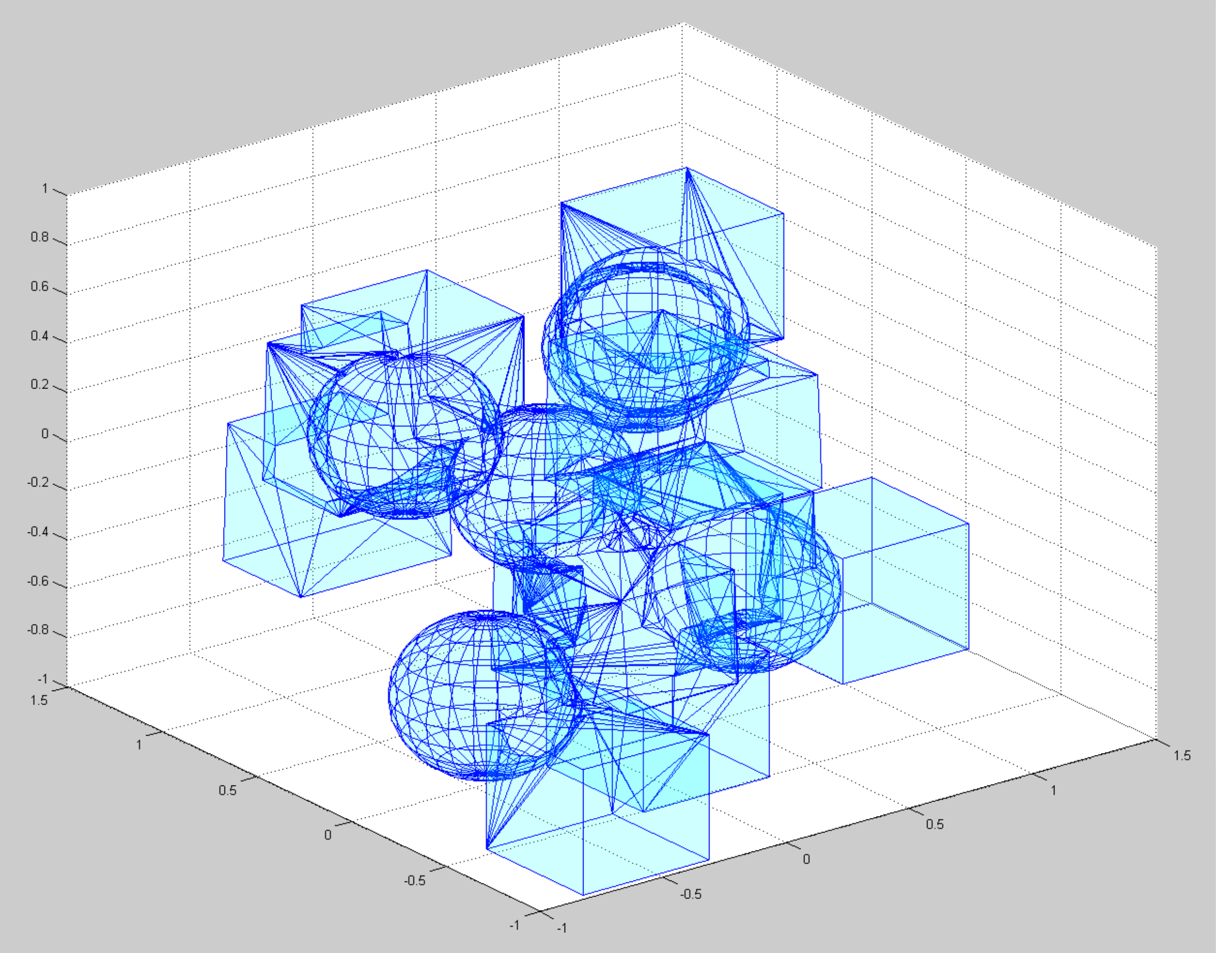
Test union solids for scalability measurements



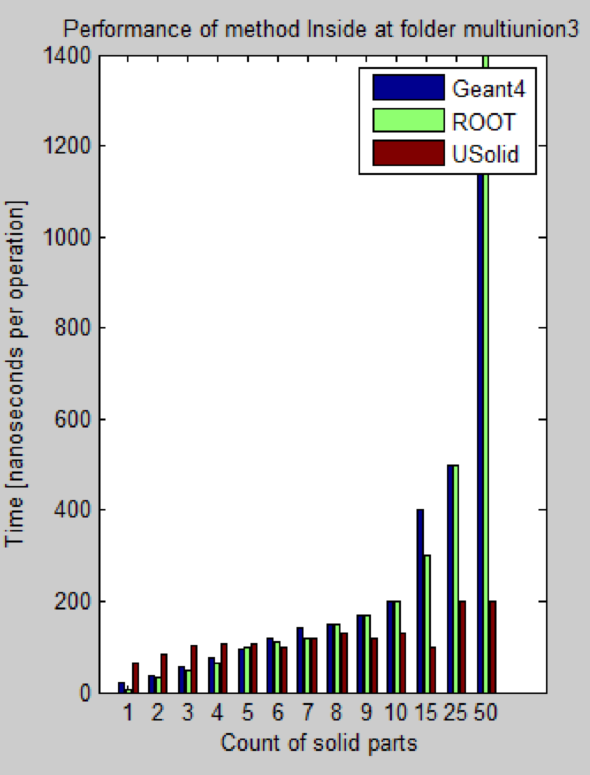
Test union solids for scalability measurements

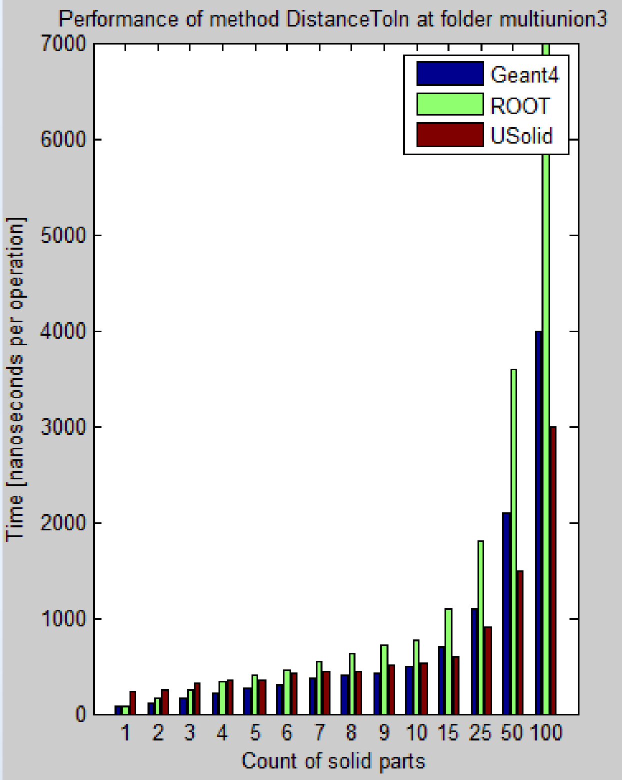


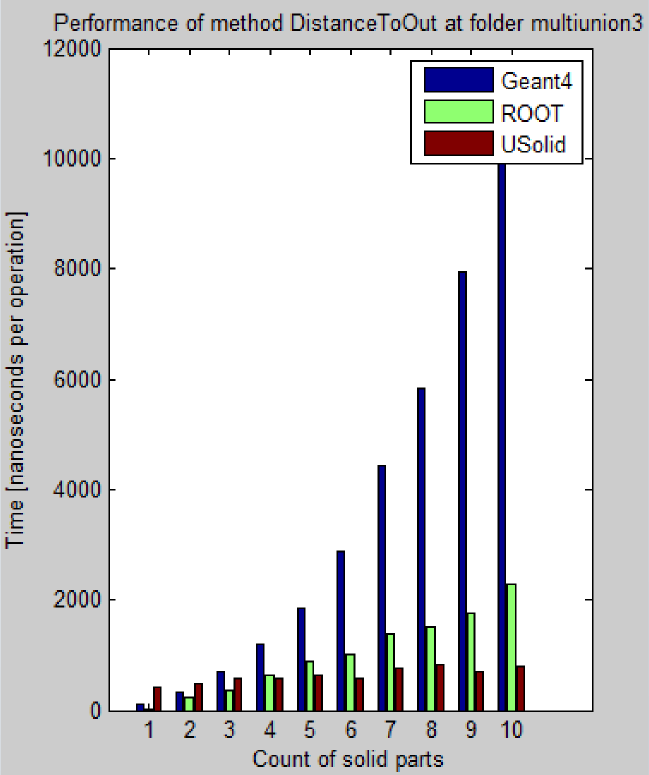
Test union solids for scalability measurements



The most performance critical methods







Future work

- Systematically analyze and implement remaining solids in the new library
- Give priority to the most critical solids and those where room for improvement can be easily identified

Thank you for your attention.

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Do you have any questions ?