Marching Intersections: an Efficient Resampling Algorithm for Surface Management

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Introduction

- A new method for surface manipulation.
- It adopts a volumetric like approach (but not a real volumetric one).
- It presents good characteristics in term of efficiency, compactness and quality of results.

Main Applications

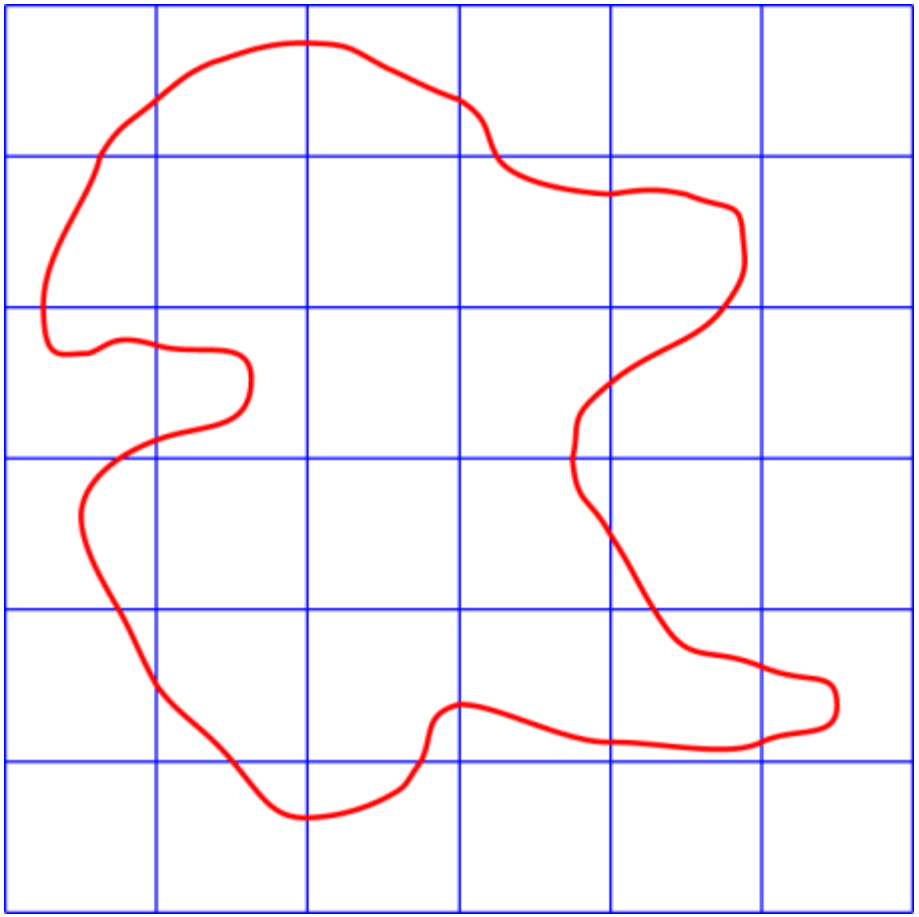
- Surface resampling
- Topological simplification
- Representation scheme conversion and Boolean operation
- Huge mesh simplification
- Range maps merging (fusion)

MI Main Steps

1. Surface Discretization
2. Removal of High Frequency Detail
3. Boolean Operation
4. Marching Cubes Code Detection
5. Surface Reconstruction

Surface Discretization

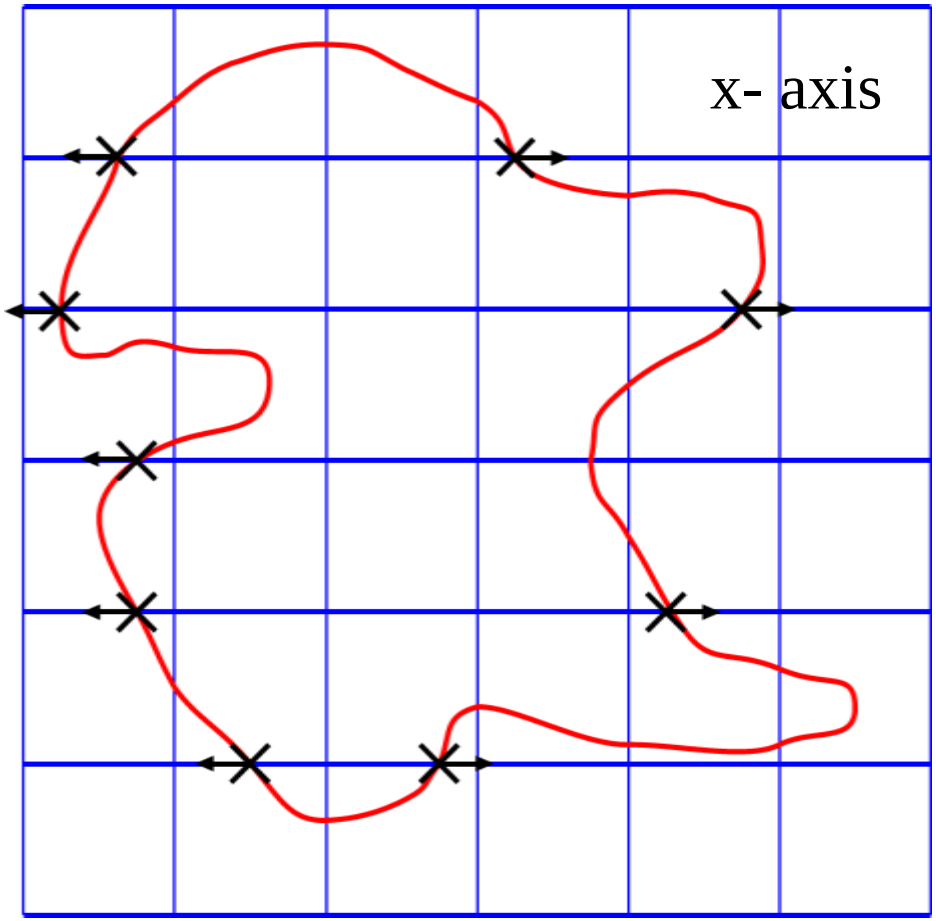
We (ideally) put the surface into a regular grid.



Surface Discretization

We detect all the intersections between the surface and a reference grid.

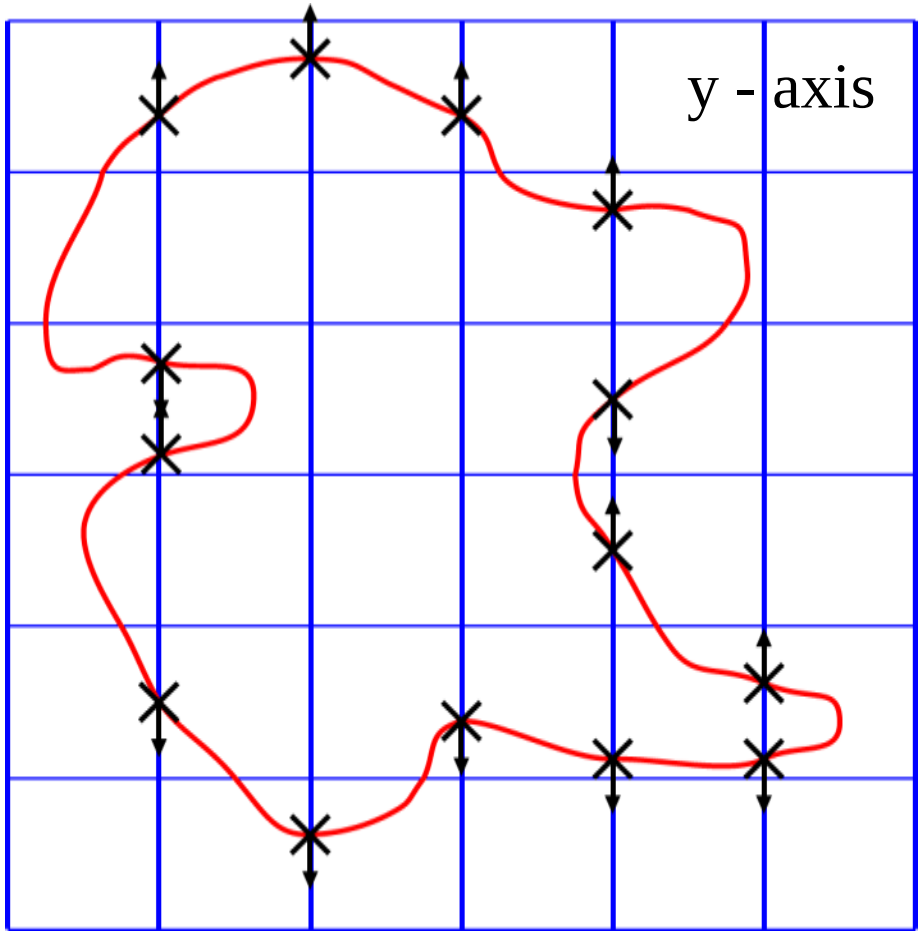
All intersections are stored into 3 sets of lists (X,Y and Z axis).



Surface Discretization

Each intersection is represented by the position along the grid line (other coordinate components are implicit) and the sign (in/out).

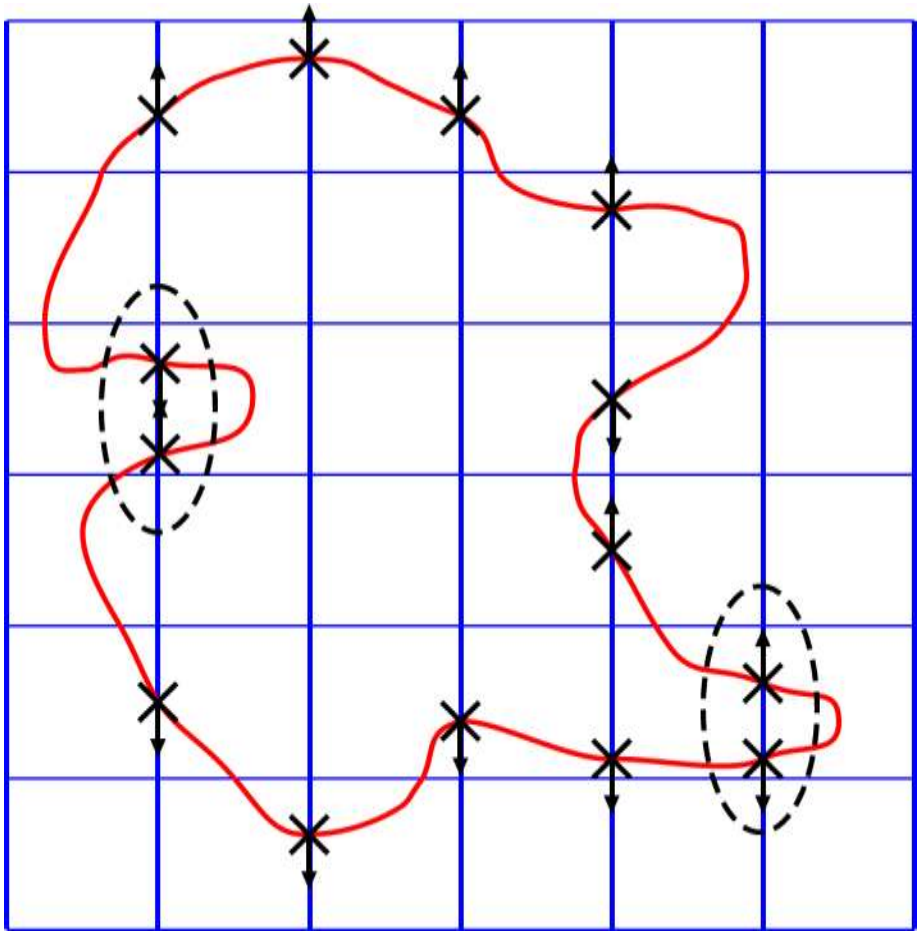
This representation is much more space efficient than the corresponding voxel based method.



Removal of High Frequency Details

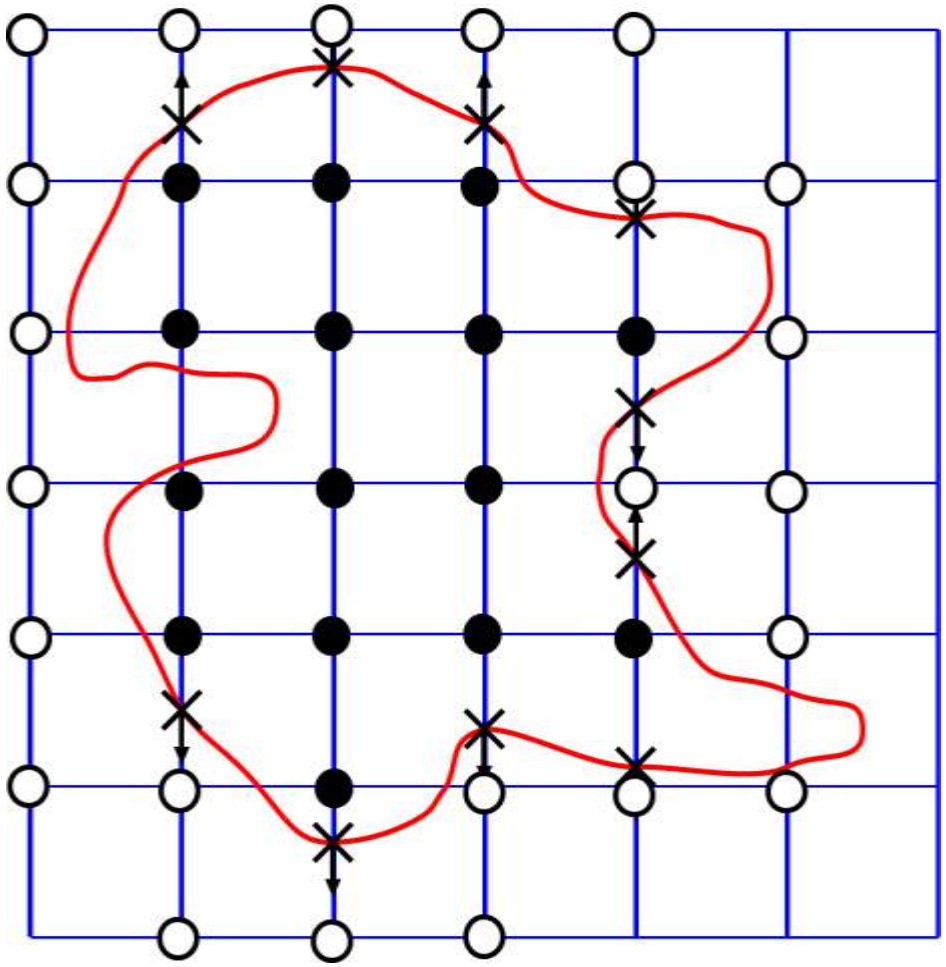
Each pair of consecutive intersections in the same (virtual) cell is removed.

This operation arranges the intersections in a MC-compliant manner.



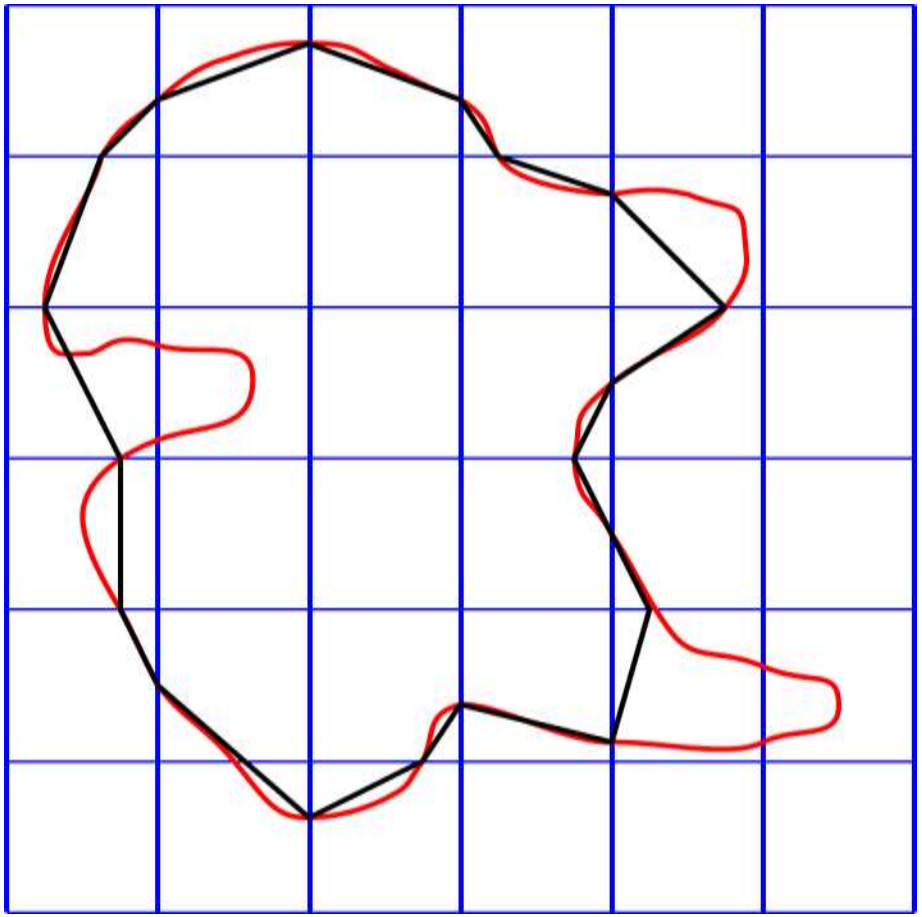
MC Code detection

For each cell which contains an intersection we classify the incident voxels using the sign field (sg).



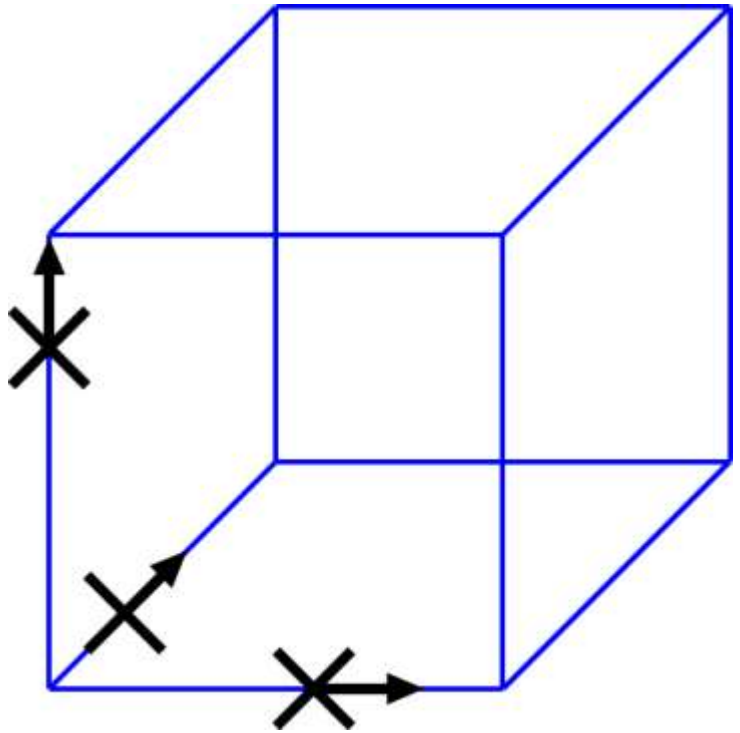
Surface Reconstruction

Finally, we compute the surfaces by means of the MC lookup table and using the existing intersections.



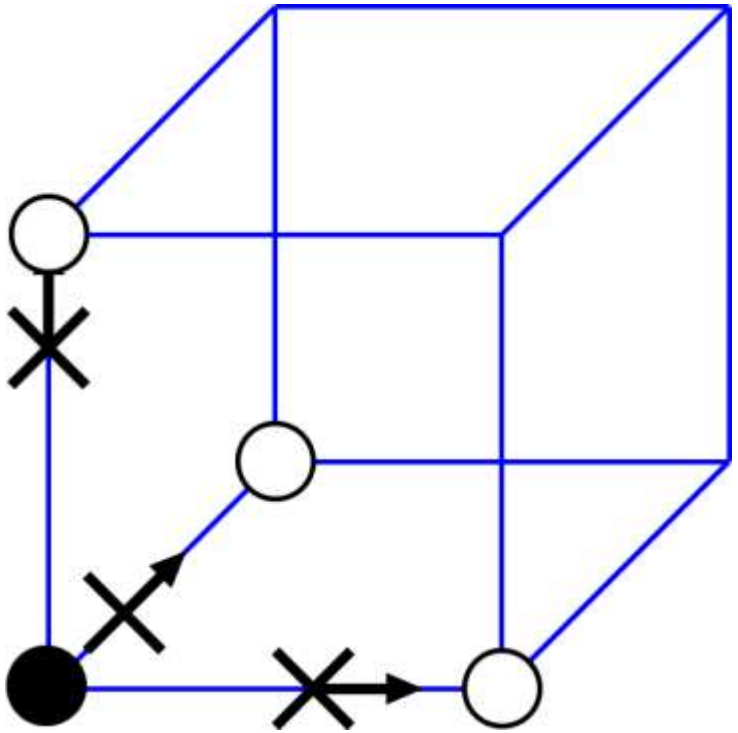
MC Code detection in 3D

Given a 3D cell with signed intercepts…



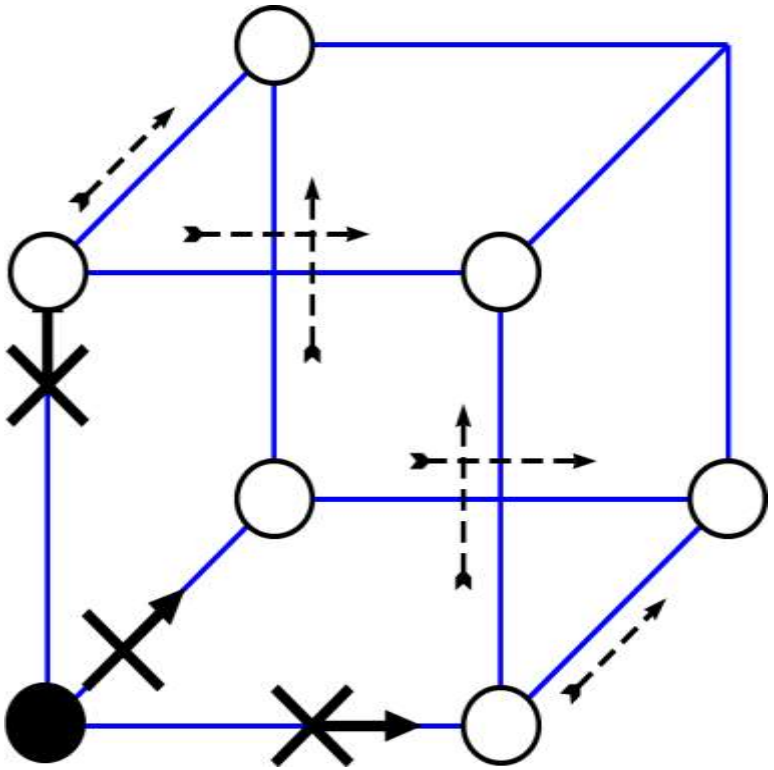
MC Code detection in 3D

First: we mark (in/out) each voxel incident on an edge with intercept.



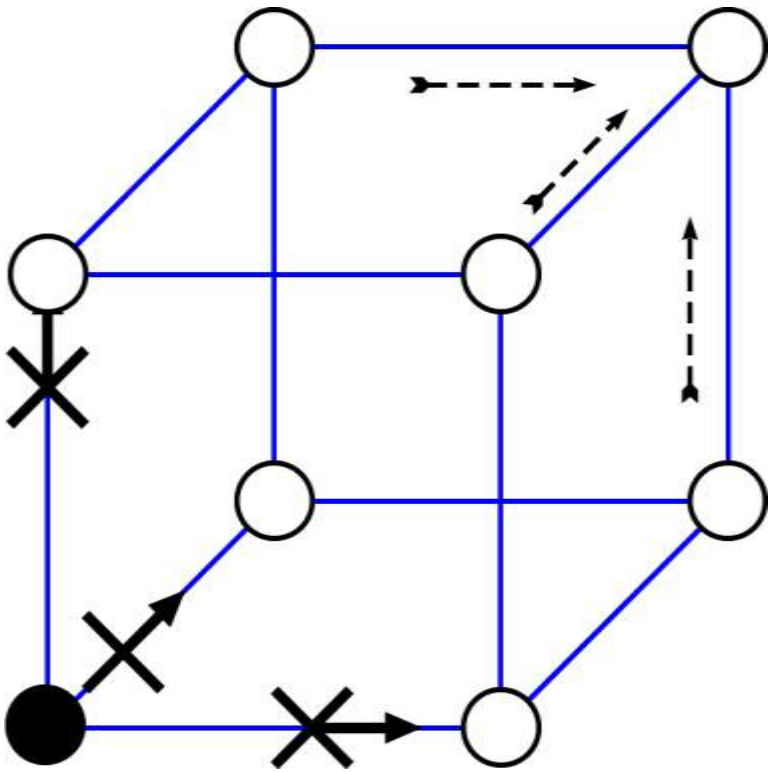
MC Code detection in 3D

Second: we propagate the mark of the voxels along the free edges.



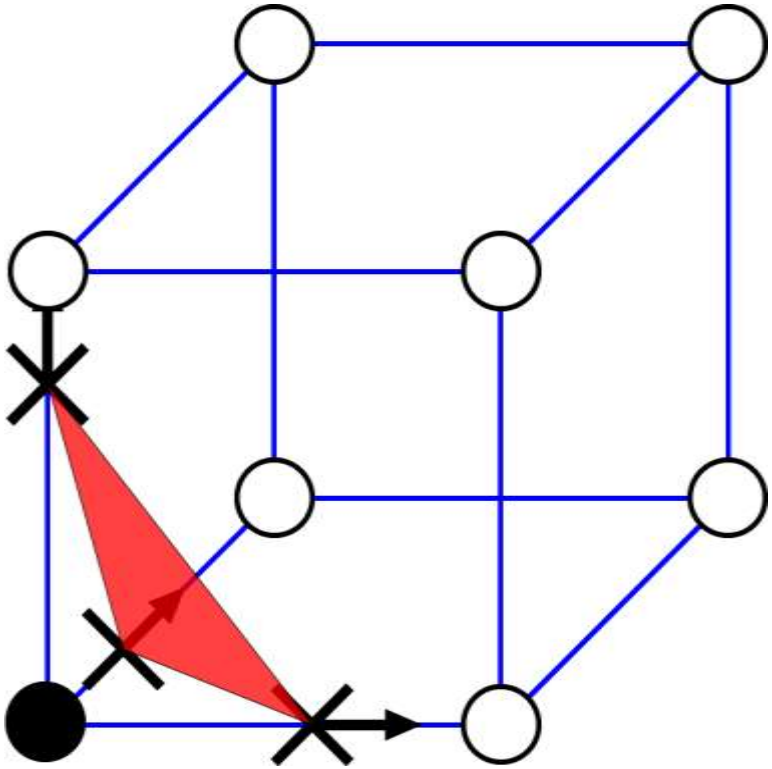
MC Code detection in 3D

At the end of this process we compute the MC code of the cell …



Surface Reconstruction in 3D

… and we produce the output surface.

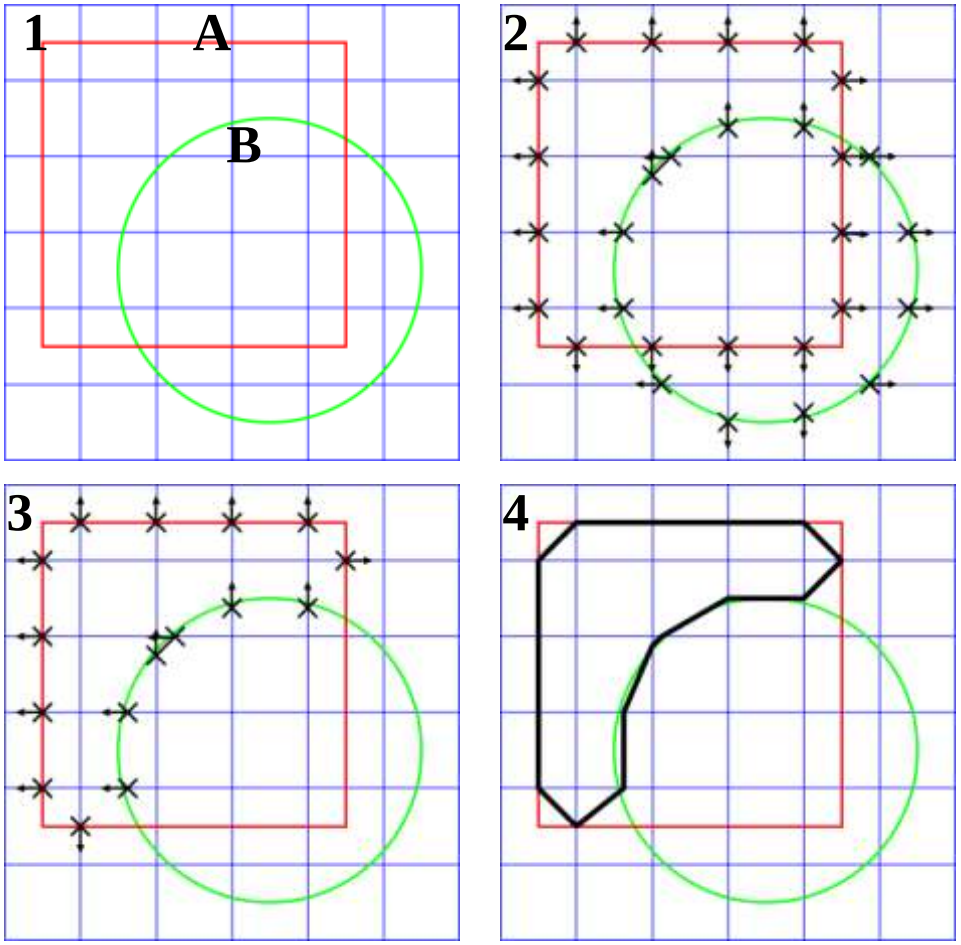


Boolean Operations

The MI scheme can be used to apply a Boolean operator between two surfaces.

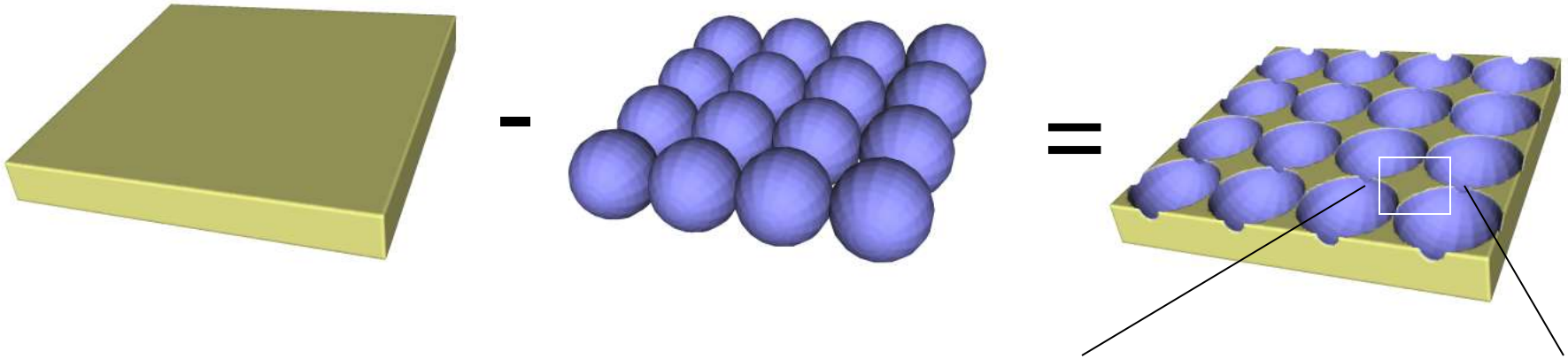
To apply this operator on the surfaces, it's sufficient to perform the Boolean operation on each intercept list, separately.

Bool. op. Sample

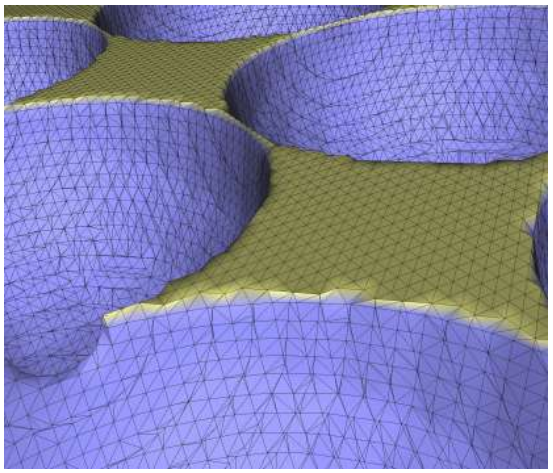


1. Given two surfaces A and B
2. We convert A and B in the MI representation.
3. We apply the bool operator A-B on each intersection list
4. Finally, we reconstruct the output surface.

Results: Boolean Operations



Example of boolean operation on surfaces



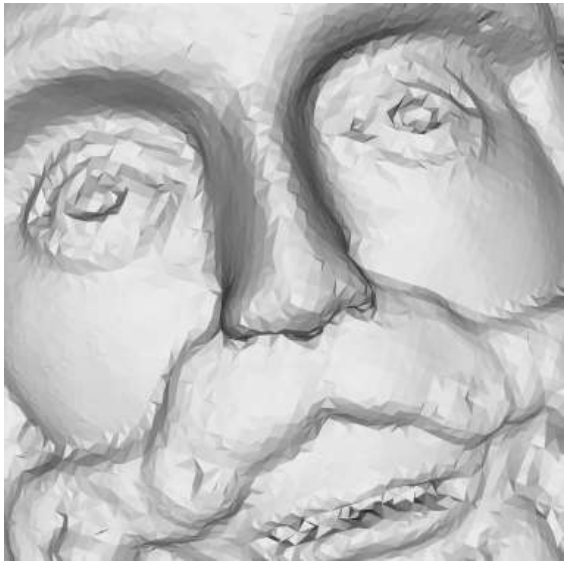
Huge Meshes Simplification

MI can be used for out of core simplification of huge meshes;

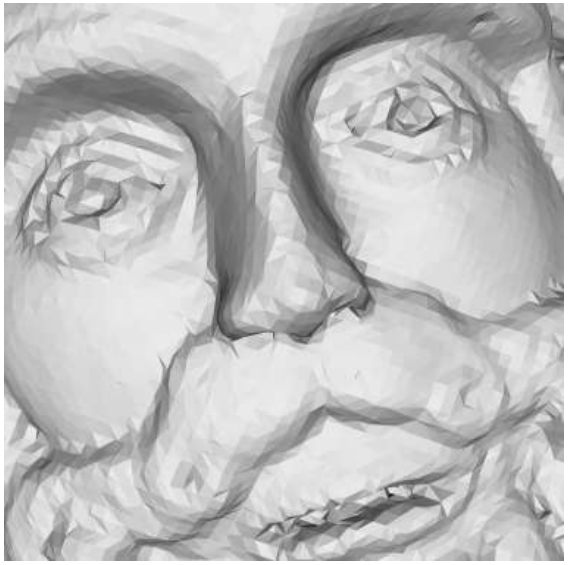
- The input mesh does not need to be stored in main memory.
- Only the vertices (intercepts) of the output mesh are stored in main memory.
- The output is always a watertight 2-manifold mesh.

Simplification Results 1

Original:
1,359,269 triangles
Frontone Pisa Dome

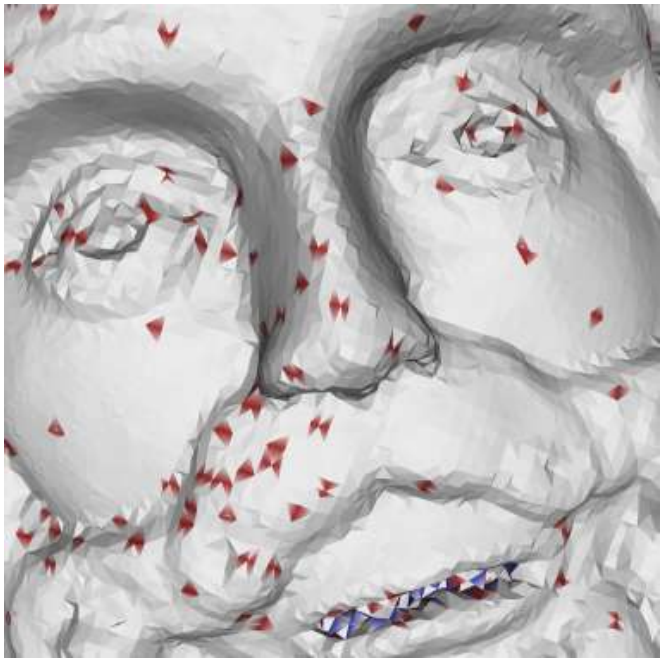


Clustering:
99,015 triangles
(10 sec.)

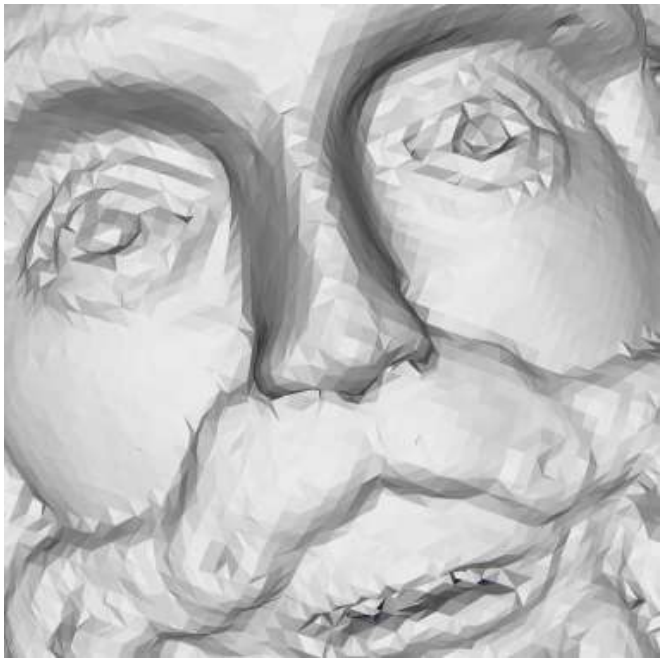


M.I. :
106038 triangles
(20 sec.)

Simplification Results 2



Clustering: Complex (red) and Holes (blue)

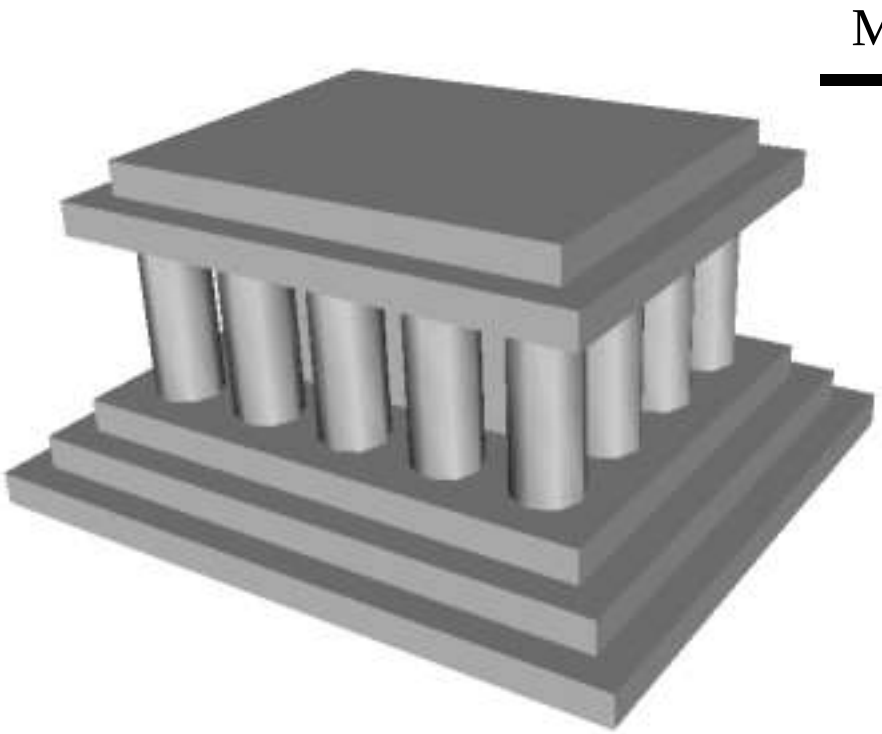


M.I. : No complex, Watertight model, all vertices are on the original surface.

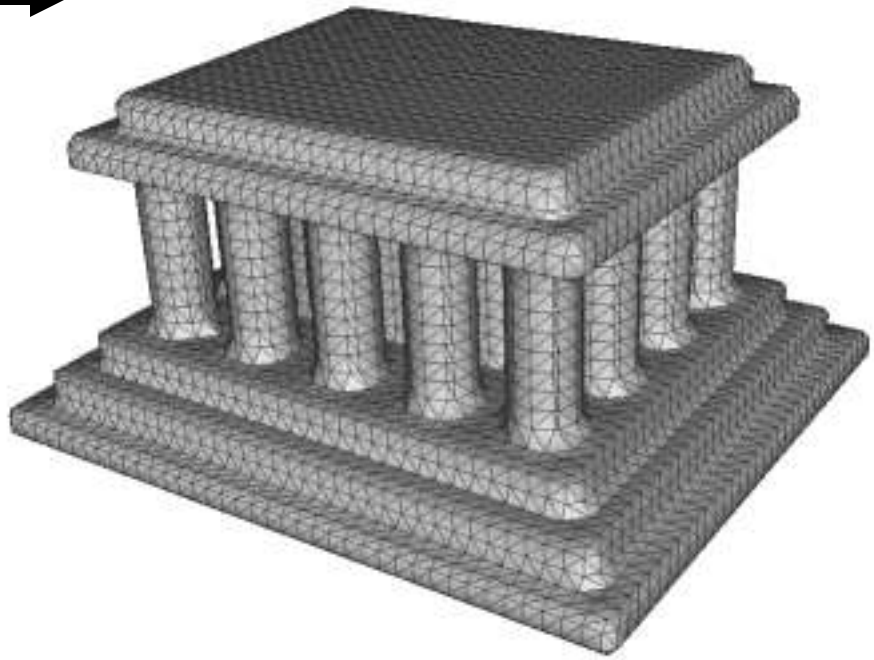
Simplification Results

Input Data		MI Output		
Name	Size (# triangles)	Grid (# virtual cells)	Size (# triangles)	Time (mm:ss)
St. Matthew	90,731,545	10M 1M 100K	435,844 89,670 18,083	21:11.0 21:01.0 21:00.0
Vase	2,104,096	10M 1M 100K	532,052 109,912 22,782	0:24.3 0:17.5 0:16.2
Bunny	69,451	500K 100K 10K	48,746 16,187 3,201	0:2.4 0:1.9 0:1.7

Results: Representation Conversion



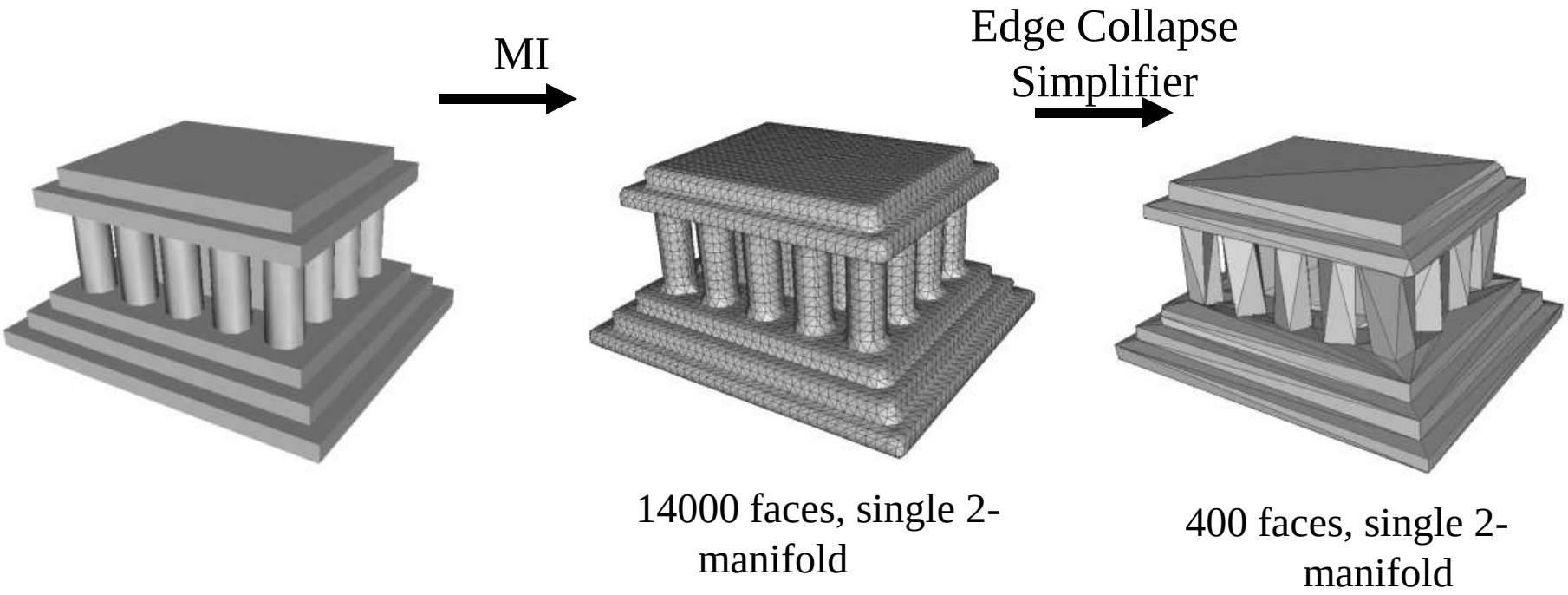
MI



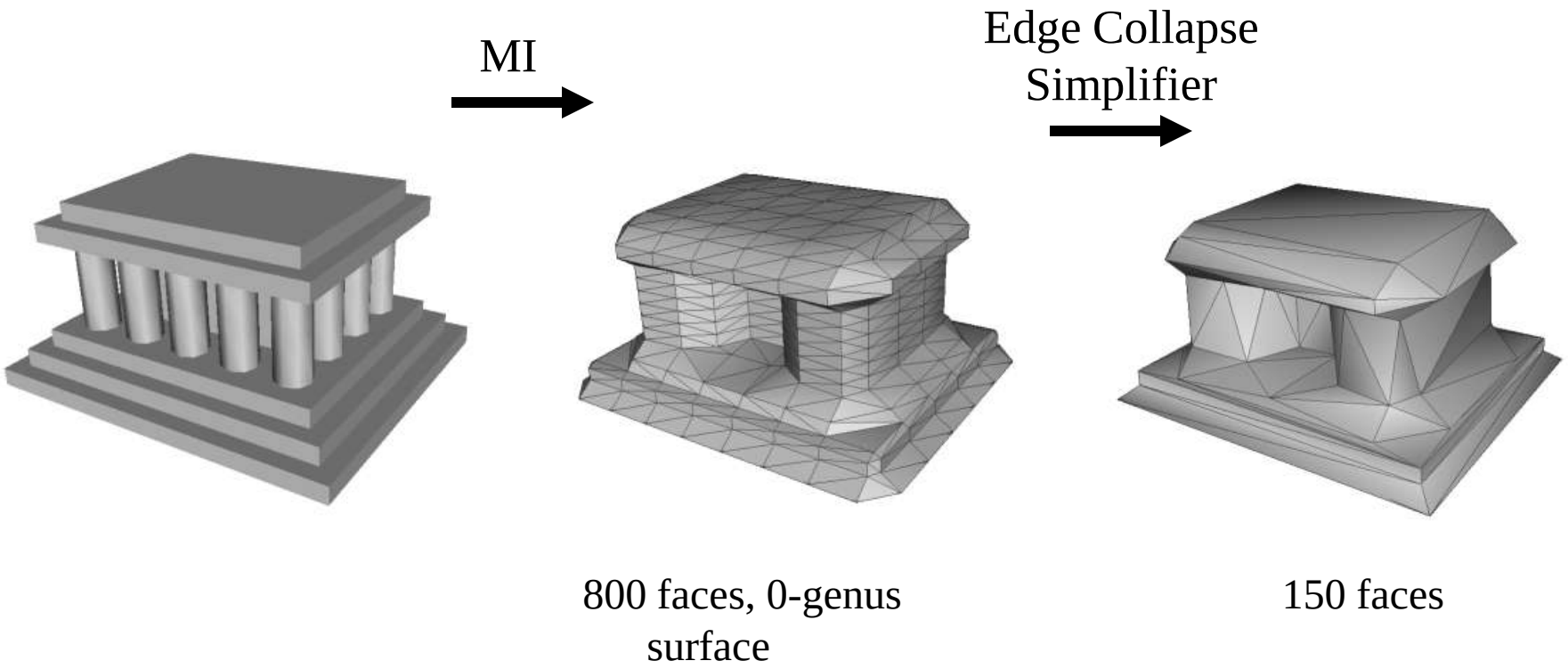
Temple: cad model, 5 boxes, 14 cylinders

Mesh product by MI: 14000 faces, single 2-manifold

Results: CAD Simplification



Results: Topology Simplification



Conclusions

- MI can be used for scheme conversion, simplification and Boolean operations between surfaces.
- Good characteristics in term on
  - efficiency,
  - Compactness
  - quality of results.

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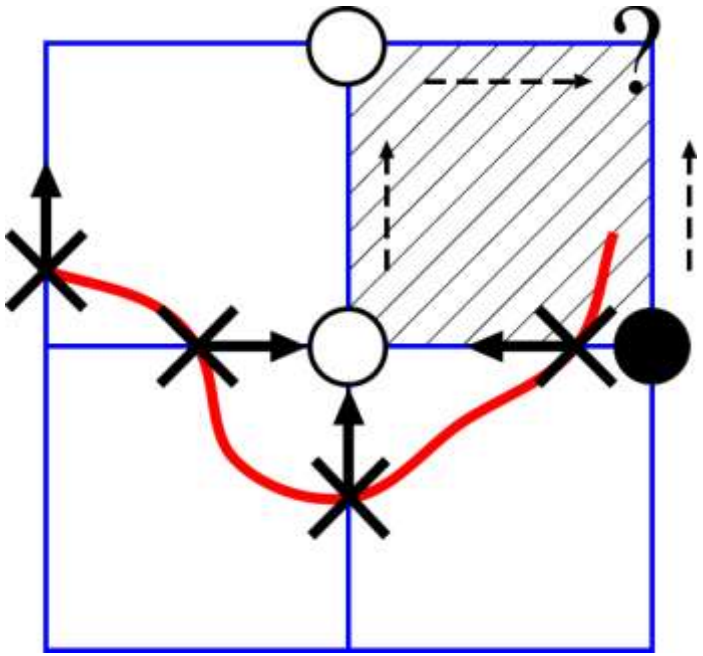
Holes ?

If the original surface contains hole?



Bad input surfaces?

Intercept inconsistency.