Recovering Primitives in 3D CAD meshes

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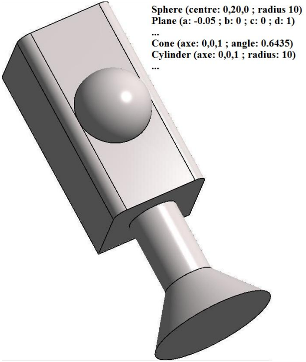
Objective

- A CAD object is usually modeled by a structured combination of primitive surfaces (Plane, Sphere, Cone, Cylinder, Splines ...)



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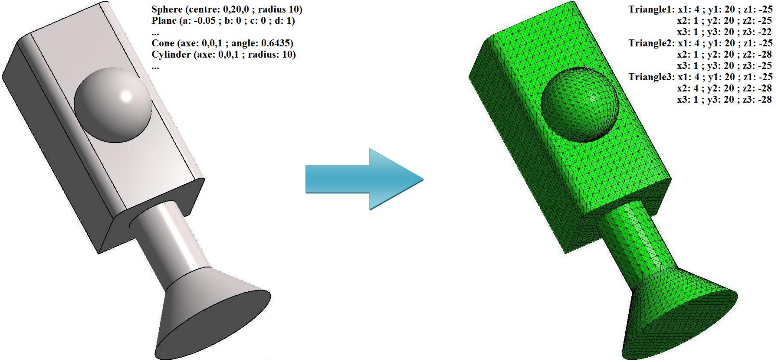

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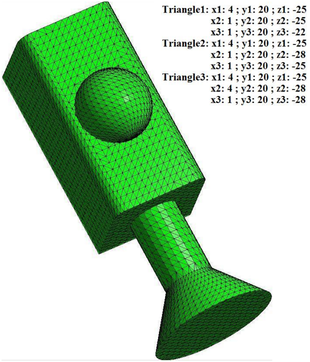

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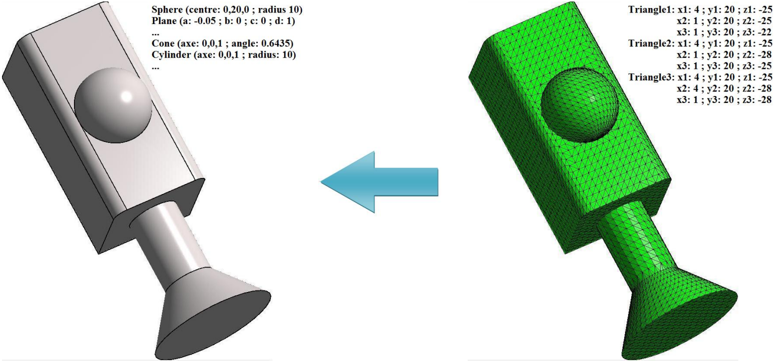
- But a discretization into a 3D mesh is used in many cases
- And the initial continuous model can be lost or not correspond anymore
- Then a primitive extraction algorithm may be required to reconstruct a continuous representation



Overview

- Benkõ *et al.*
  Algorithms for reverse engineering boundary representation models
  Computer-Aided Design 33(11): 839-851 2001

- Sunil and Pande
  Automatic recognition of features from freeform surface CAD models
  Computer-Aided Design 40(4): 502-517 2008

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Our method:

1. Definition of a local shape criterion

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Our method:

1. Definition of a local shape criterion
2. Grouping vertices into areas corresponding to one primitive type
3. Computation of the primitive parameters

Local shape definition

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$\Rightarrow$ points contained in Plane, Sphere, Cone or Cylinder have specific features:

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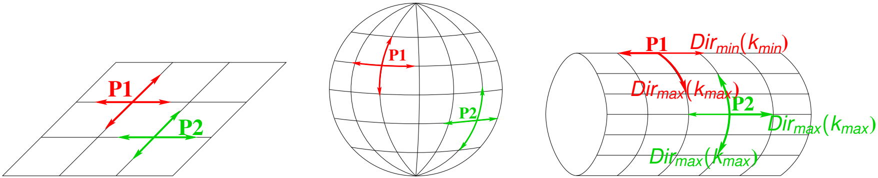

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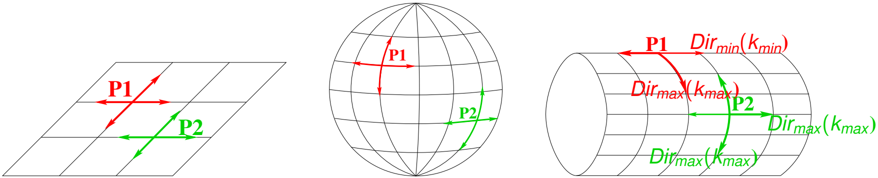

	k_{min}	k_{max}	$\mathbf{Dir_{min}}$	$\mathbf{Dir_{max}}$
Plane	$= 0$	$= 0$	not defined	not defined
Sphere	$= \frac{1}{Radius}$	$= \frac{1}{Radius}$	not defined	not defined
Cone/Cylinder	$= 0$	$= \frac{1}{Radius}$	$=$ generating line	not used
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Curvature computation

⇒ We choose a method based on **Euler formula**

Dong and Wang
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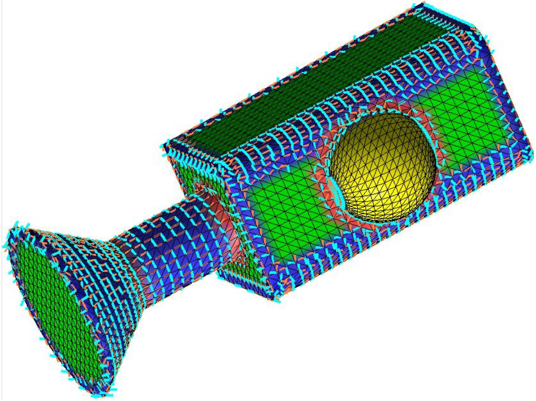
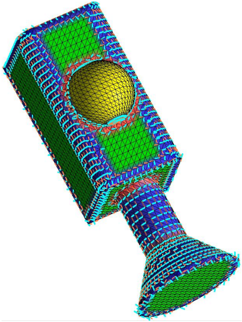


Concave point
Convex point
Plane point
Sphere point
Dir_{max}
Dir_{min}

Neighborhood ring= 1

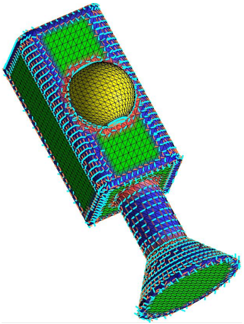
Plane/Sphere Extraction

- Compute k_{min}, k_{max}, $\mathbf{Dir_{min}}$ and $\mathbf{Dir_{max}}$



Plane/Sphere Extraction

- Compute k_{min}, k_{max}, $\mathbf{Dir_{min}}$ and $\mathbf{Dir_{max}}$
- Group all adjacent points with $k_{max} = k_{min} \approx k$ (if plane then $k = 0$)



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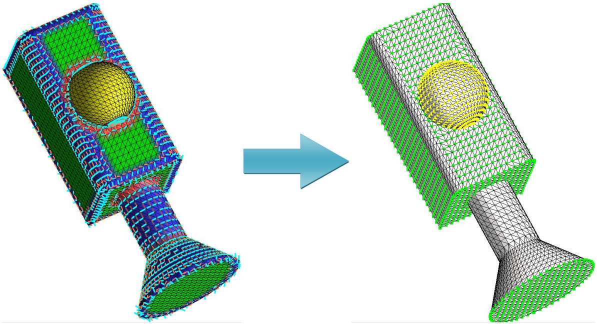

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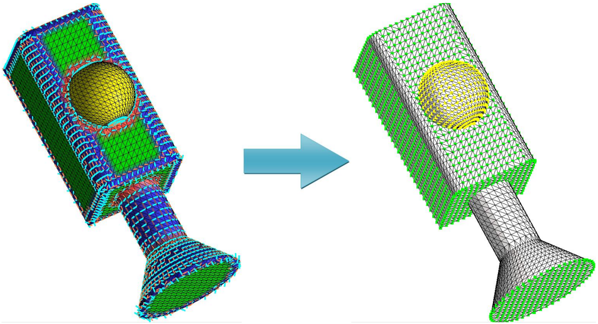
- Compute k_{min}, k_{max}, $\mathbf{Dir_{min}}$ and $\mathbf{Dir_{max}}$
- Group all adjacent points with $k_{max} = k_{min} \approx k$ (if plane then $k = 0$)
- Approximation by a least square regression with the implicit equations



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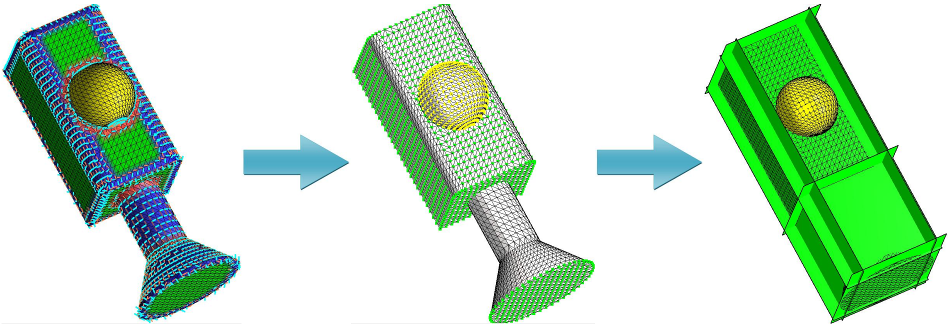
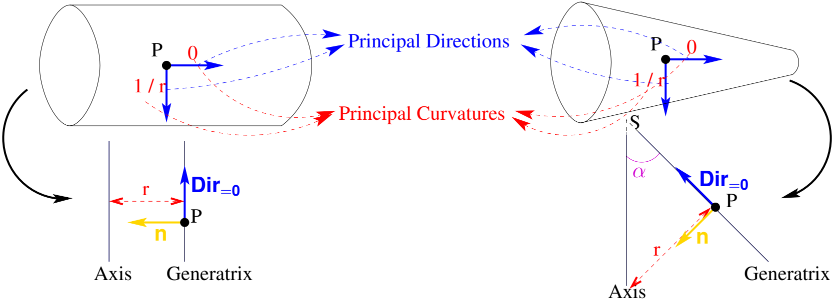


Cone/Cylinder Extraction

General features of cones and cylinders:



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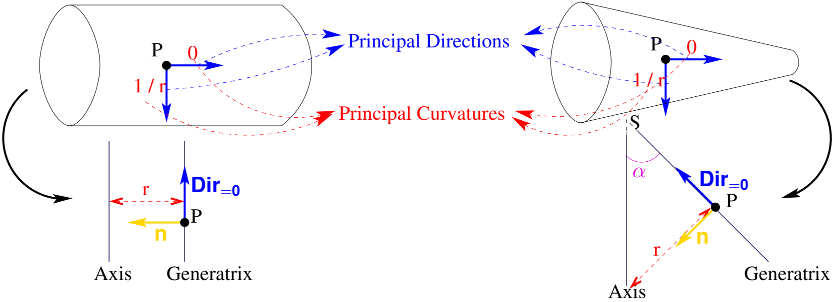
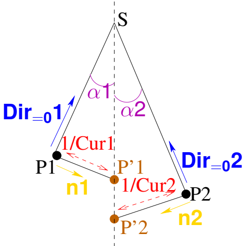


Criterion (C):

If P_1 and $P_2 \in$ same cone

$\Rightarrow \alpha_1 = \alpha_2$



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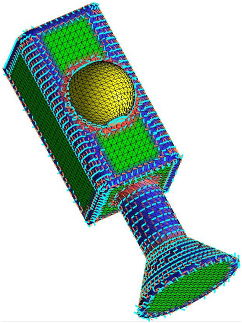
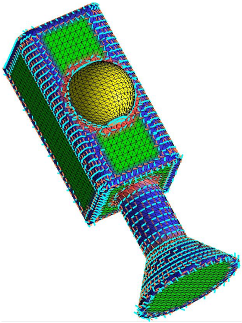


Cone/Cylinder Extraction

- Compute k_{min}, k_{max}, $\mathbf{Dir_{min}}$ and $\mathbf{Dir_{max}}$
- Group adjacent points with ($k_{min} = 0$ & $k_{max} \neq 0$) or ($k_{min} \neq 0$ & $k_{max} = 0$) and the criterion (C)



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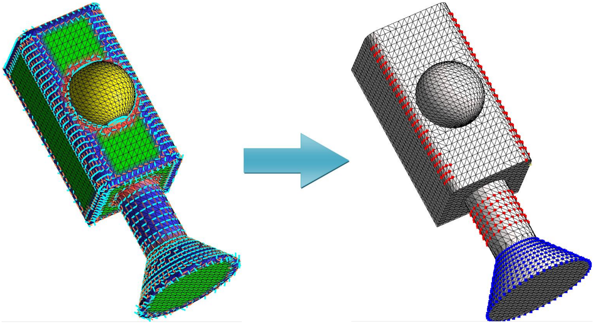

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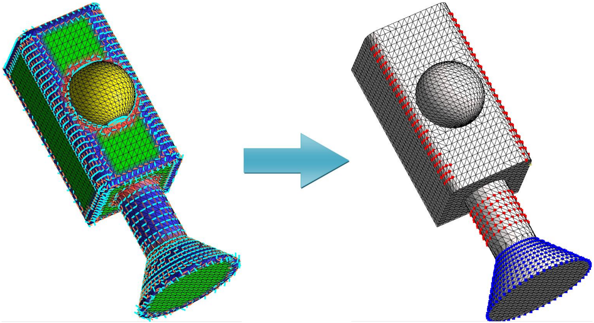
- By regression on all *pointAxis* (P') $\Rightarrow$ rotation axis



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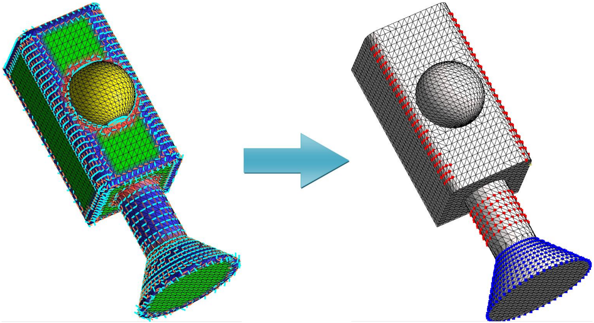

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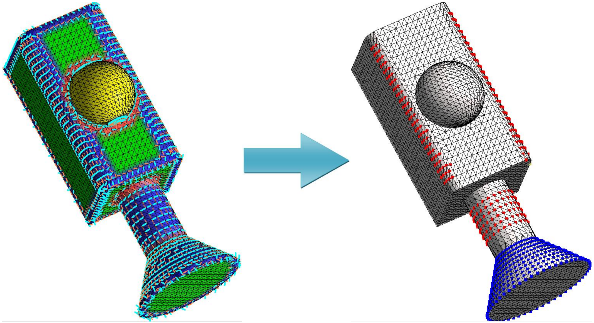

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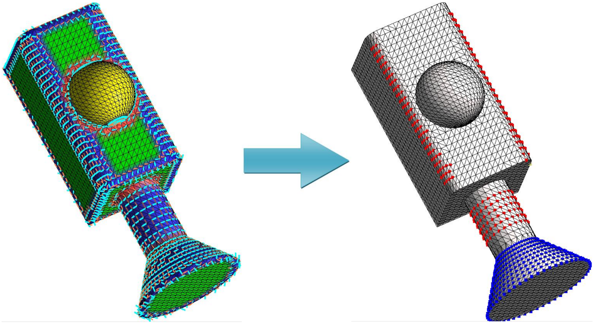

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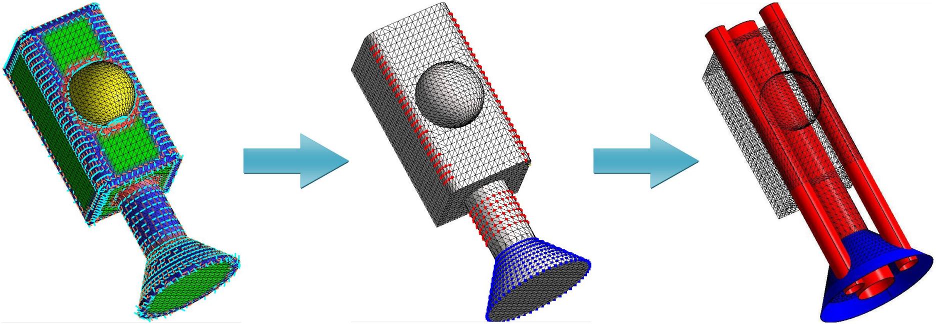
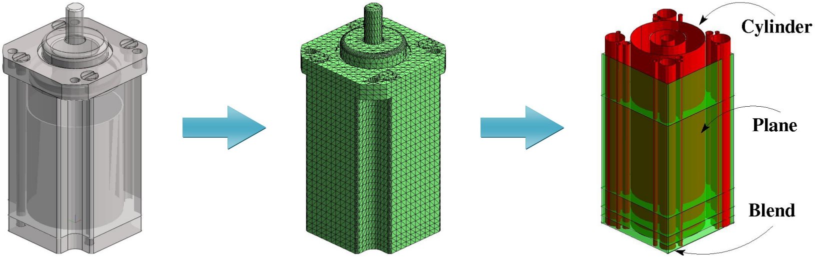


CAD results: Motor

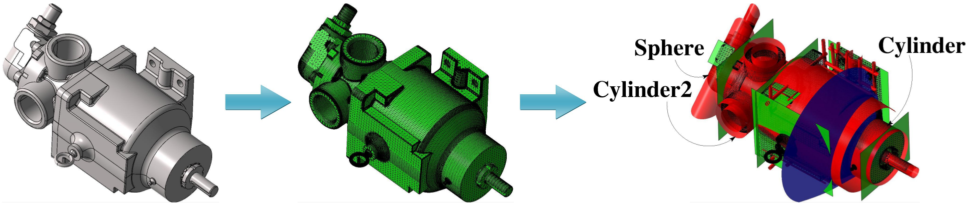


22,482 triangles $\Longrightarrow$ extraction of 26 planes + 25 cylinders

		Original Values	*MotorMesh*
Cylinder	Axis (x;y;z)	0;0;1	0;0;0.999
	Radius	33.5	33.499
Blend	Axis (x;y;z)	0;0;1	0;0;0.999
	Radius	7	7.079
Plane	Coefficients (a;b;c;d)	0;0.024;0;1	0;0.024;0;1

http://shapes.aimatshape.net/viewgroup.php?id=1242

CAD results: Pump



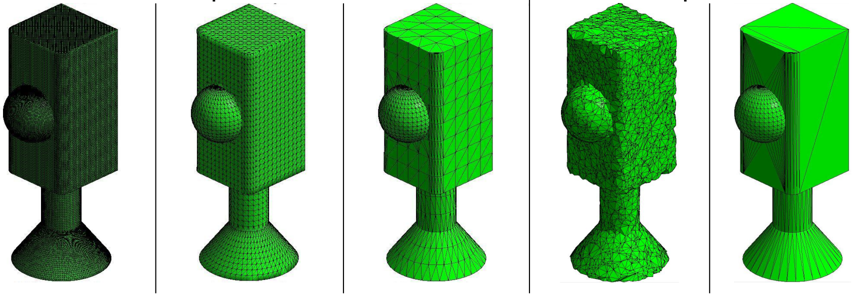
158,746 triangles $\Longrightarrow$ extraction of
9 planes + 1 sphere + 1 cone + 13 cylinders + 31 blends

		Original Values	*PumpMesh*
Cylinder1	Axis (x;y;z)	1;0;0	0.999;-0.011;-0.004
	Radius	49.669	49.669
Cylinder2	Axis (x;y;z)	0;1;0	-0.006;1;0.002
	Radius	34.162	34.175
Sphere	Center (x;y;z)	409.175;367.654;515.722	409.167;367.682;515.780
	Radius	23.114	23.088

http://www.vikingpump.com/en/engineering/3dmodels.html

Influence of the discretization

Isotropic Meshes | Anisotropic Meshes



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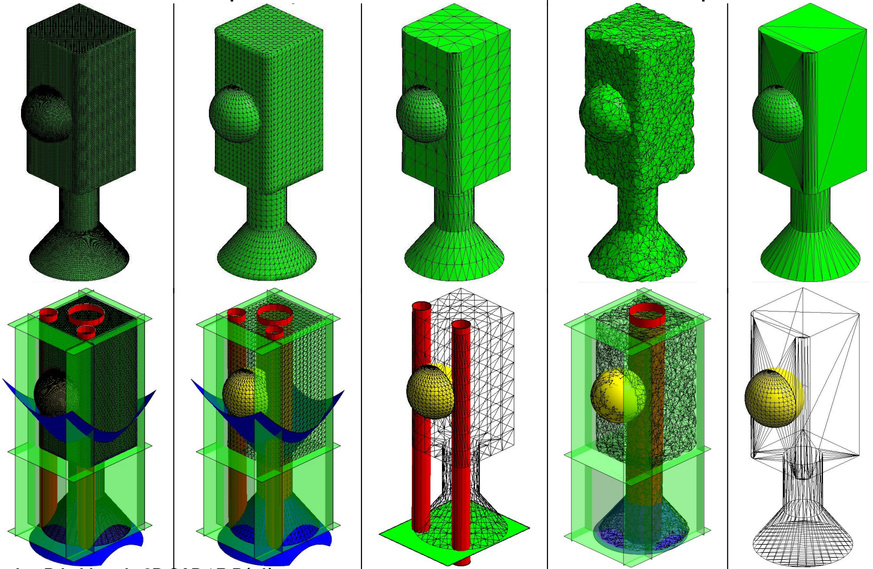

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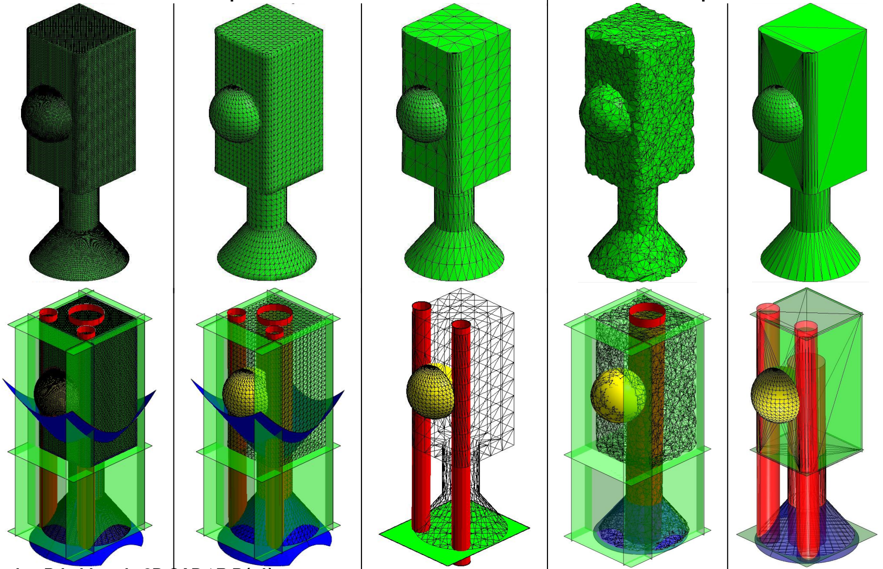
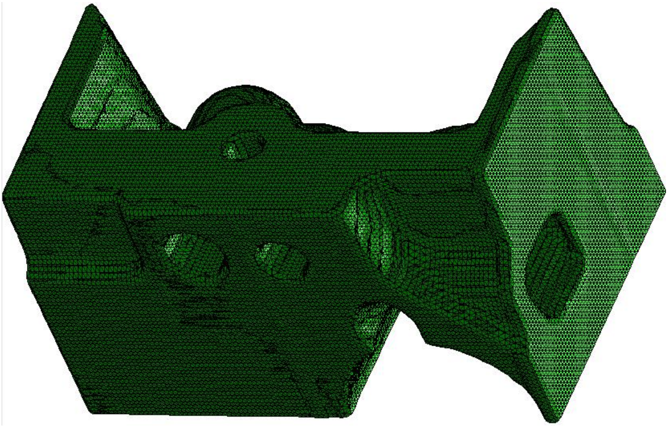


Scanned Mesh



Conclusion

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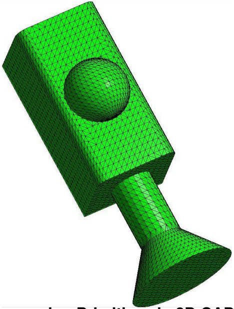

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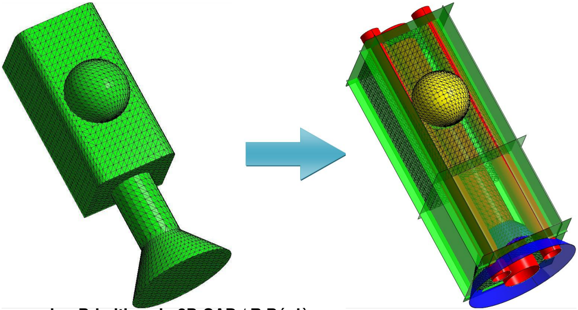
Our method takes a mesh $\Longrightarrow$ extract geometrical primitives



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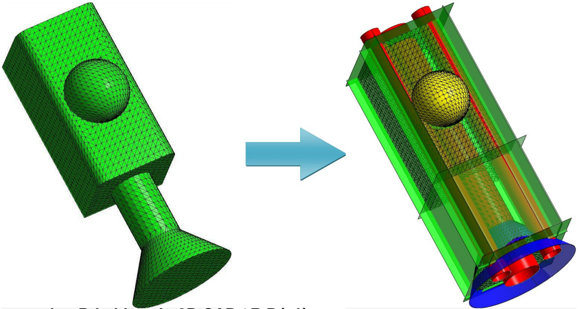

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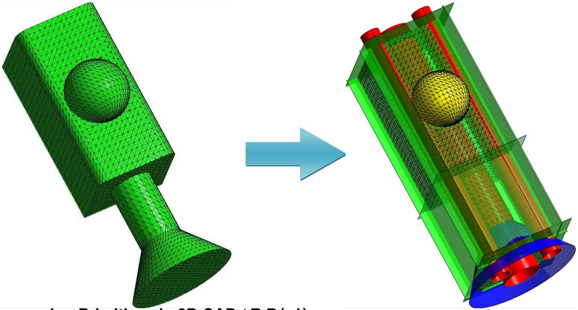

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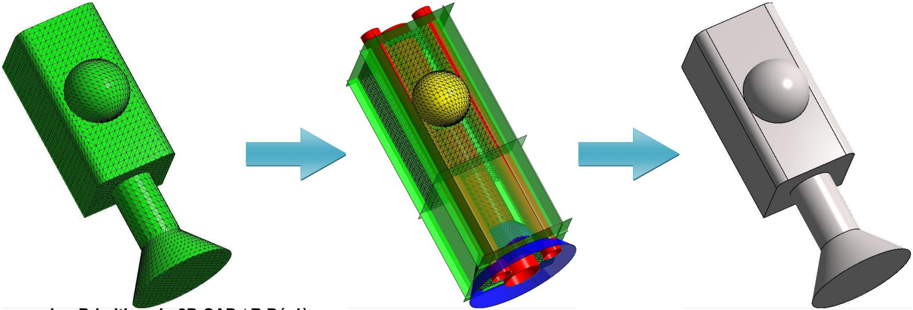

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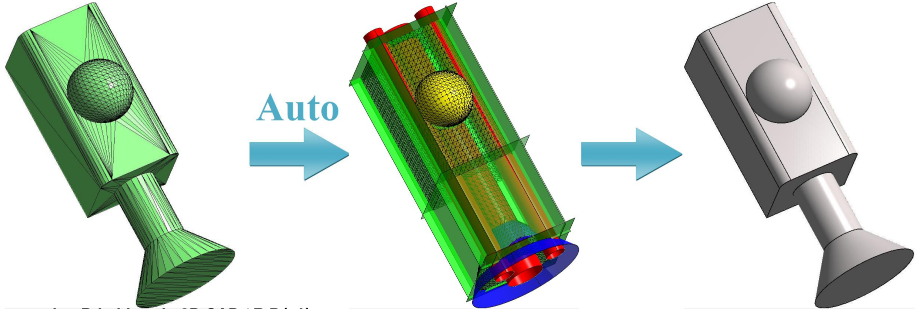

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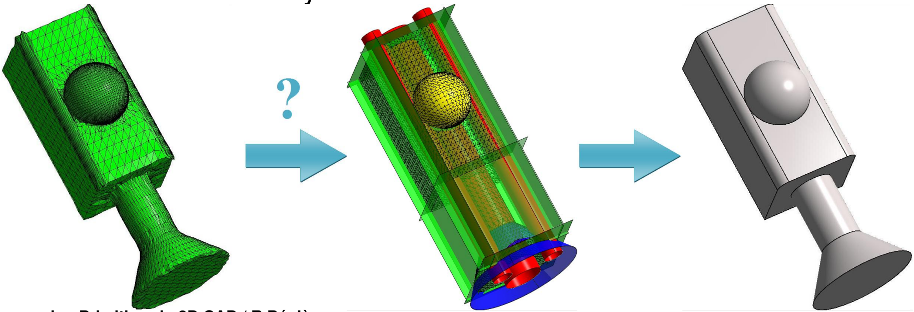
- Add an automatic segmentation step (sparse meshes)
- Deal with noisy meshes



Thank you for your attention

QUESTIONS?

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Mail: roseline.beniere@lirmm.fr
C4W site: www.c4w.com

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Recovering Primitives in 3D CAD meshes, SPIE, *San Francisco*, 2011