

# Physics Driven Geometrical Model Reduction (GMM)

Vincent Vadez, François Brunetti, Pierre Alliez

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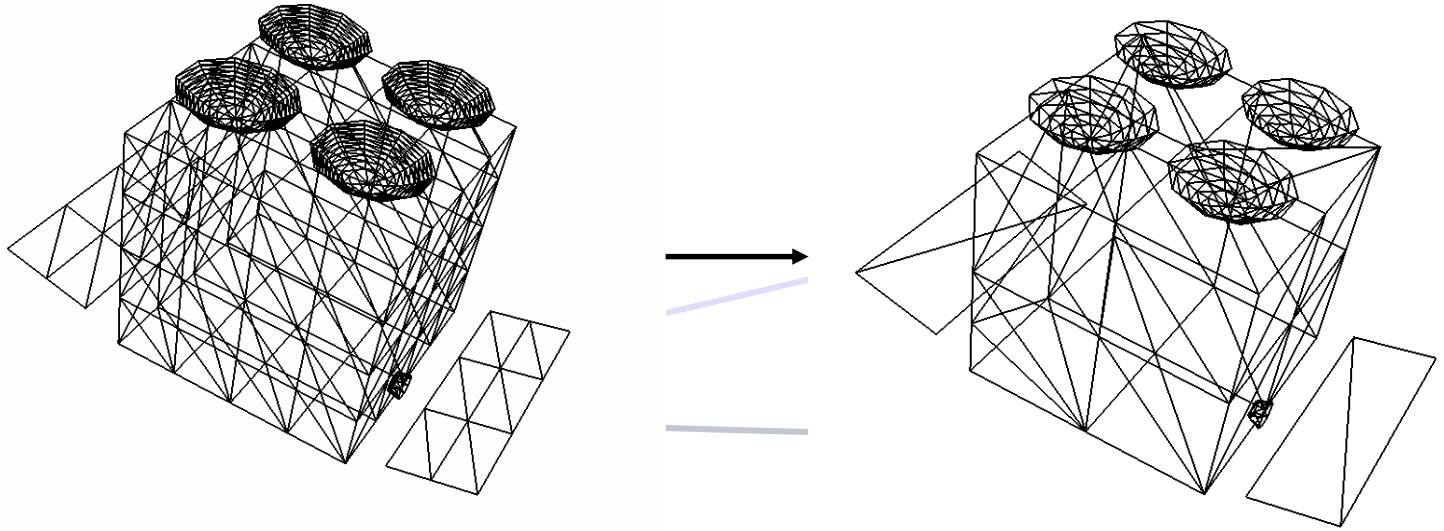
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# Physics Driven Geometrical Model Reduction (GMM)

Vincent Vadez
vincent.vadez@dorea.eu
François Brunetti
francois.brunetti@dorea.fr
Pierre Alliez
pierre.alliez@inria.fr

# Outline

- **Previous results on new view factor computation methods**
- **Physics driven geometrical model reduction**
  - Problem statement
  - Reduction process coupled to an oracle for the physical component (here thermal)
  - Limits
- **Conclusion & future works**

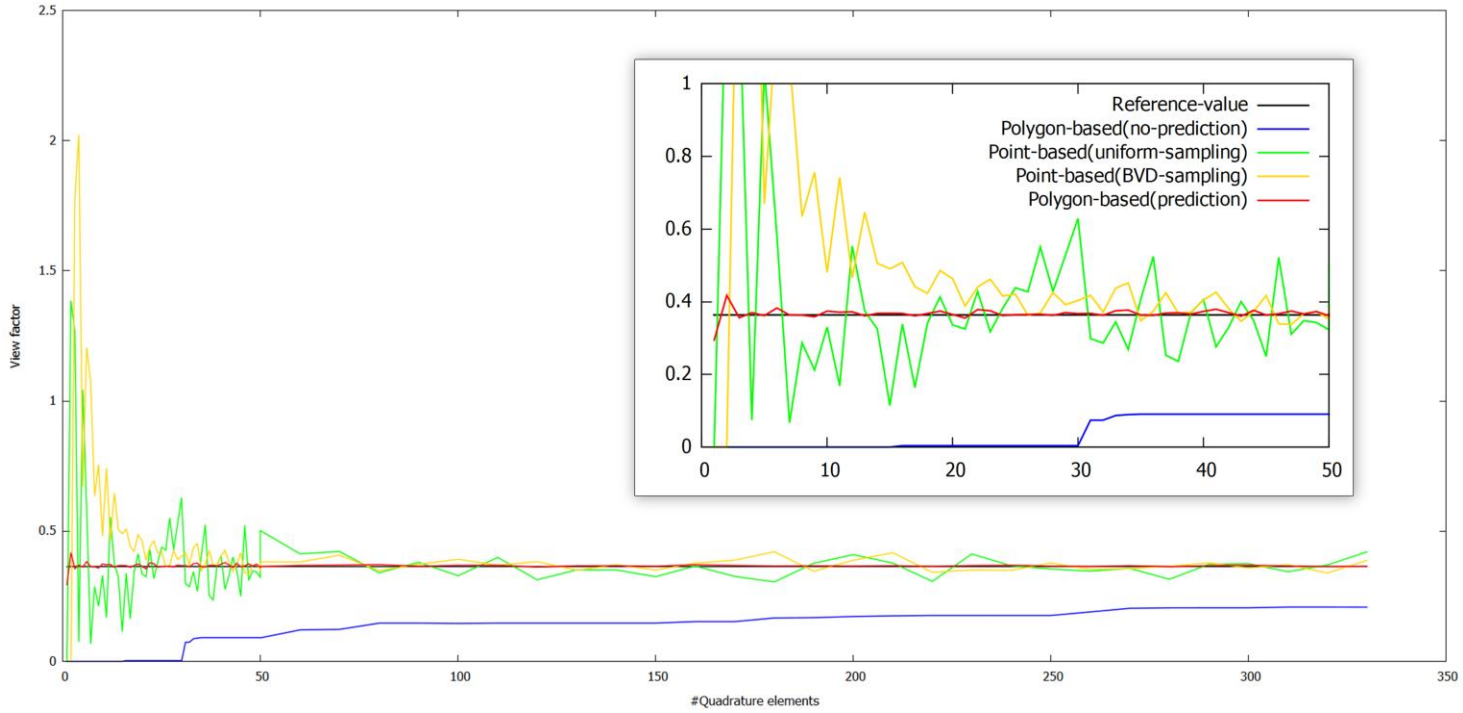


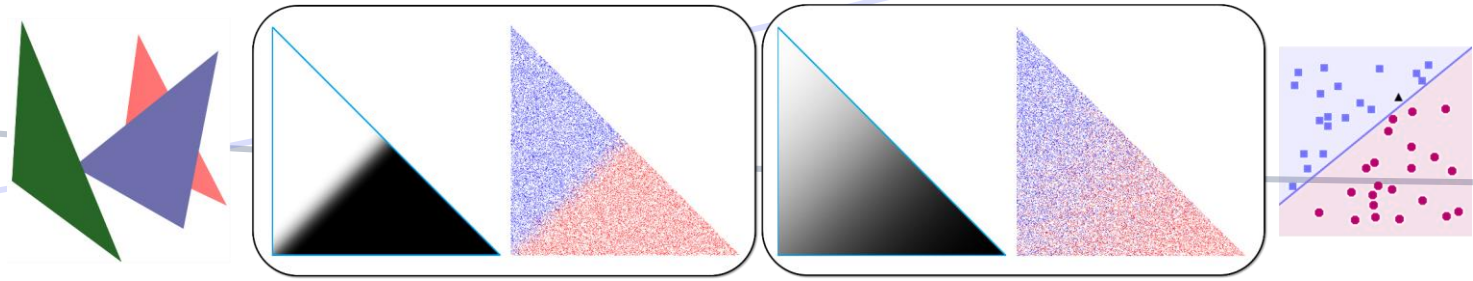
# Progressive geometric view factors

- **Polygon-based quadrature**
- **Adaptive splitting**
- **Predictions**

**More details here:**

V. Vadez, F. Brunetti, P. Alliez. Progressive Geometric View Factors for Radiative Thermal Simulation. *International Conference on Environmental Systems (ICES2020)*



# Physics driven geometrical model reduction

- **Problem statement:**
  - Radiative thermal computations are time consuming
  - Goal: Geometric reduction consulting **physics unaware** but **physics driven** thanks to an oracle
    User inputs: Geometric file & decimation step
    Output: Distortion

- **Global generic architecture:**
  - Preparation: reference calculation case request and clustering
  - Reduction: decimation iterations for each cluster
  - Reassembling: reduced geometry reconstitution and calculations request
  - Distortion: stop criteria according to user input and calculations results (max distortion)

Reduction tool
physics unaware
but
physics driven

DOREA

Oracle (physics calculus)

**Model geometry**

Inputs: reduction ratio & max distortion

**API**

**Preparation**

input: geometry format

output: distortion quantity

**Clustering**

(If required)

**Reduction**

**Reassemble geometric clusters**

**Computations**

**Distortion**

If max distortion not reached

If max distortion reached

**Output**

Reduction tool
physics unaware
but
physics driven

DOREA

Oracle (physics calculus)

**Model geometry**

Inputs: reduction ratio & max distortion

API

**Preparation**

input: geometry format

output: distortion quantity

**Clustering**

(If required)

Nodal breakdown

**Reduction**

If max distortion not reached

**Reassemble geometric clusters**

**Computations**

Thermal solver

**Distortion**

Temperatures

If max distortion reached

**Output**

# Physics driven geometrical model reduction

- **Current prototype thermal limitations**
  - View surfaces face to face only (no solar or albedo fluxes computed)
  - Node-to-node radiative couplings
  - Thermal equation solved: steady state
  - No conductive part in considered model (so only radiative couplings influence final temperatures aka radiative component totally drives temperatures)
  - Same thermo-optical properties everywhere

**Note:** if solar and albedo computations are performed, if conductive couplings are added, if thermo-optical properties are different for each node -> final reduced output would be different **BUT reduction algorithm does not change**

# Physics driven geometrical model reduction

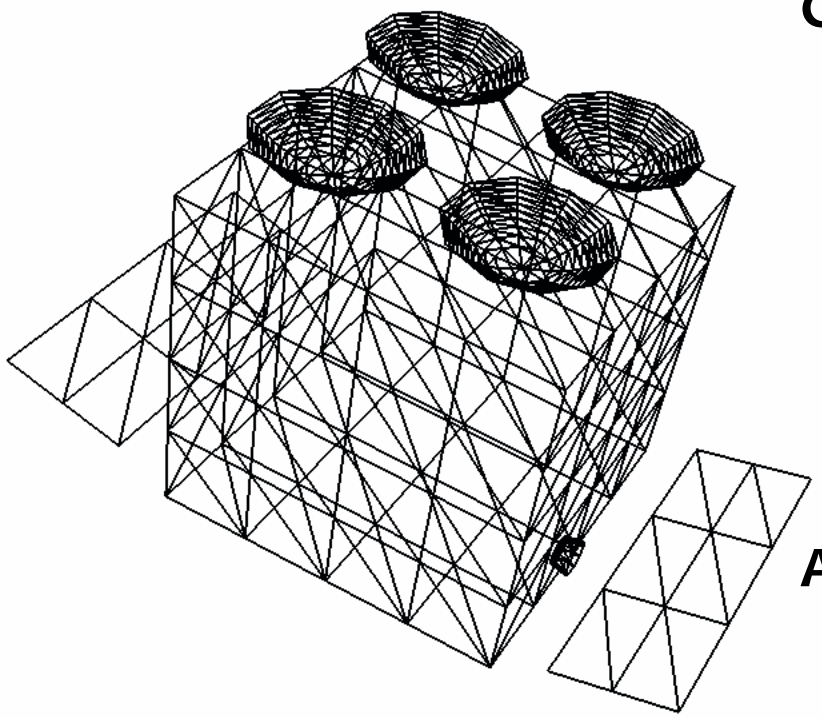
- **State of the art on geometric model reduction**
  - Edge-collapse or halfedge-collapse
  - Cost function & placement function
    - Lindstrom-Turk [1]: optimizes shape, volume & boundaries
    - Garland-Heckbert [2]: encodes approximate distance to the original mesh by using quadric matrices that it assigns to each vertex
    - Volume preserving memory-aware
    - Normal preserving




[1] Peter Lindstrom and Greg Turk. Fast and memory efficient polygonal simplification. In *IEEE Visualization*, pages 279–286, 1998.

[2] M. Garland and P. S. Heckbert. Surface simplification using quadric error metrics. In *Proc. SIGGRAPH '97*, pages 209–216, 1997.

# Physics driven geometrical model reduction



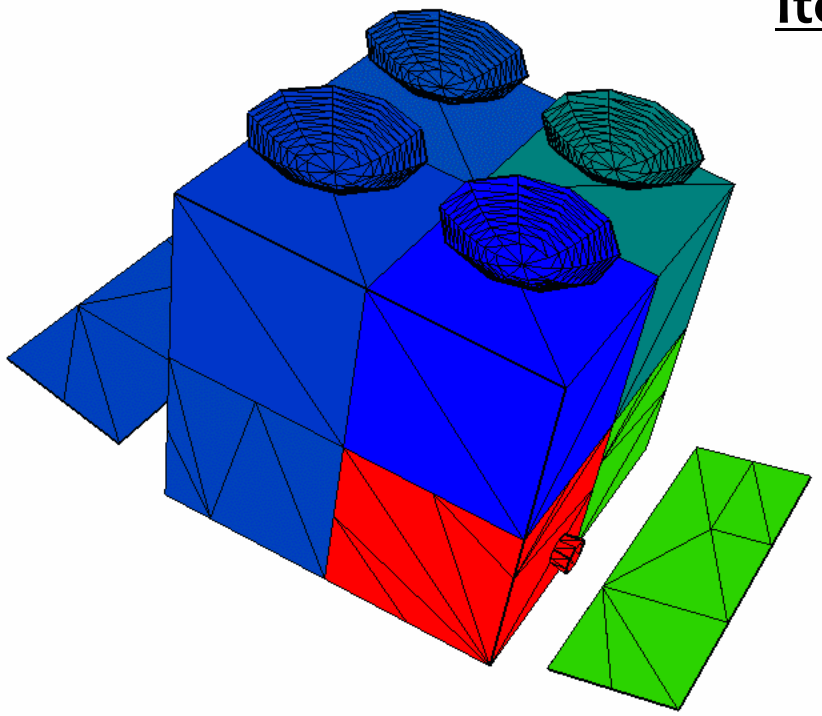
**Considered model:**

- 10 thermal nodes
- 1006 triangle faces
- 4 antennas oriented towards Earth and 2 reflectors
- 0,1W injected at the nozzle
- 1 boundary node

**Algorithm inputs:**

- reduction step ratio: **10%** of faces
- desired max distortion: **0.5° C**
- Lindstrom-Turk edge collapse (appropriate since boundaries are preserved and view factors depend on area, squared distance and orientations of the faces)

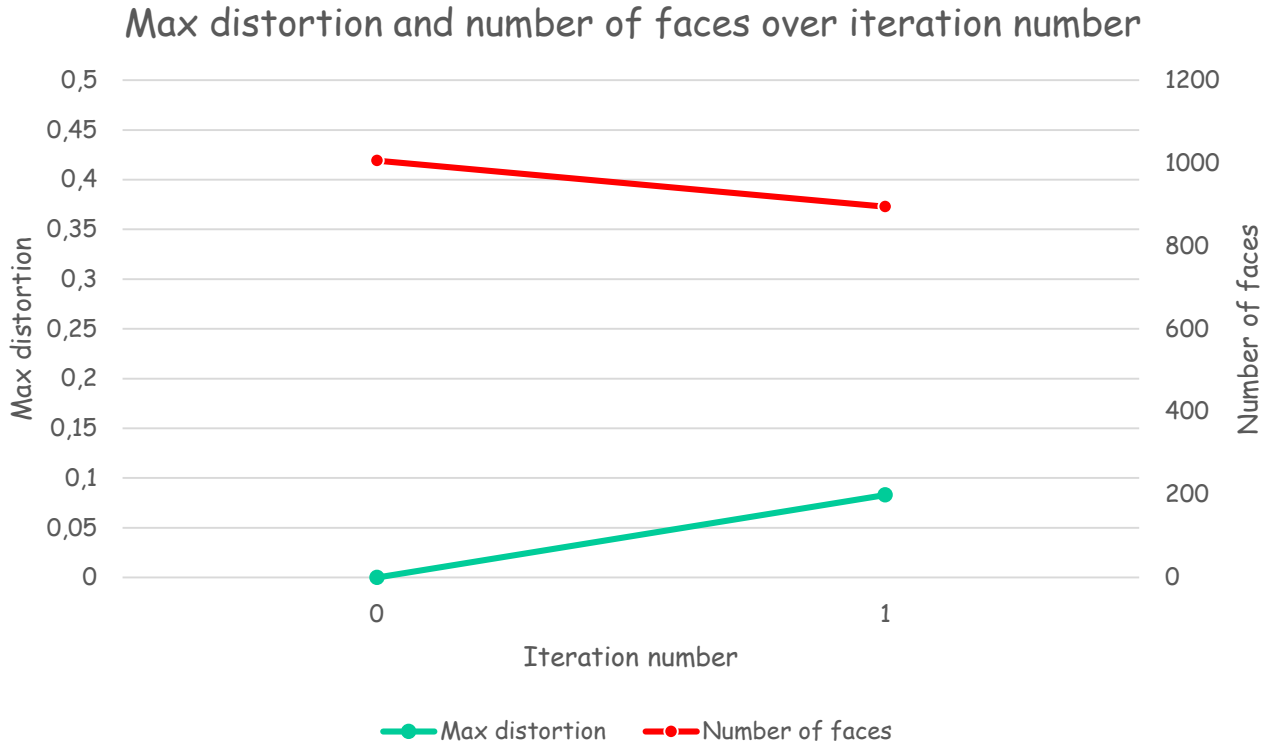
# Physics driven geometrical model reduction



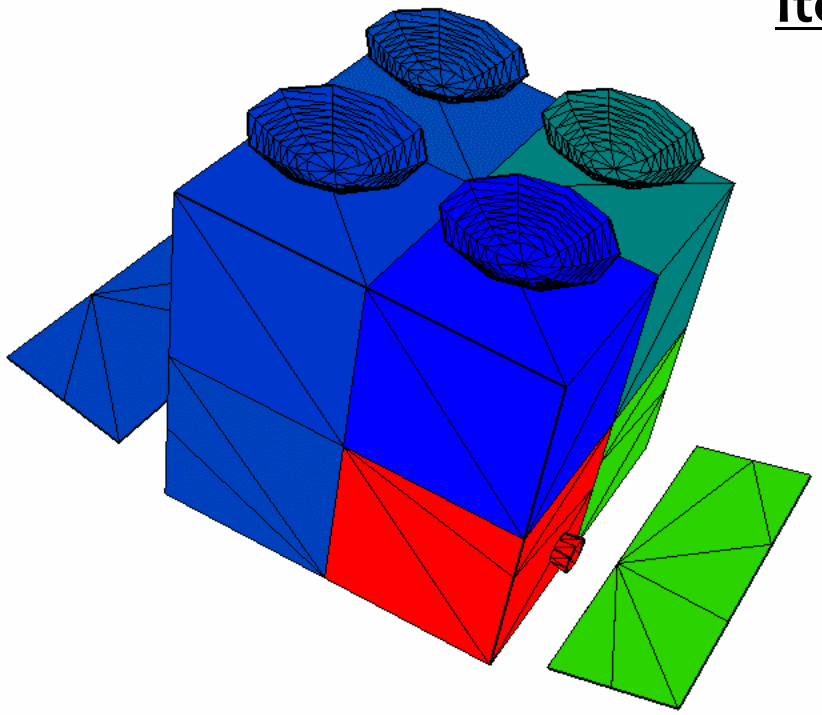
**Iteration 1:**

895 faces over 1006 original faces (89%)

Max distortion: 0.083° C



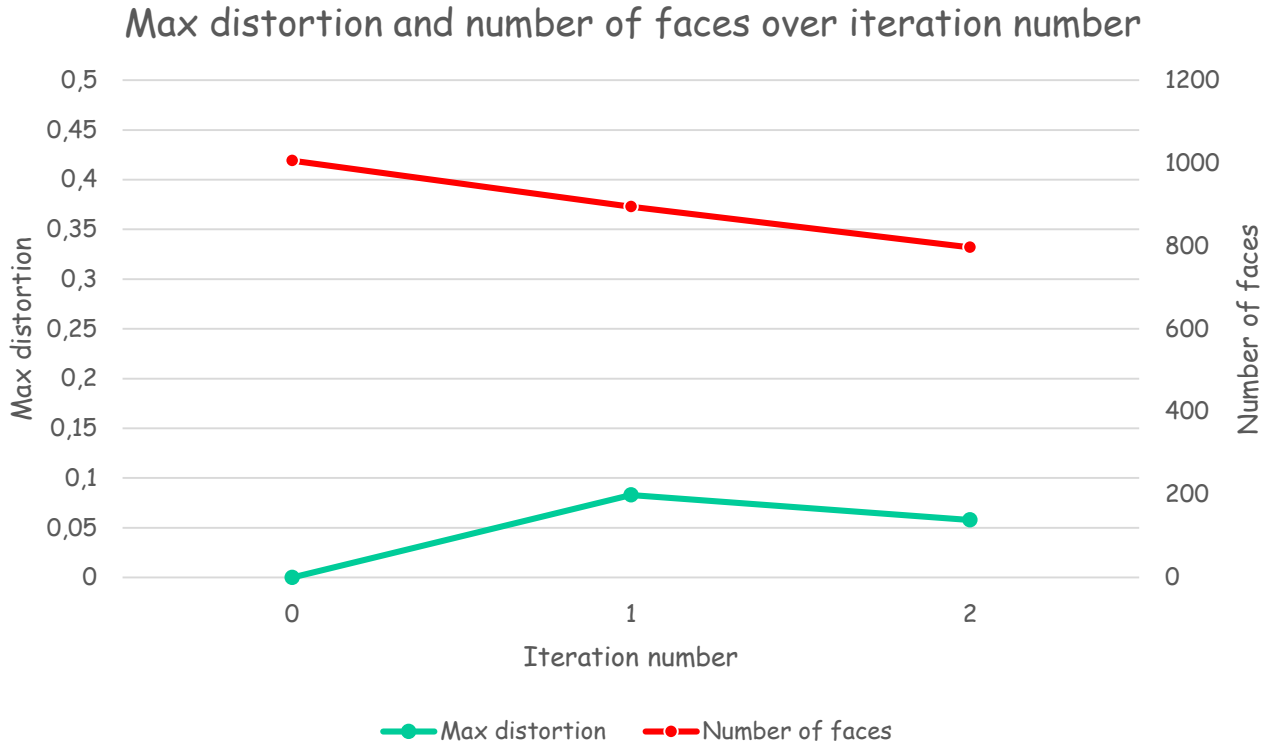
# Physics driven geometrical model reduction



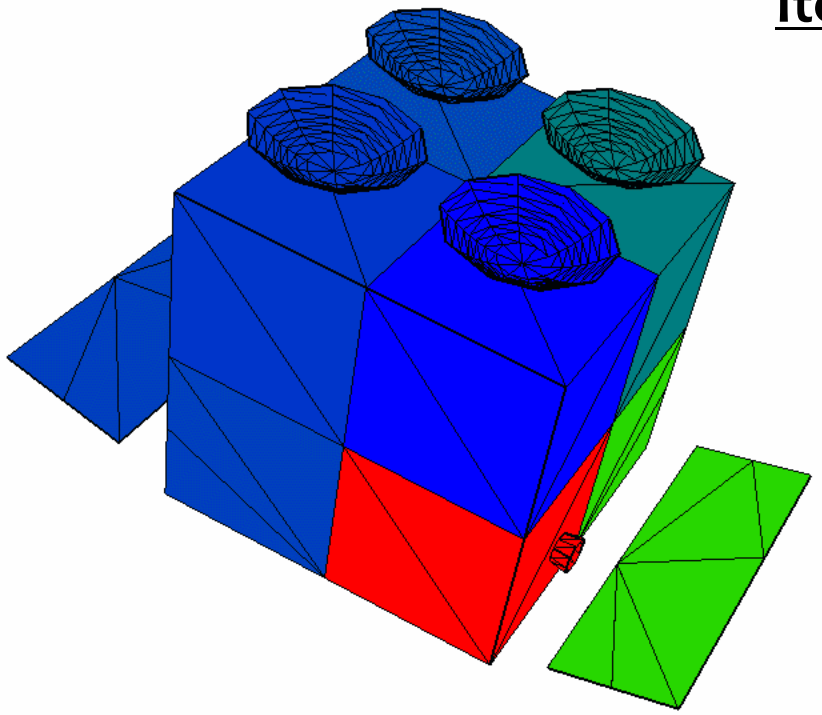
**Iteration 2:**

797 faces over 1006 original faces (79%)

Max distortion: 0.058° C



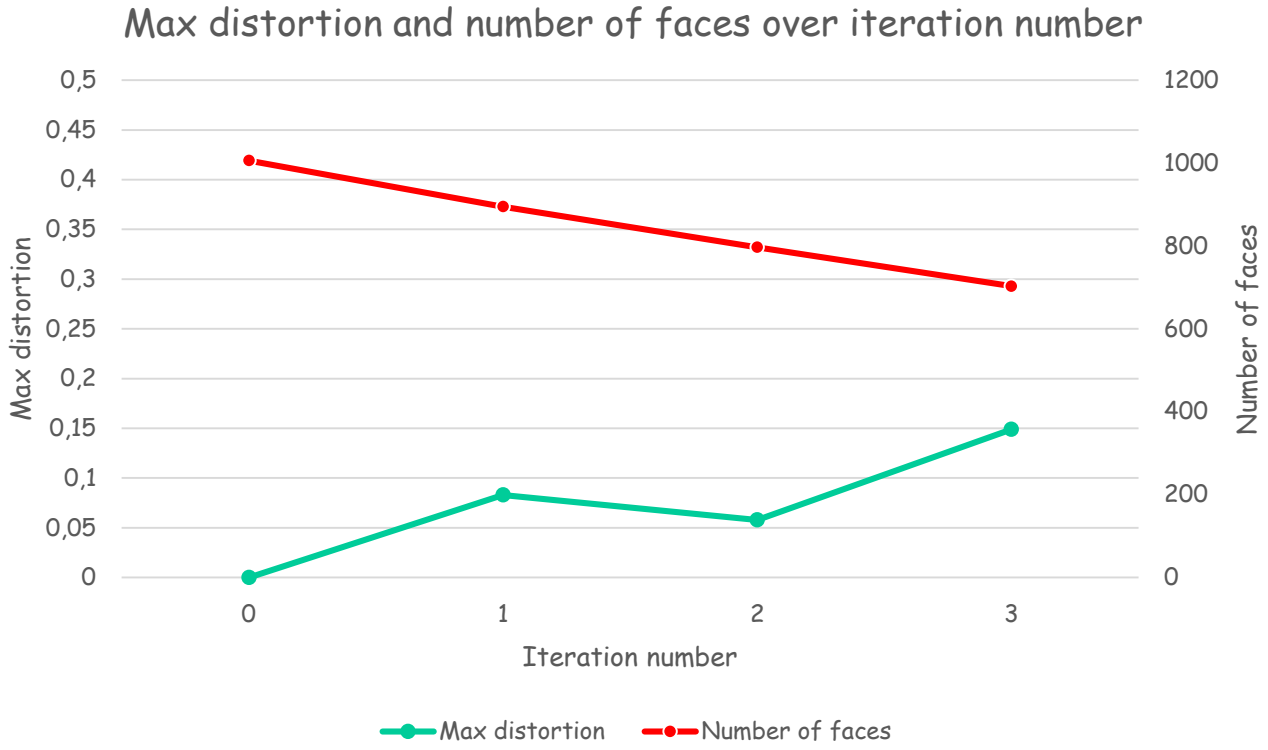
# Physics driven geometrical model reduction



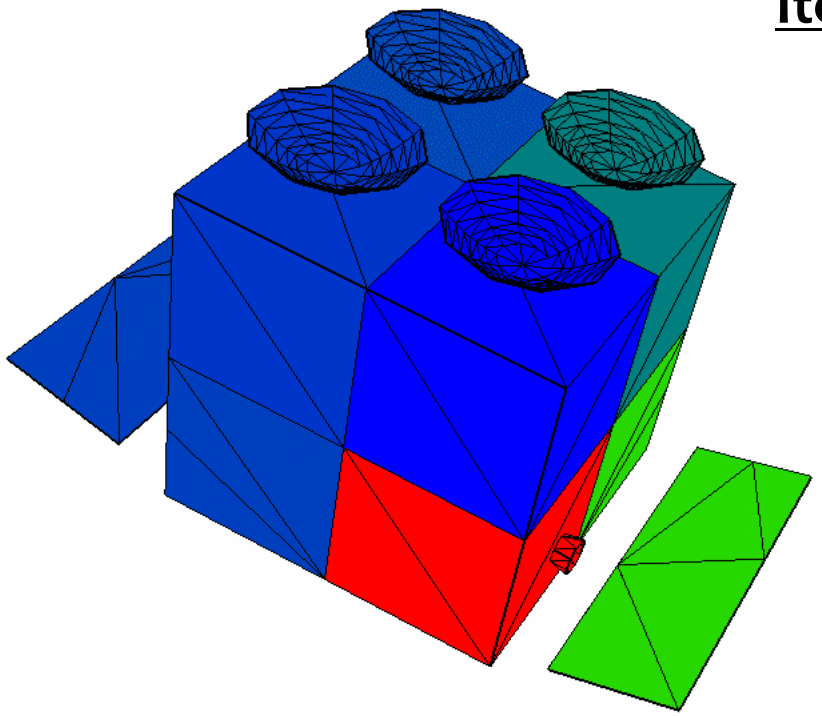
**Iteration 3:**

703 faces over 1006 original faces (70%)

Max distortion: 0.149° C



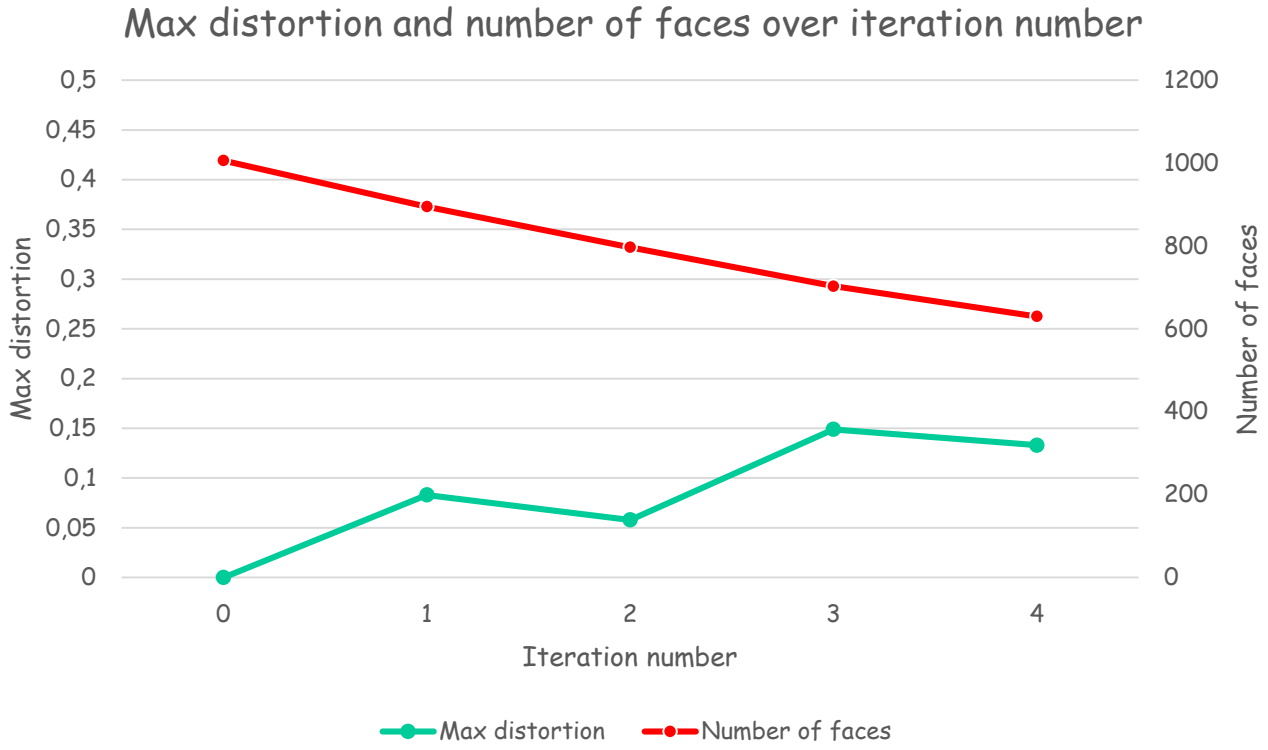
# Physics driven geometrical model reduction



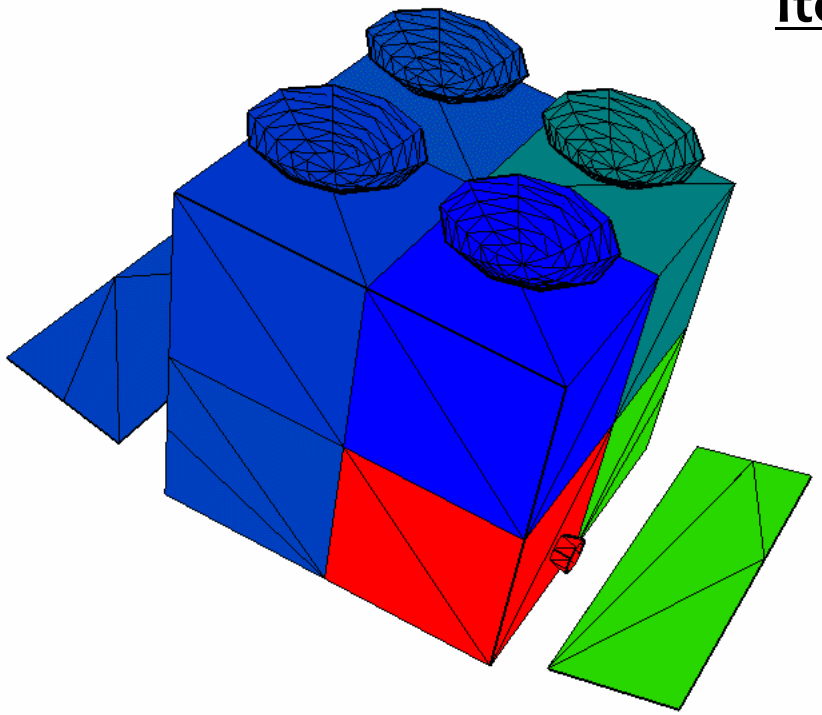
**Iteration 4:**

630 faces over 1006 original faces (63%)

Max distortion: 0.133° C



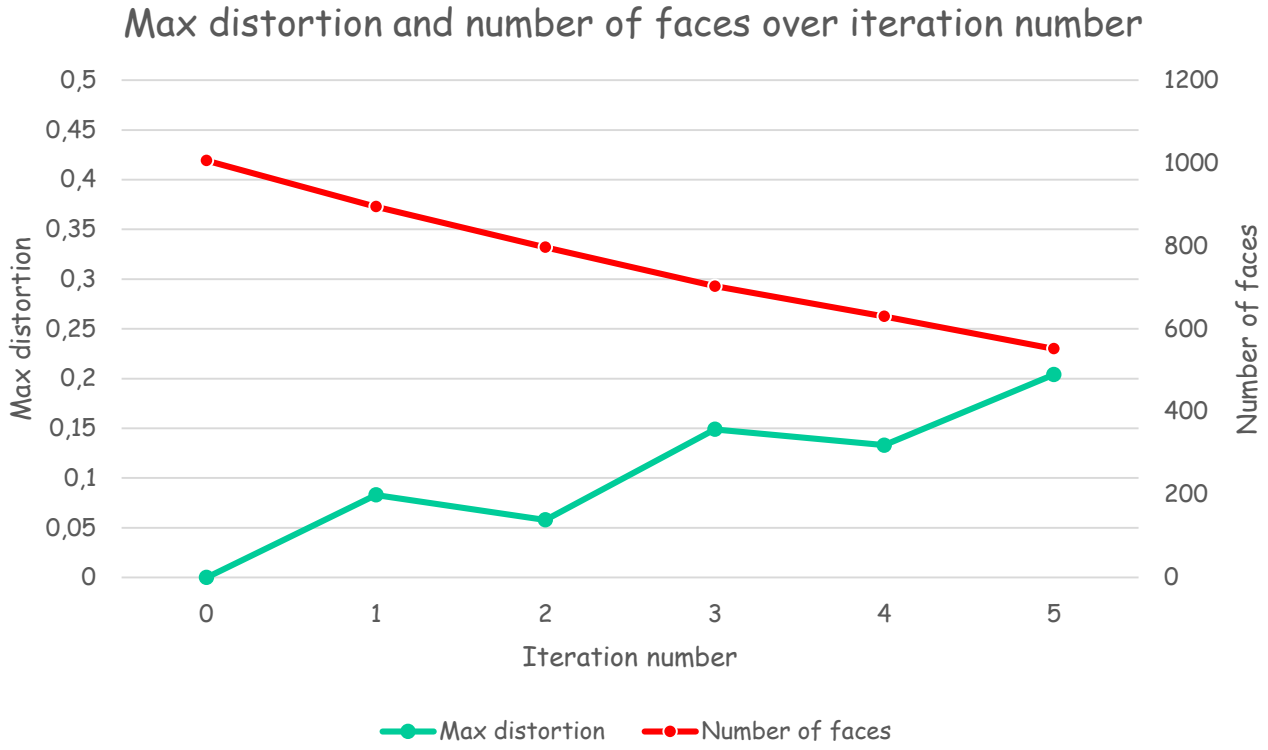
# Physics driven geometrical model reduction



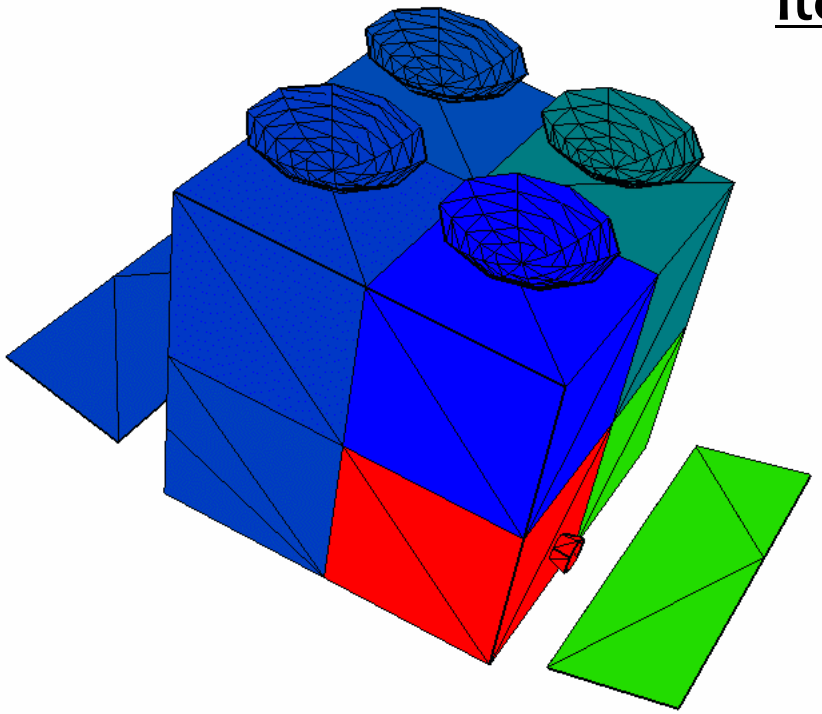
**Iteration 5:**

552 faces over 1006 original faces (55%)

Max distortion: 0.204° C



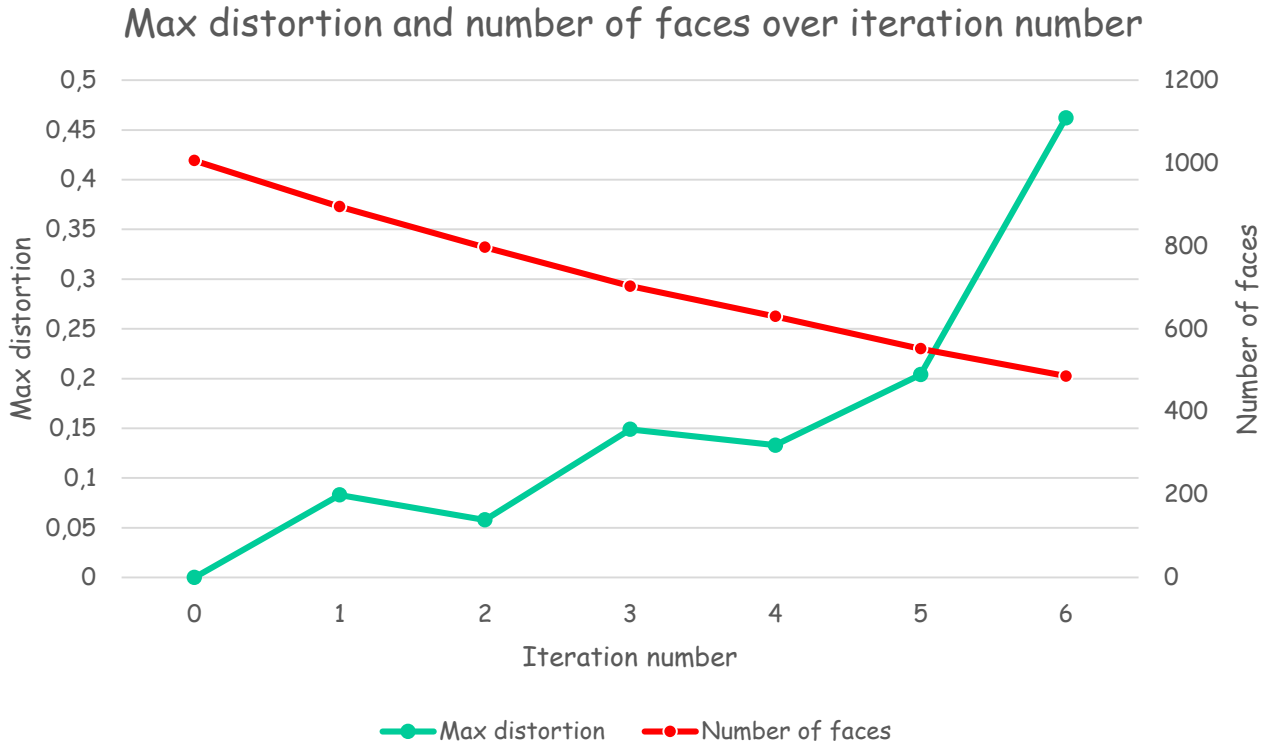
# Physics driven geometrical model reduction



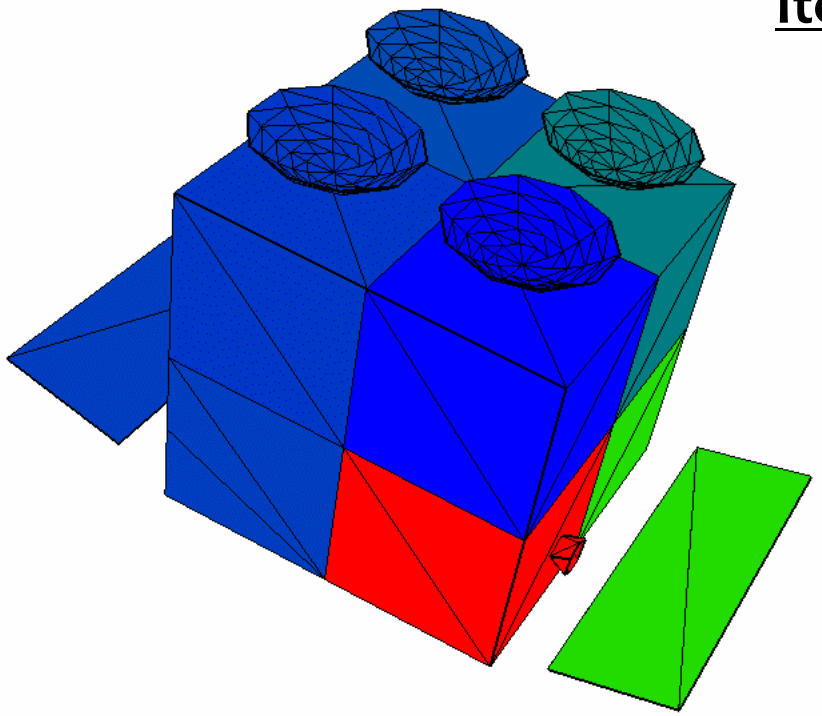
**Iteration 6:**

486 faces over 1006 original faces (48%)

Max distortion: 0.462° C



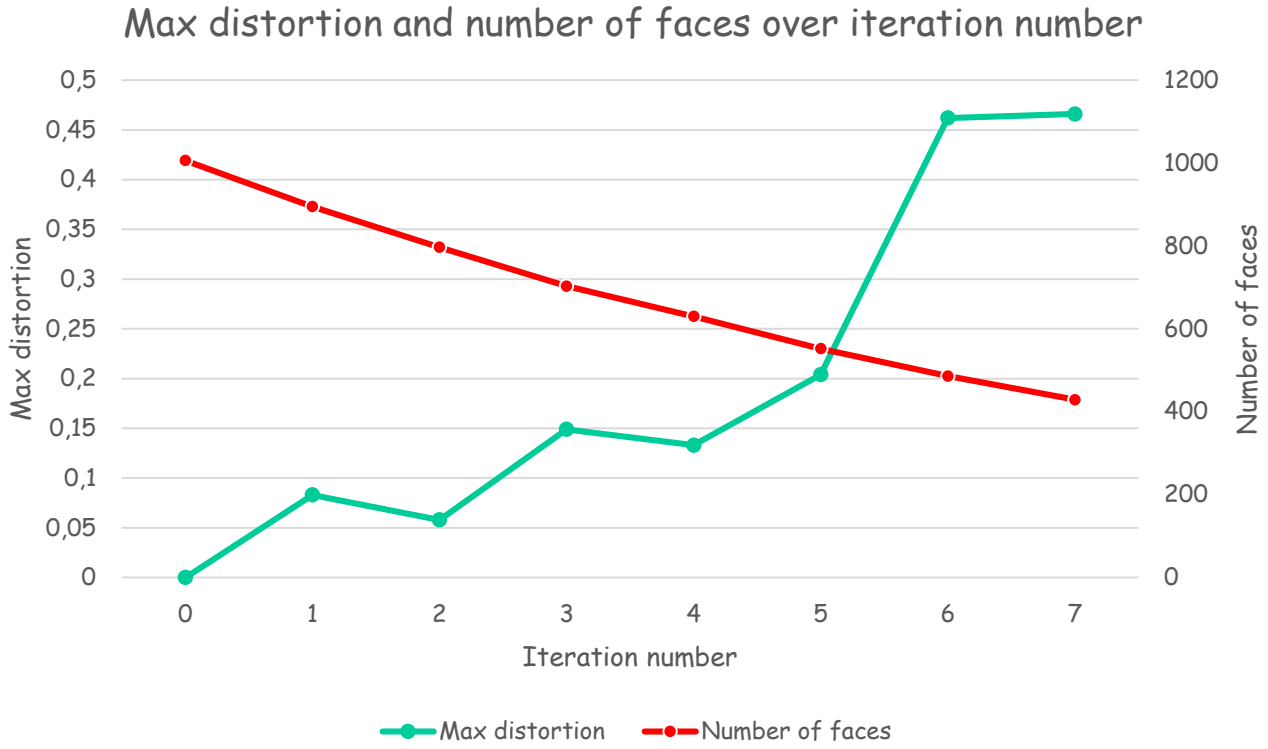
# Physics driven geometrical model reduction



**Iteration 7:**

429 faces over 1006 original faces (48%)

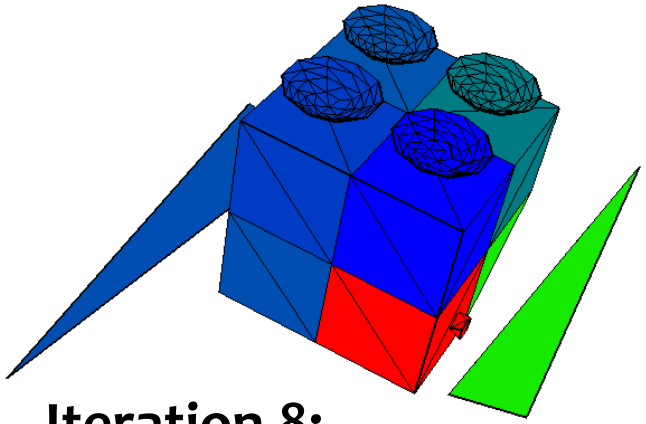
Max distortion: 0.466° C



# Physics driven geometrical model reduction

- **Conclusion**
  - Volume and boundaries preserved thanks to Lindstrom-Turk edge collapse
  - Results are acceptable until geometry is too much approximated
  - Fast computation times (around 2 minutes for reduction and thermal calculus for this model). And faster at each iteration.

**Note:** The prototype shows that the algorithm can be improved. Even if the geometry is drastically corrupted, the temperatures are still acceptable thanks to the chosen reduction metric preserving the areas.



**Iteration 8:**

370 faces

Distortion: 1.838° C

But antennas can still be reduced without altering too much the global geometry!

# Physics driven geometrical model reduction

- **Future works on geometric model reduction**
  - Progressive reduction (with adaptive ratio for each reduction step)
  - Reduce large clusters first to avoid small clusters to be too much approximated

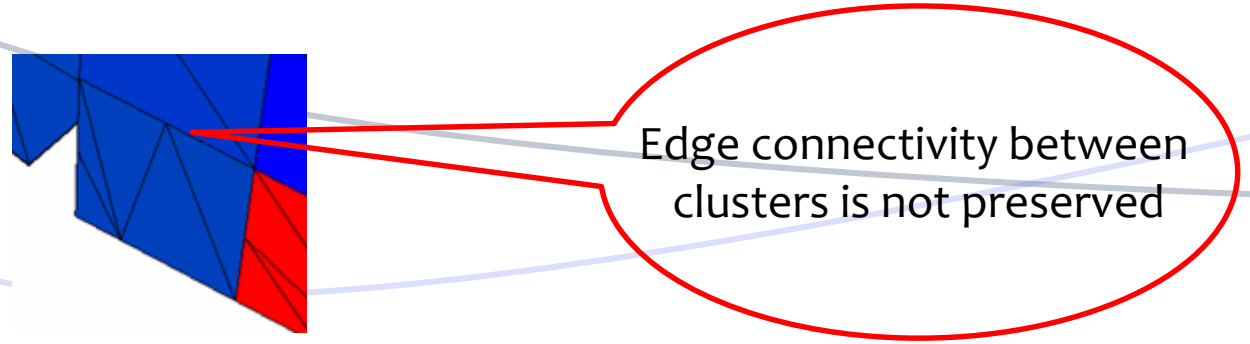
- **Future works for thermal simulation**
  - Test on a complete radiative model by adding maskings & shadows for incident fluxes (albedo, solar & Earth)
  - Test on a real model, with ESA permission Sentinel-3 and BepiColombo are good candidates
  - Examine standard exchange formats between our reduction outputs and STEP-TAS & STEP AP203
  - Sensitivity analysis on thermo-optical properties, use of machine learning to acquire thermal expertise about what drives the reduction process

# Physics driven geometrical model reduction

- **Future works for 3D conductive couplings**
  - Implement a new oracle for 3D conductive couplings (finite elements computations)
  - Max distortion based on conservation of defined interface nodes conductive couplings
  - The oracle could be improved to preserve mechanical structures characteristics

**Note:** Edge connectivity conforming is not required for the radiative calculation. Due to finite elements (volumic connectivity), the edge connectivity between clusters is mandatory.





# Thank you for your attention!

**Questions are welcomed!**