
3D GEOMETRIC MODELING & PROCESSING

Paolo Cignoni

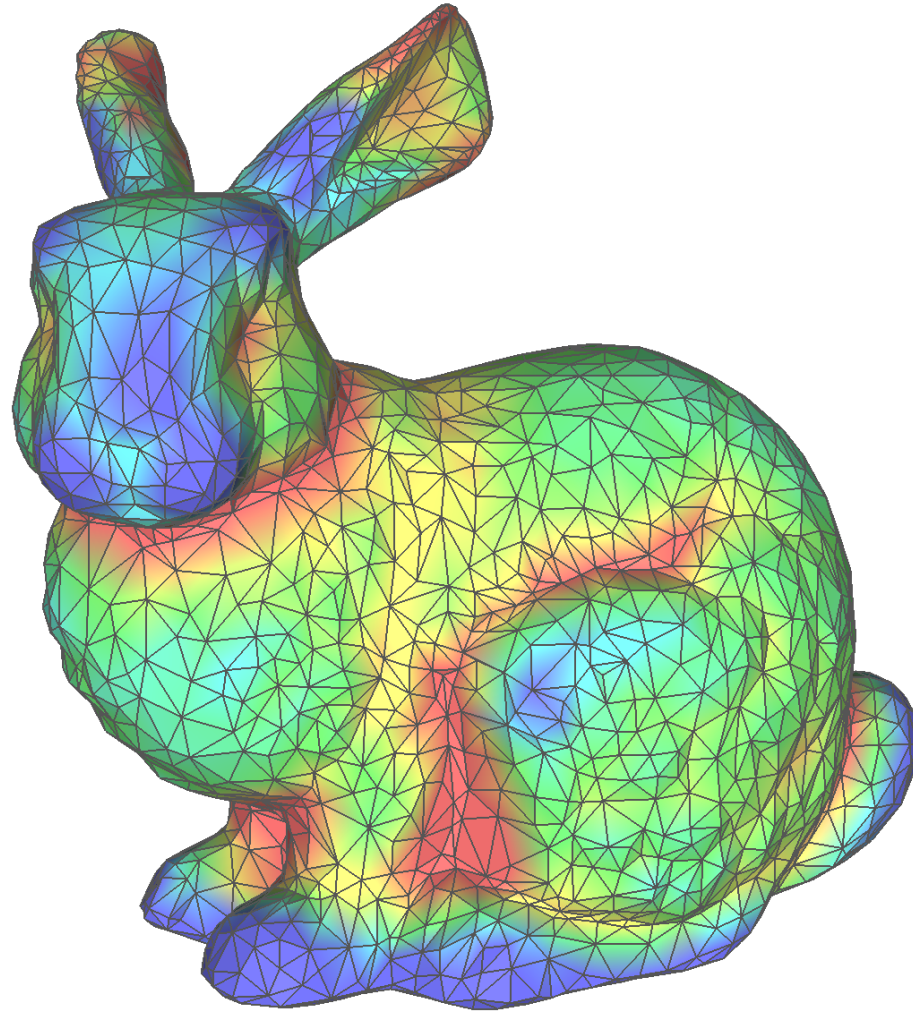
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<http://vcg.isti.cnr.it/~cignoni/GMP2526>

Objectives

- ❖ Foundations for treating 3D surfaces and shapes in mathematics and computer science
 - ❖ Discrete Representations for Surfaces
 - ❖ Data Structures for Simplicial Complexes and spatial Indexing
 - ❖ Differential Geometry and Topology for Comp. Graphics
 - ❖ Mesh Processing Algorithms
 - ❖ Remeshing, Refinement & Simplification
 - ❖ Parametrization and Texturing
 - ❖ Fairing and Smoothing
 - ❖ Surface reconstruction and Sampling
 - ❖ Shape Analysis and Representations for Machine Learning

Why geometry is important?



3D models are pervasive

Animation and serious gaming, CAD and product modeling,
Cultural heritage, Archaeology, Architecture,
Digital fabrication and 3D
printing, Biology and environmental monitoring, Medicine and
eHealth systems, Fashion of the future, Security and
defense...

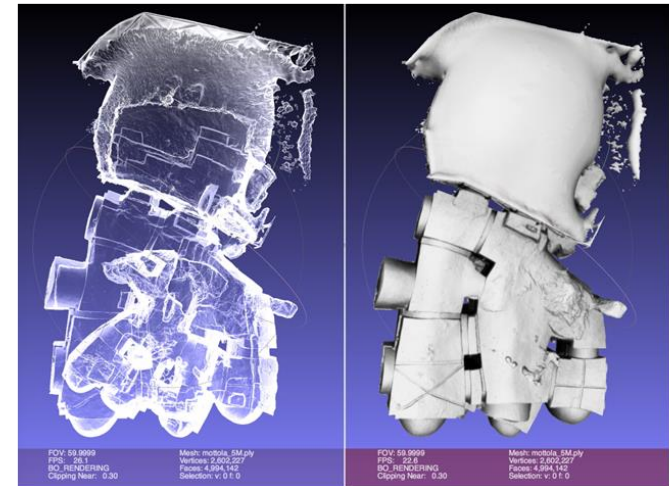


*[Toy Story (1995) –
and the Utah teapot]*

*[Avatar 2,
2022]*

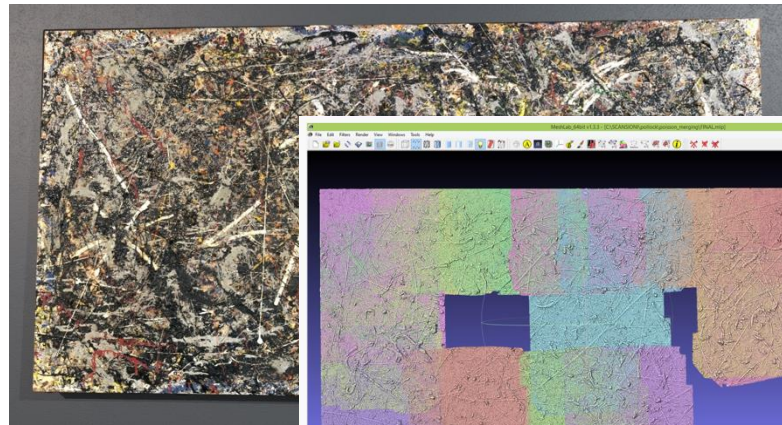
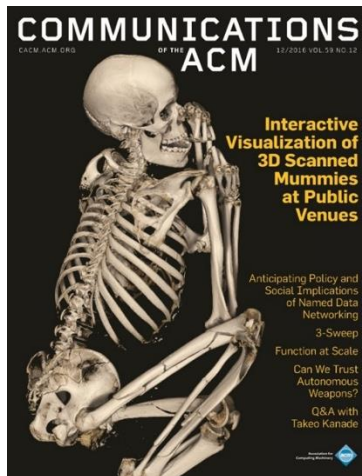


[\[https://www.meshlab.net/\]](https://www.meshlab.net/)

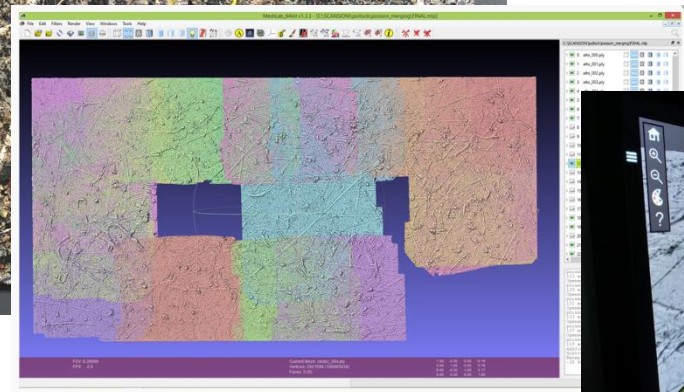


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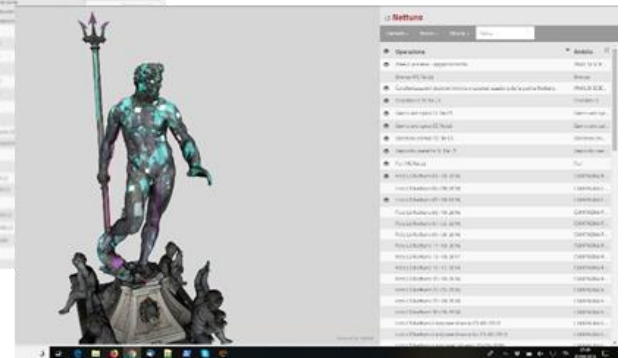
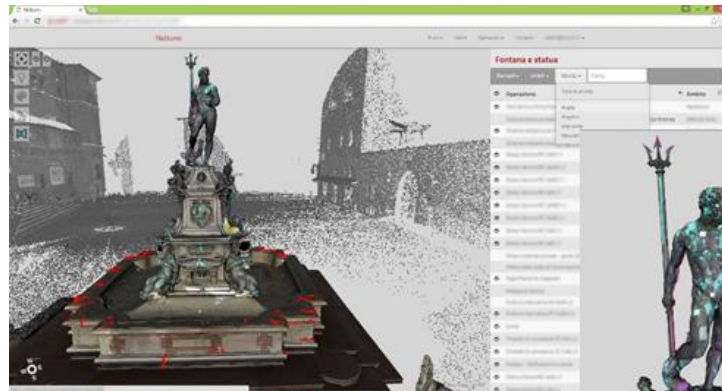
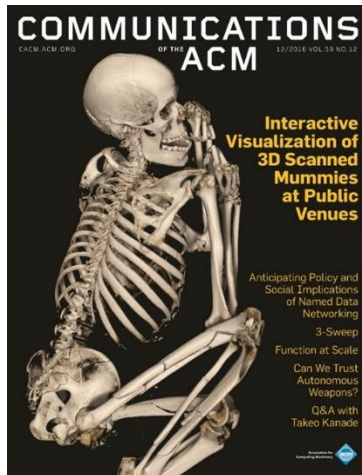


["Alchemy" by Jackson Pollock]



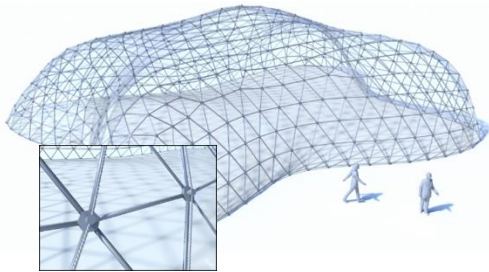
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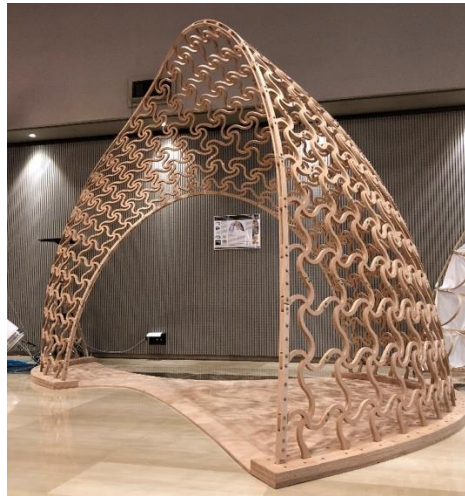


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[Laccone et al: FlexMaps Pavilion: a twisted arc made of mesostructured flat flexible panels, 2019]

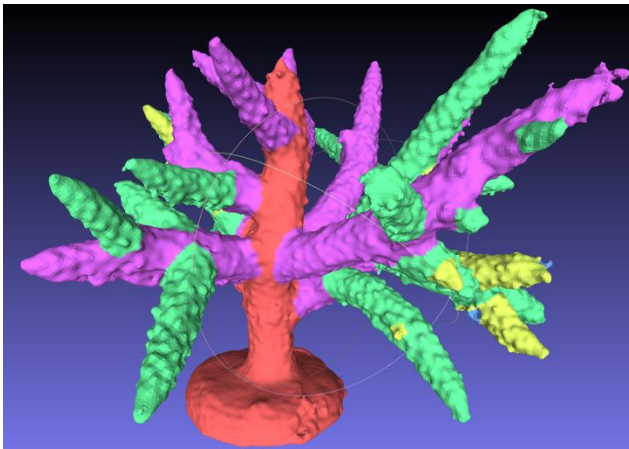


[Pietroni et al. (2017): Position-based tensegrity design]



3D models are pervasive

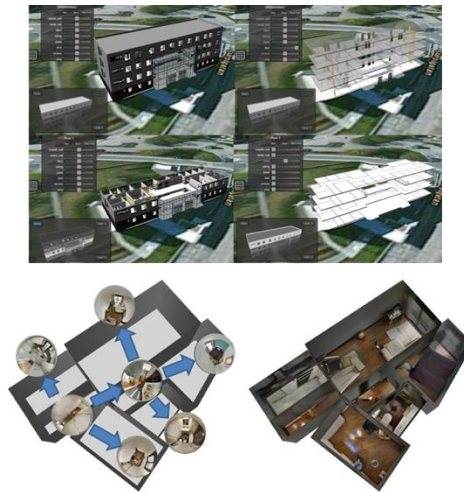
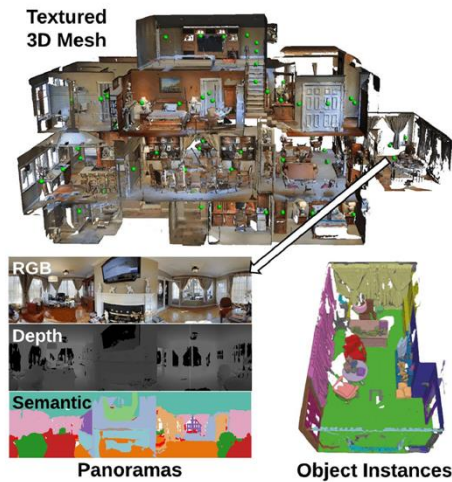
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*[Alderighi et al. (2021):
Computational
design, fabrication
and evaluation of
rubber protein
models]*

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Take-away message

3D models are everywhere and there is room for improving and complementing the current tools for 3D data processing and analysis

Requisiti

- ❖ Conoscenza minima delle basi della grafica
 - ❖ Rendering?
 - ❖ RayTracing vs Rasterization?
 - ❖ Texture Mapping?
 - ❖ Lighting Models?

Requisiti

- ❖ Geometria, algebra lineare e un minimo di analisi
- ❖ Conoscenza del C++
 - ❖ Buona. Se non la avete iniziate subito.
- ❖ Conoscenza python
 - ❖ Media. Basta che sia migliore della mia :)
- ❖ Git as usual

Esame

- ❖ Costituito da una parte teorica ed una progettuale.
- ❖ La parte teorica riguarda gli argomenti teorici non coperti dal progetto e' sostenuta con un orale al momento della consegna della parte progettuale.
- ❖ La parte progettuale vale 20/30, mentre la parte teorica vale 10/30.

Voto finale = progetto +orale

MeshLab

- ❖ Generic mesh processing tool
- ❖ Open source GPL available for win and linux
 - ❖ The system relies on a vcglib large GPL library for mesh processing
- ❖ Aimed to the (almost) automatic processing of large unstructured 3d models
 - ❖ acquired 3D models are different from human built models
 - ❖ No structure, no particular need of a scene graph
 - ❖ Large datasets : millions of primitives

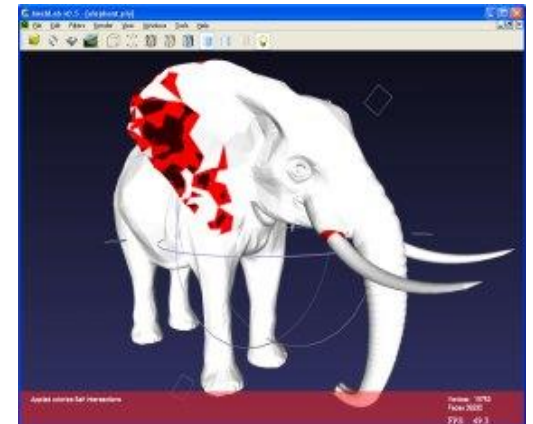
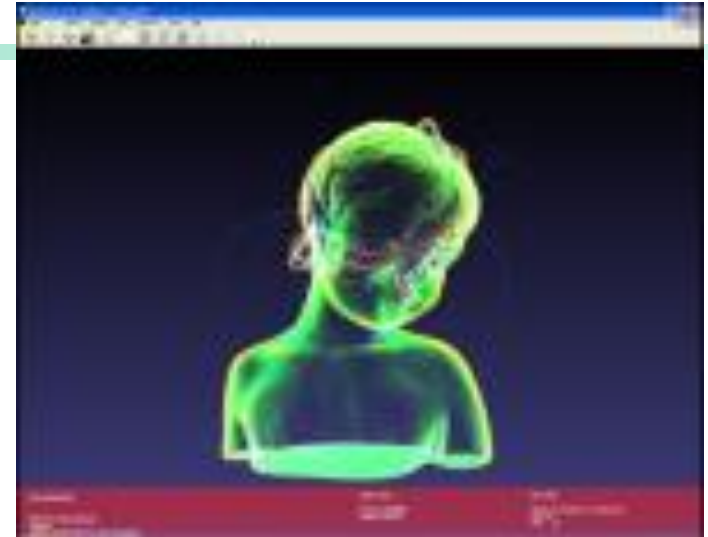
MeshLab

❖ Audience

- ❖ 3D scanning (mesh cleaning, etc)
- ❖ Entertainment industry (mesh reduction, checking, conversion)
- ❖ Simulation (checking, visualization)
- ❖ 3D printing
- ❖ Research Labs (it is a swiss knife)

Checking

- ❖ Visual inspection
 - ❖ See through filters (shaders)
- ❖ Quality evaluation
 - ❖ Curvatures, distances
- ❖ Automatic marking of mesh inconsistencies
 - ❖ topological: non manifoldness)
 - ❖ Geometric: self intersection
 - ❖ Small connected components removal



MeshLab tasks

❖ Filtering

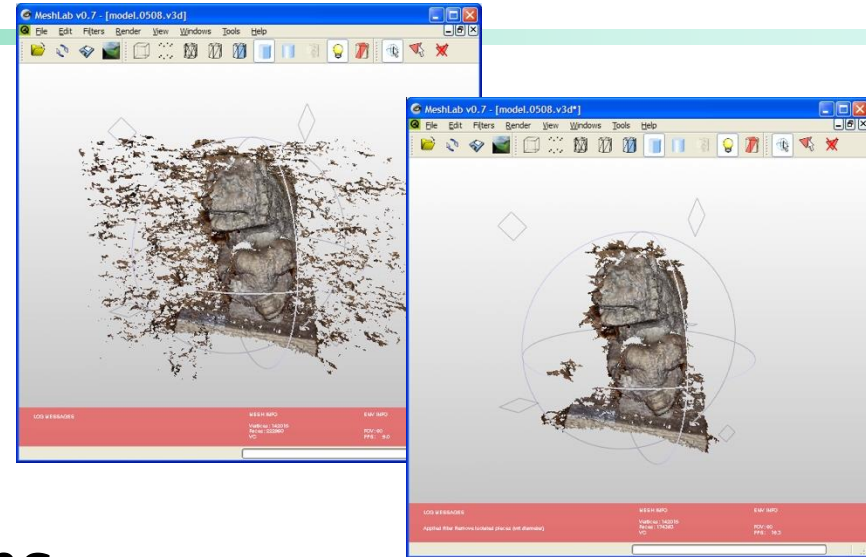
- ❖ Removal of outliers according to various heuristics

❖ Smoothing out noise

- ❖ Various fairing algorithms

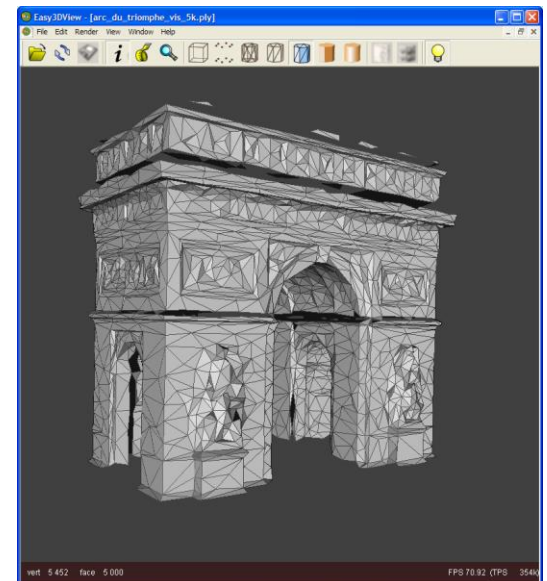
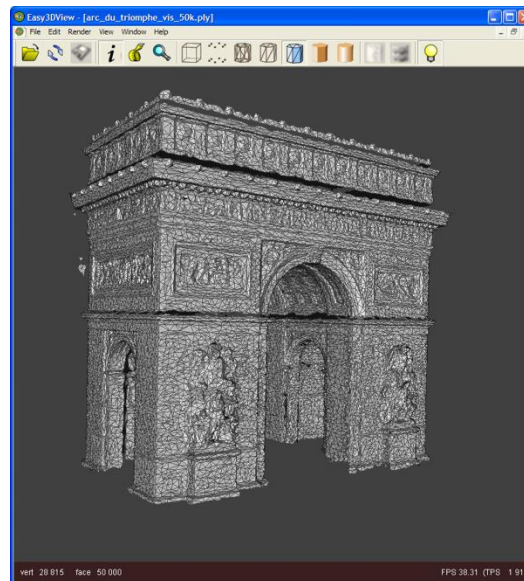
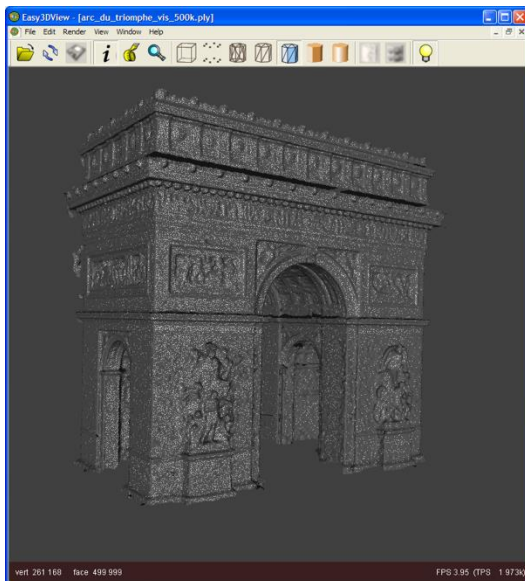
❖ Editing

- ❖ Selection of parts and removal of non interesting portions of the acquired data



Remeshing

- ❖ Subdivision Surface (loop and butterfly)
- ❖ Reducing complexity through simplification
 - ❖ Both fast approximate and slower high quality algorithms
- ❖ 500k 50k 5k



MeshLab Architecture

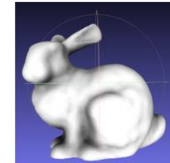
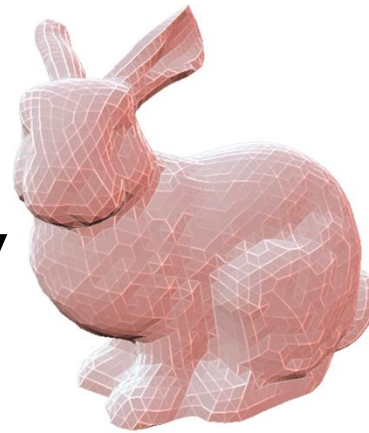
- ❖ Basic plugins are the filters
 - ❖ Algorithms that take some meshes in input, some user parameters and create/modify meshes.
 - ❖ Automatic dialog creation
 - ❖ Developer of filters simply declare the parameters and the gui for asking them is automatically created.
- ❖ More than two hundred filters
- ❖ pymeshlab
 - ❖ python version of meshlab that exploits the same filtering plugins for exposing scriptable functions

MeshLab numbers

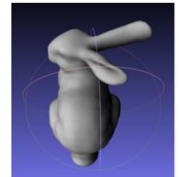
- ❖ 2M download in the last 3y
- ❖ 30k monthly downloads
- ❖ Used in hundred of university all over the world
- ❖ Many companies using it
 - ❖ Game, simulation, aerospace, 3d scanning, FX industries, military, medical,

Successful Projects

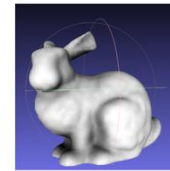
- Discrete Developability
- Embree adaptors
(efficient Intel library for raytracing)
- Cubization filter



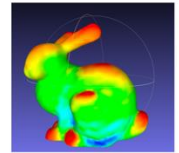
(c) Ambient Occlusion



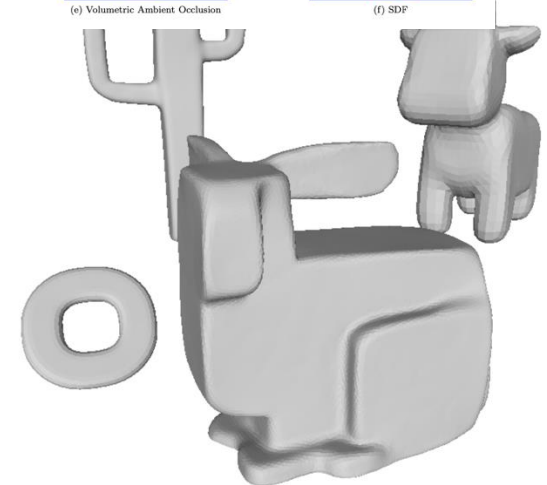
(d) Directional Ambient Occlusion



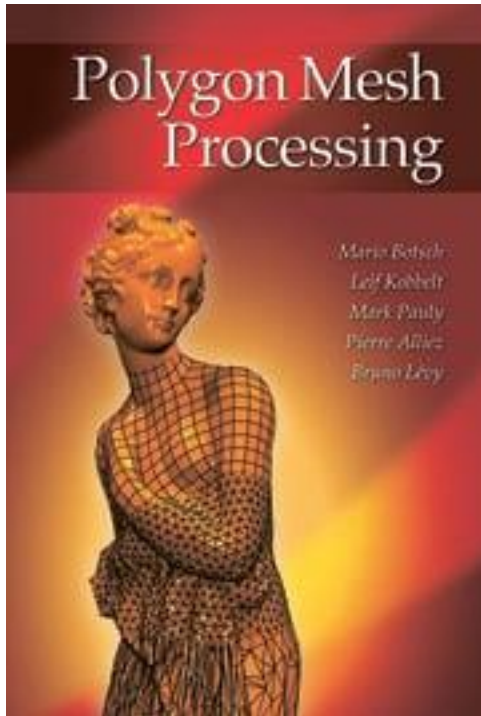
(e) Volumetric Ambient Occlusion



(f) SDF



Riferimenti Biblio



❖ Polygon Mesh Processing

*Mario Botsch, Leif Kobbelt,
Mark Pauly, Pierre Alliez,
Bruno Levy*

A K Peters/CRC Press