

STLCutter.jl

Pere Antoni Martorell

<http://github.com/pmartorell/STLCutters.jl>

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Performed tests

Experiments from issue #11

1.1. Relative position - robustness test

- ▶ Set of 13 geometries
- ▶ Constant background mesh h -refinement
- ▶ 17 relative positions ($\Delta x = 10^{-17:-1}$)
- ▶ 17 rotation angles ($\theta = 10^{-17:-1}$)

1.2. Relative position - Poisson test

- ▶ Idem as 1.1. w/ Poisson eq. manufactured solution $u(x) = x + y - z$

2.1. h -refinement - robustness test

- ▶ 1.1. geometries
- ▶ 6 constant h -refinements

2.2. h -refinement - Poisson test

- ▶ Idem as 2.1. w/ Poisson eq. manufactured solution
 $u(x) = x^2 + y^2 - z^2$

3. Large geometry dataset

- ▶ 5k geometries filtered from Thingi10k
- ▶ Unique criterion for background mesh refinement: maximum of 100 divisions per direction

1.1. Relative position - Robustness test

Setup

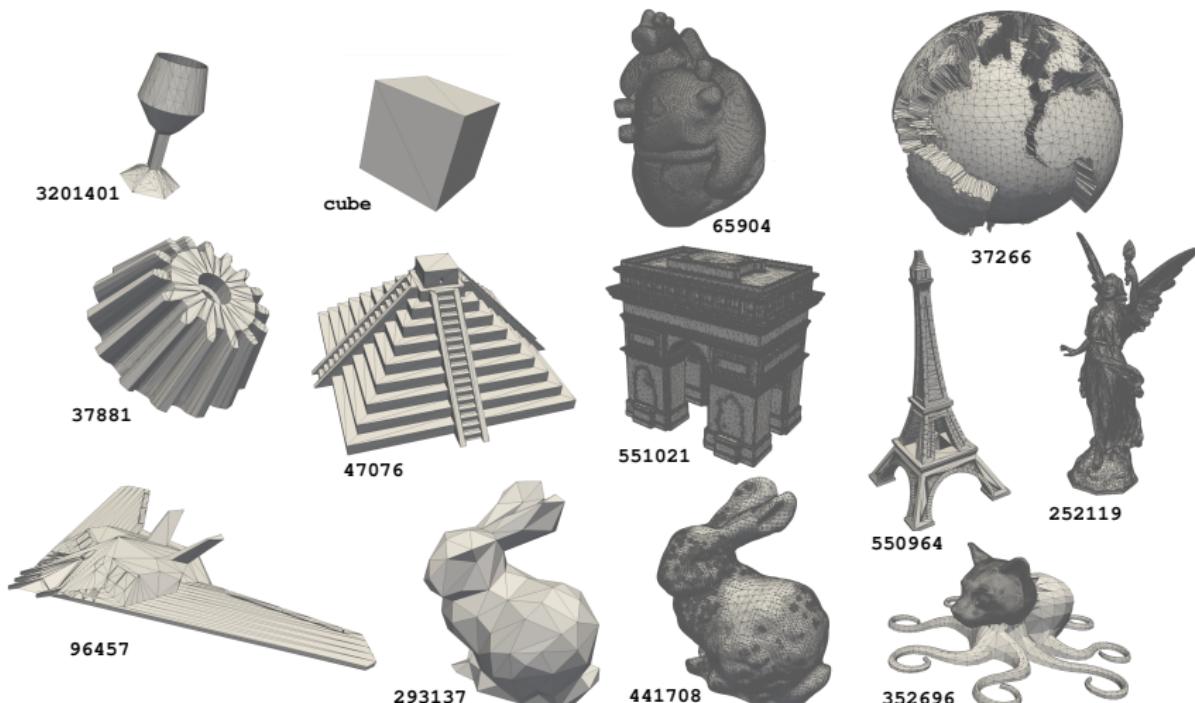
13 STLs; 17 relative positions; 17 rotation angles; $\{\Delta x, \theta\} = 10^{-17:-1}$



1.1. Relative position - Robustness test

Setup

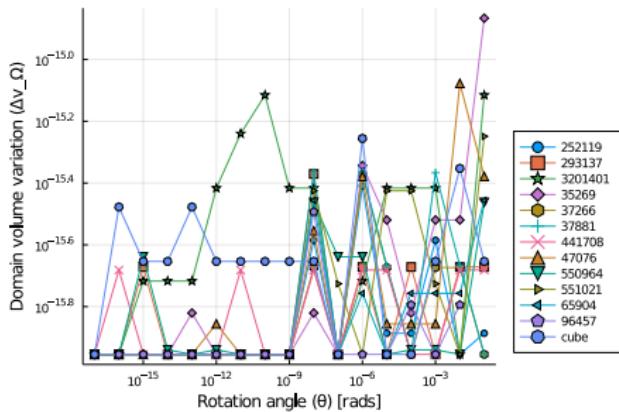
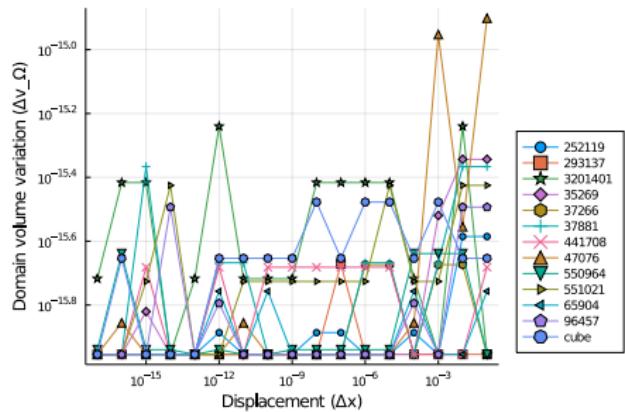
13 STLs; 17 relative positions; 17 rotation angles; $\{\Delta x, \theta\} = 10^{-17:-1}$



1.1. Relative position - Robustness test

Domain volume variation

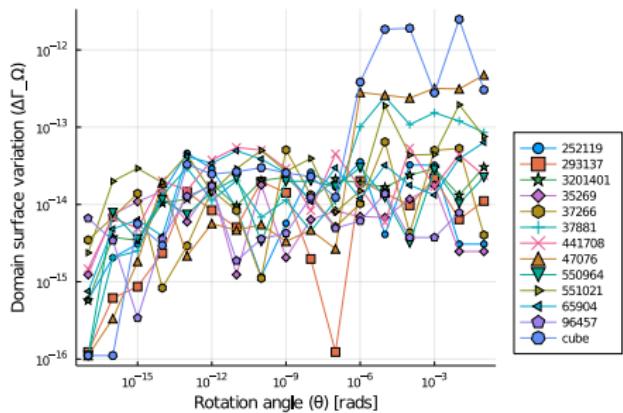
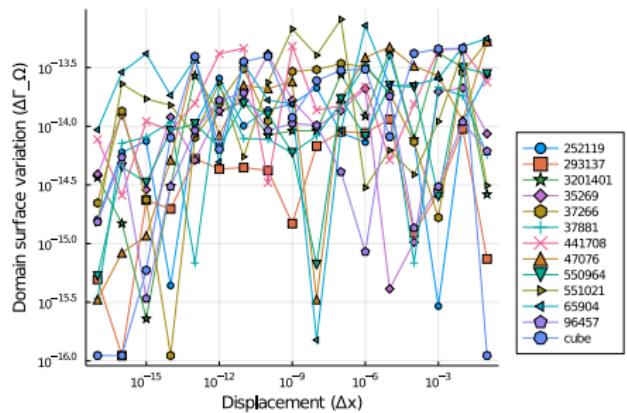
► Maximum volume variation $< 10^{-14}$



1.1. Relative position - Robustness test

Domain volume variation

- Maximum volume variation $< 10^{-11}$
- Rotations introduce more rounding errors at planes



1.2. Relative position - Poisson test

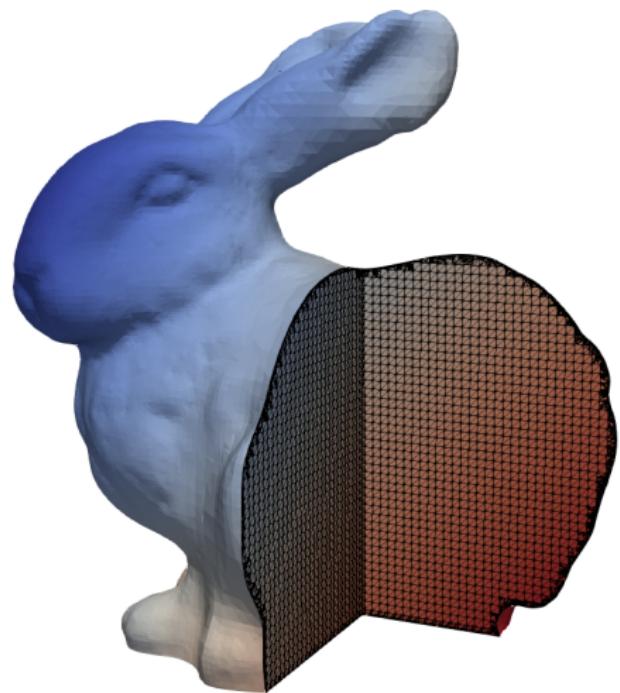
Setup

- ▶ Same configurations as 1.1.
- ▶ Poisson eq. w/ manufactured solution

$$-\Delta u = f,$$

$$u(x) = x + y - z$$

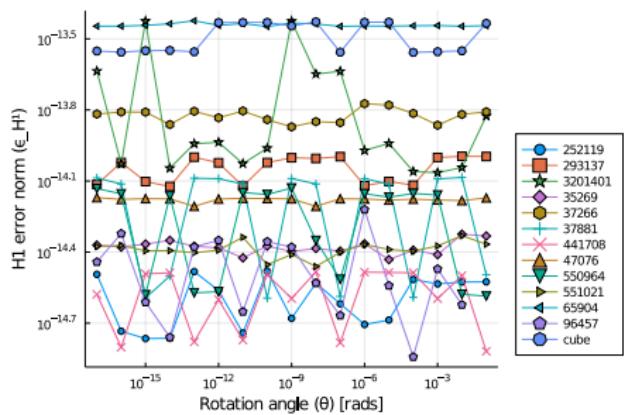
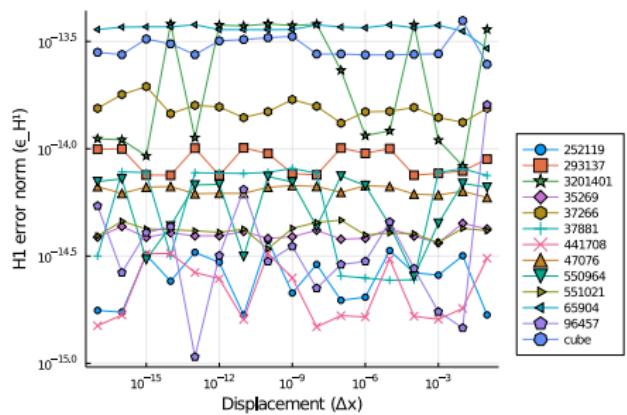
- ▶ AgFEM w/ aggregate threshold 0.5



1.2. Relative position - Poisson test

H1 error norm

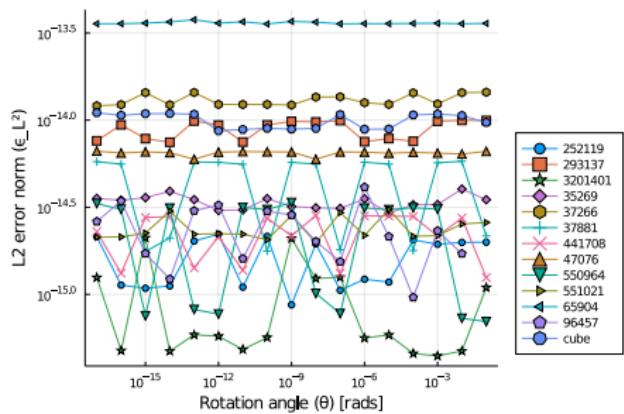
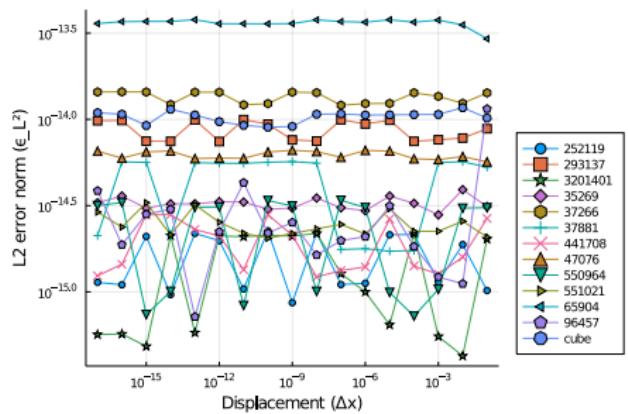
- Maximum H1 error norm $< 10^{-12}$
- Minor variations on rotation/displacement



1.2. Relative position - Poisson test

L2 error norm

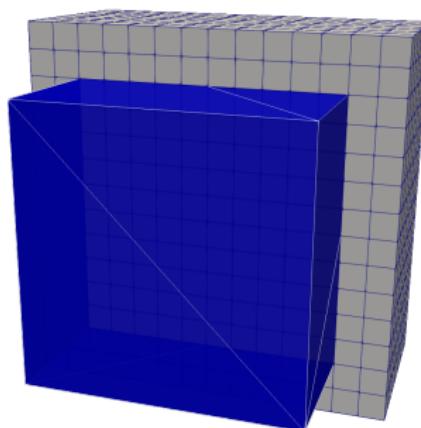
- Maximum L2 error norm $< 10^{-13}$
- Minor variations on rotation/displacement



2.1. *h*-refinement - Robustness test

Setup

- ▶ 13 geometries from 1.1.
- ▶ 6 refinement sizes: $N_{max} = 14 \cdot 2^{0:5}$

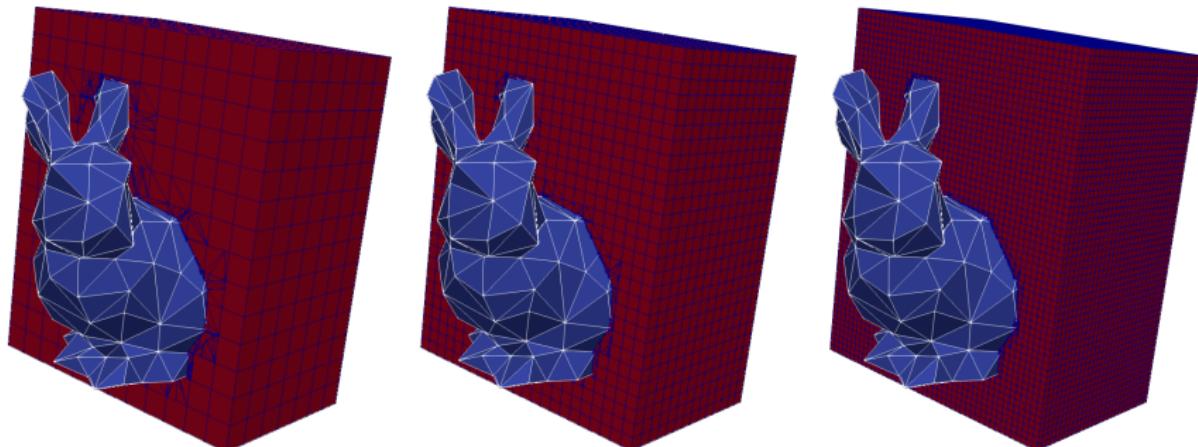


NOTE 1: The N_{max} is multiple of 14 to force the STL faces and background cell faces to be aligned, thus stress more the algorithm. As the background mesh is expanded 0.2 in each direction of the STL's bounding box.

2.1. h -refinement - Robustness test

Setup

- ▶ 13 geometries from 1.1.
- ▶ 6 refinement sizes: $N_{max} = 14 \cdot 2^{0:5}$

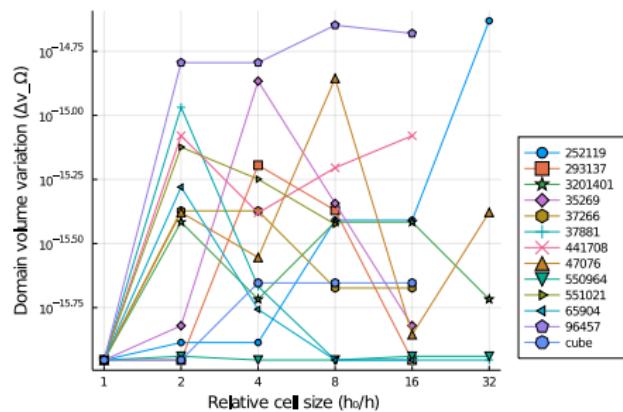
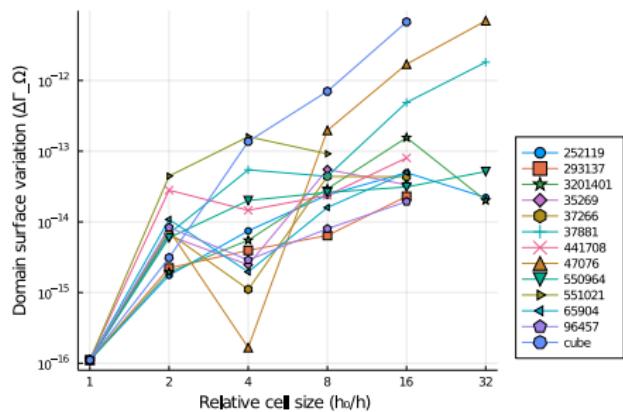


NOTE 2: In order to keep the background cell aspect ratio, N_{max} is the number of divisions on the largest side of the bounding box.

2.1. h -refinement - Robustness test

h -refinement

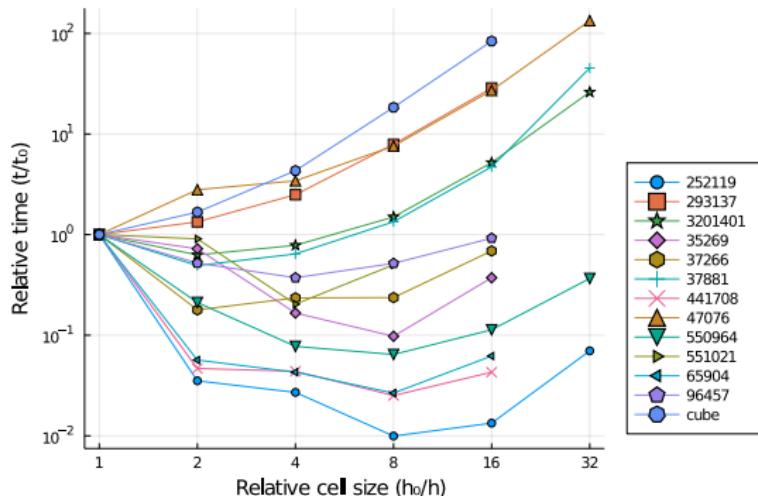
- Surface variation increases with $1/h$ ($\Delta\Gamma < 10^{-11}$)
- Volume is constant at refinement ($\Delta V < 10^{-14}$)



2.1. h -refinement - Robustness test

CPU time with h -refinement

- Not precise measure (single runs)
- Tend to be linear after first complexity reduction



2.2. *h*-refinement - Poisson test

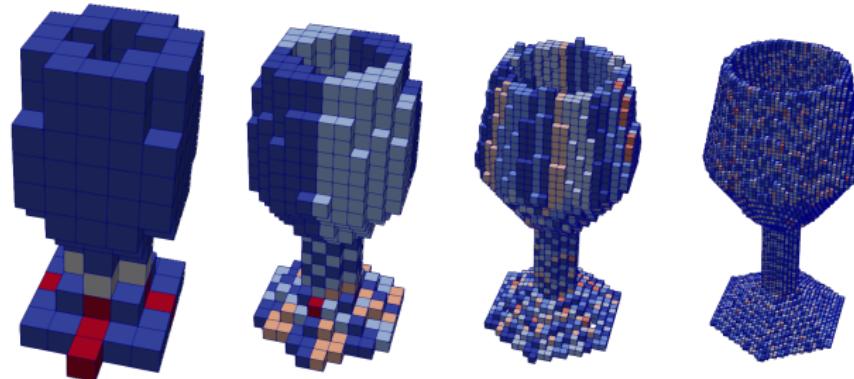
Setup

- ▶ Same configurations as 2.1.
- ▶ Poisson eq. w/ manufactured solution

$$-\Delta u = f,$$

$$u(x) = x^2 + y^2 - z^2$$

- ▶ AgFEM w/ aggregate threshold 0.5

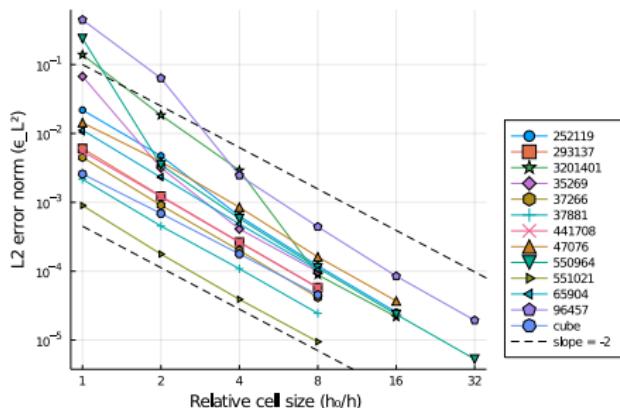
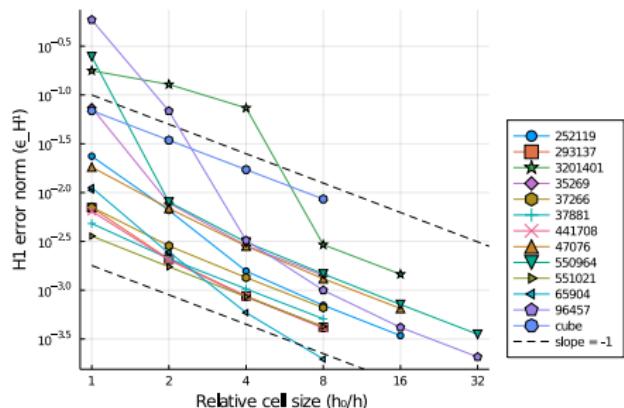


Cell aggregation in thin walls

2.2. h -refinement - Poisson test

FE convergence with h

- H1 and L2 error norms tend to the convergence slope



3. Large geometry dataset

Setup

- ▶ 5052 geometries filtered from Thingi10k
- ▶ $N_{max} = 100$ (unique h -refinement criterion)



3. Large geometry dataset

Summary

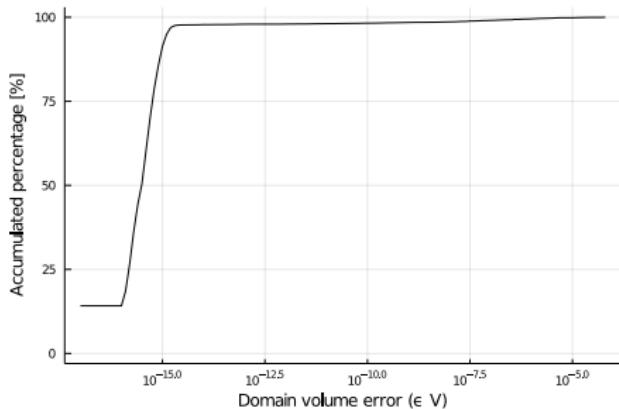
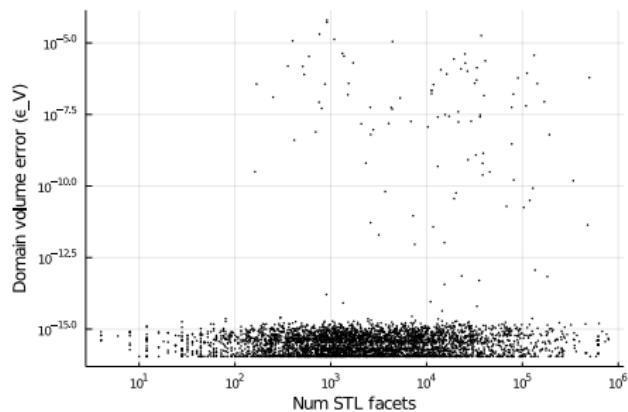
```
Total: 5052
  └── Not available: 312
  └── Load error: 6
  └── Available: 4734
      └── Launched on HPC: 4544
          └── Success: 4440
          └── Large volume error: 70
          └── Not ended: 34
      └── Pending: 170
      └── Degenerate: 20
```

NOTE: As shown in next slides large volume error is due to small facets.

3. Large geometry dataset

Volume error

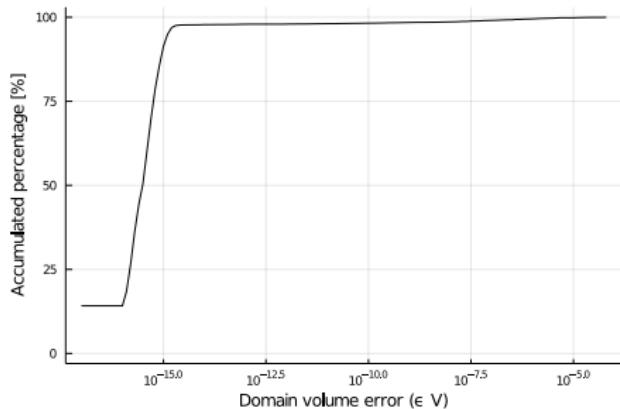
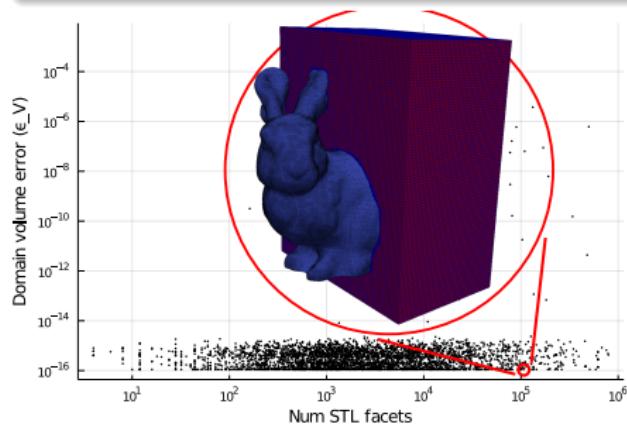
- $\epsilon_V = V_{IN} + V_{OUT} - V_{BBOX}$
- 98.6% of 4136 is below 10^{-9}
- All STLs above 10^{-9} contain small facets



3. Large geometry dataset

Volume error

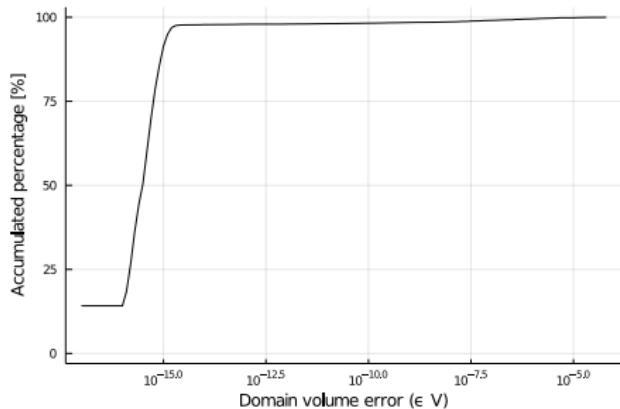
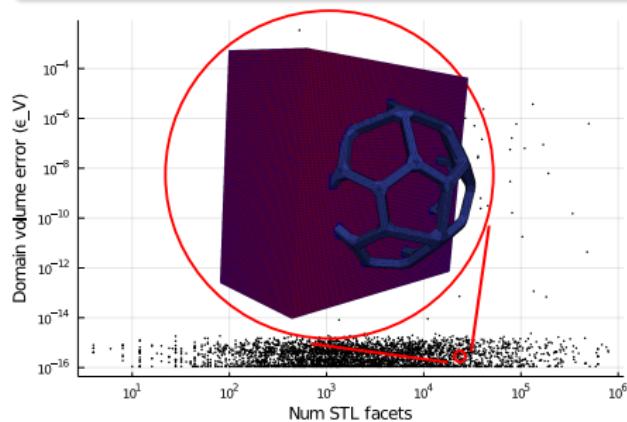
- $\epsilon_V = V_{IN} + V_{OUT} - V_{BBOX}$
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3. Large geometry dataset

Volume error

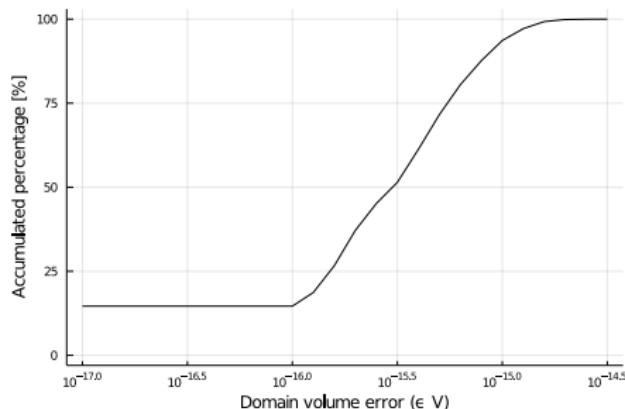
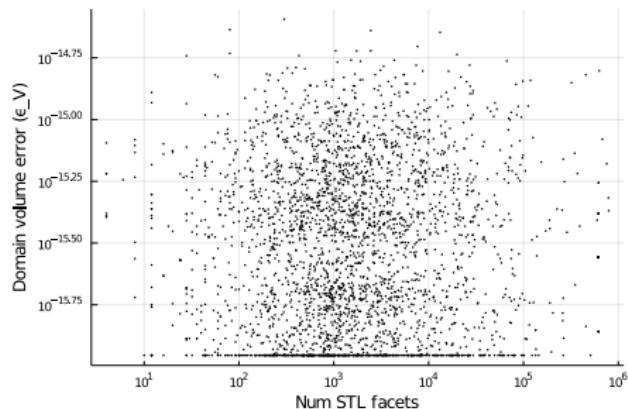
- $\epsilon_V = V_{IN} + V_{OUT} - V_{BBOX}$
- 98.6% of 4136 is below 10^{-9}
- All STLs above 10^{-9} contain small facets



3. Large geometry dataset

Volume error [filtering STLs with small facets]

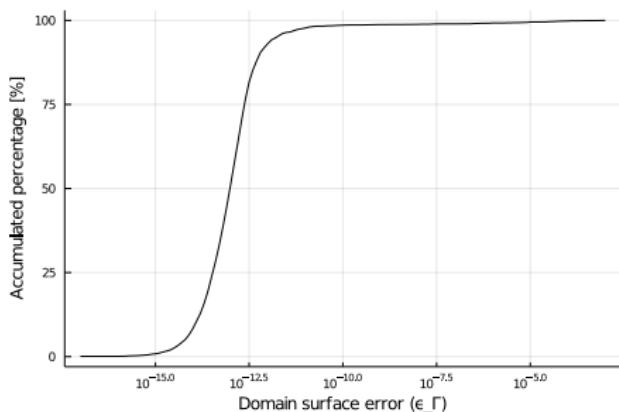
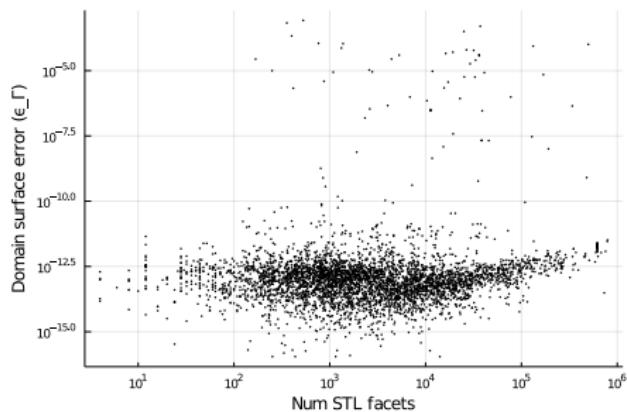
- $\epsilon_V = V_{IN} + V_{OUT} - V_{BBOX}$
- 100% is below 10^{-14}



3. Large geometry dataset

Surface error

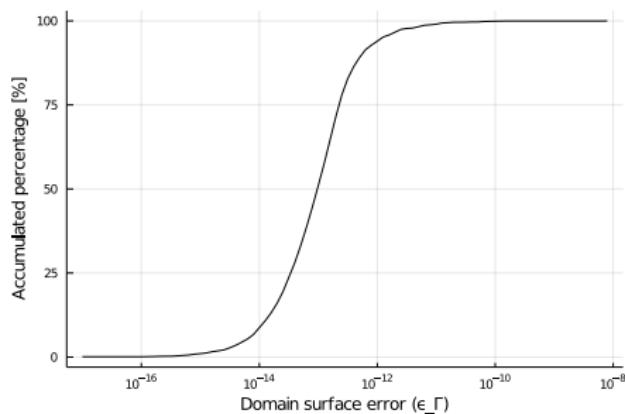
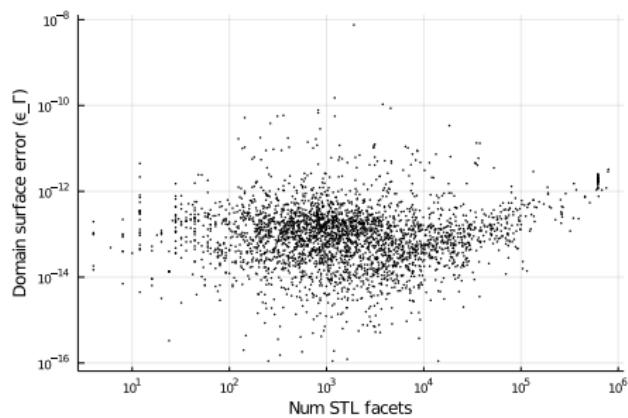
- $\epsilon_{\Gamma} = \Gamma - V_{STL}$
- 98.9% of 4136 is below 10^{-9}
- (almost) all STLs above 10^{-9} contain small facets



3. Large geometry dataset

Surface error [filtering STLs with small facets]

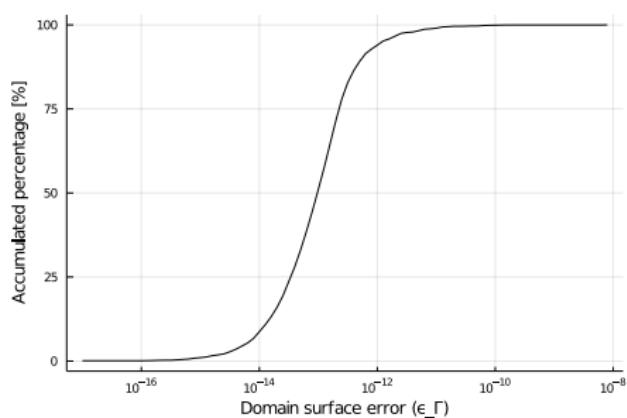
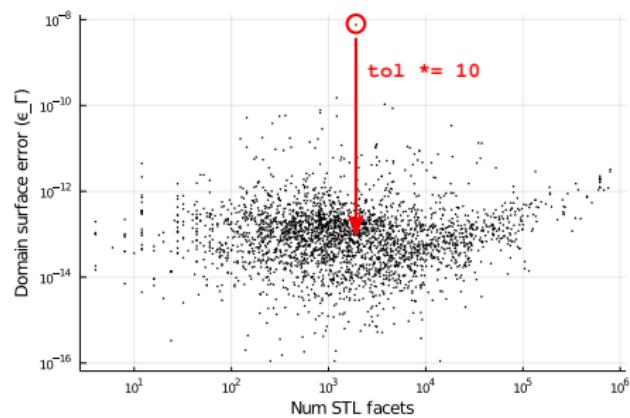
- $\epsilon_{\Gamma} = \Gamma - V_{STL}$
- 99.9% is below 10^{-9}
- One outlier can be moved by increasing the tolerance



3. Large geometry dataset

Surface error [filtering STLs with small facets]

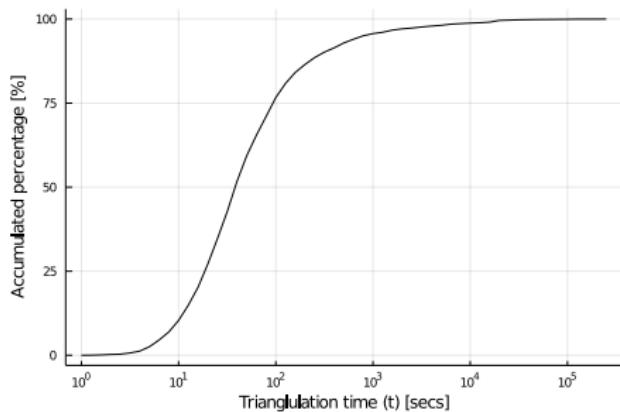
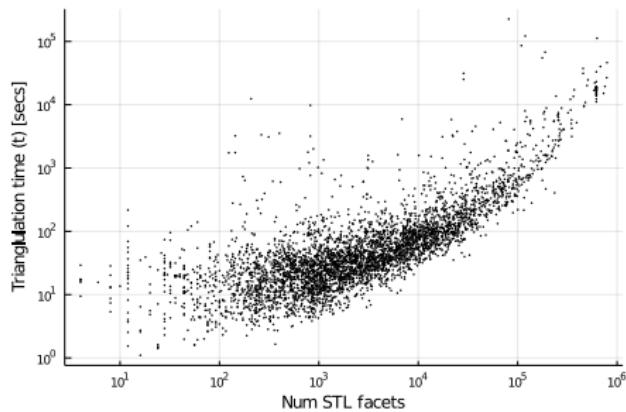
- $\epsilon_{\Gamma} = \Gamma - V_{STL}$
- 99.9% is below 10^{-9}
- One outlier can be moved by increasing the tolerance



3. Large geometry dataset

CPU time

- ▶ Not precise measure (different machines, single runs)
- ▶ Increasing with the number of STL facets



Conclusions and pending work

Conclusion so far

- ▶ Issues are depending on the geometry
- ▶ Most of problematic geometries can be found *a priori*
- ▶ Optimal convergence with AgFEM

Ongoing work

- ▶ Detect true degenerated geometries