Metodi di Analisi di Superfici Discrete e loro Applicazioni

Silvia Biasotti & Giuseppe Patanè
IMATI-GE/CNR
{silvia,patane}@ge.imati.cnr.it

Outline

- ✓Shape Modeling
  - ✓Paradigm, motivations, open problems, challenges;
  - ✓Overview on geometric and topological methods for triangle meshes;
- ✓Course and Lab presentation.

What is shape?

Shape = any individual object having a visual appearance which exists in some (two-, three- or higher- dimensional) space (pictures, sketches, images, 3D objects, videos, 4D animations,...)

- ✓ Shapes have a geometry (the spatial extent of the surface/object);
- ✓ they can be described by structures (surface features and part-whole decomposition);
- ✓ they have attributes (colours, textures, names, attached to a surface/object, its parts and/or its features);
- ✓ they have a semantics (meaning, purpose), and they may also have interaction with time (e.g., history, shape morphing, animation, video).

User needs

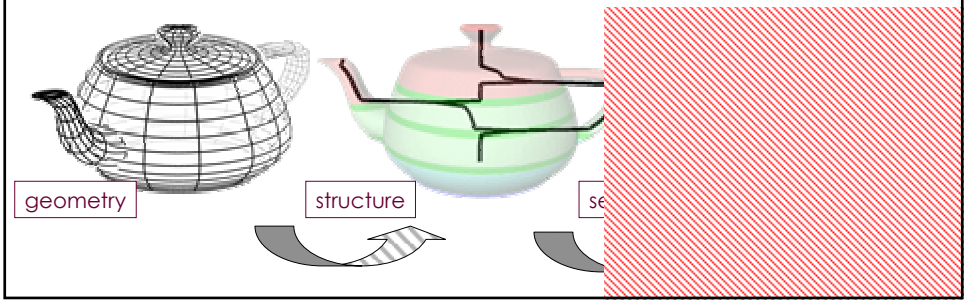
- ✓ Understand the meaning of a surface;
- ✓ Compare a surface with another one.

✓ What does it look like?

✓ Which is its function?

New shape paradigm

- ✓Shape
- ✓Geometry
- ✓Structure
- ✓Functionality (semantics)
- ✓Shift from a purely geometric to a semantic-aware level of representation of digital shapes



Motivations

- ✓Developments have focused on geometry;
- ✓Geometric modeling, computational geometry;
- ✓Structure can be the link between geometry and semantics;
- ✓Tools for automatic extraction, coding and handling of structure (and even more of semantics) are still missing.

Why shapes are important?

Shapes are likely to become the 4th wave of digital multimedia content, after sound in the ’70s, images in ’80s, and video in the ’90s: technology is converging to support the creation and delivery of high fidelity, high performance shape content (3D, 3D+T).

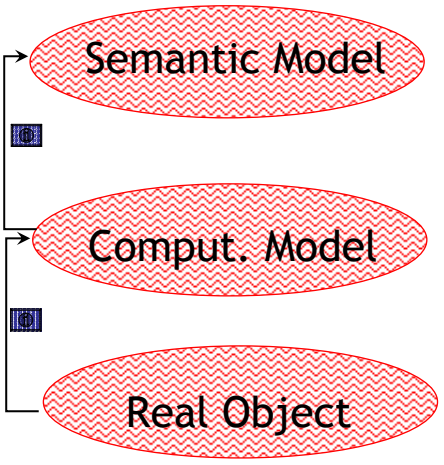
Related problems

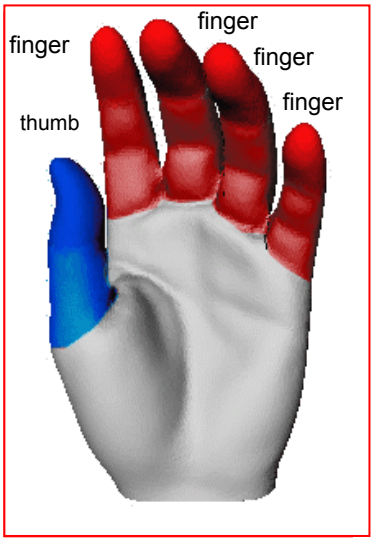
- ✓Size & volume of shape data (data deluge);
- ✓knowledge carried is small;
- ✓information encoded is implicit;
- ✓large spectrum of fundamental disciplines (CG, CV, GM, CM, CAD, …);
- ✓fragmentation of theoretical and technological research.

Challenges

- ✓ Represent shape semantics;
- ✓ Maximize automation of the Shape knowledge lifecycle:
  - ✓ top-down approach: semantics → raw data;
  - ✓ bottom-up approach: raw data → semantics (Capture shape knowledge from raw data, through geometry and structure);
- ✓ Design new platforms for shape models and software tools based on ontologies.

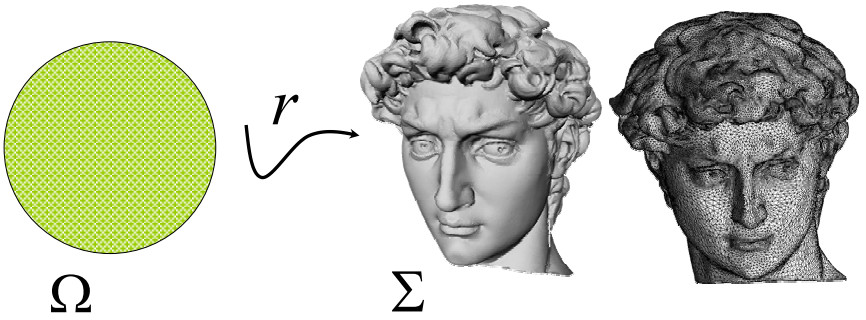
Bottom-up approach





Triangle mesh

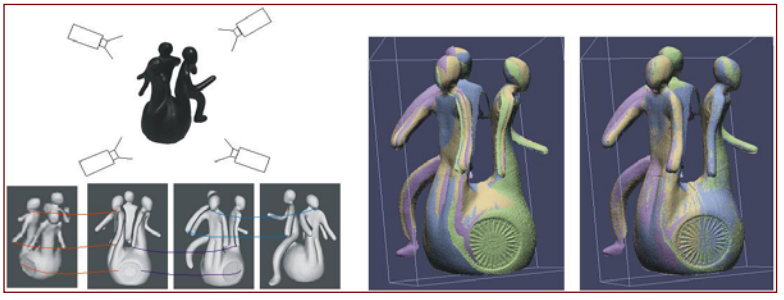
Triangle mesh=piecewise linear surface achieved by sampling parametric surfaces.



$$\Sigma := \left\{ r(u,v) : \ (u,v) \in \Omega \subseteq R^2 \right\}$$

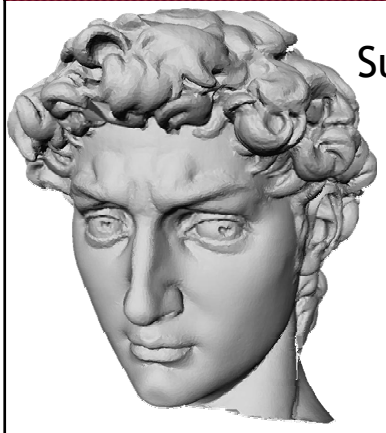
T-mesh: acquisition & reconstruction

Objective: to preserve and enhance shape information during acquisition and approximation processes.

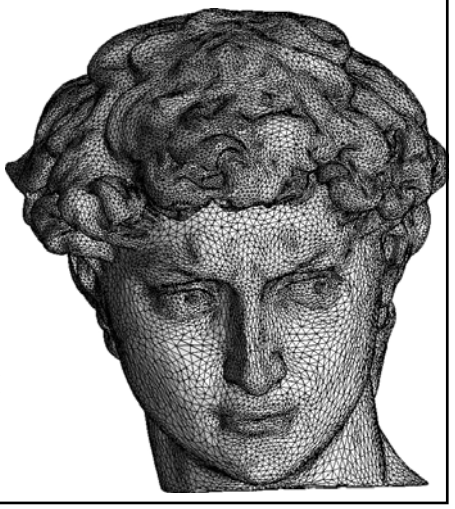


Acquire, merge, and model several views on the input surface.

Triangle mesh

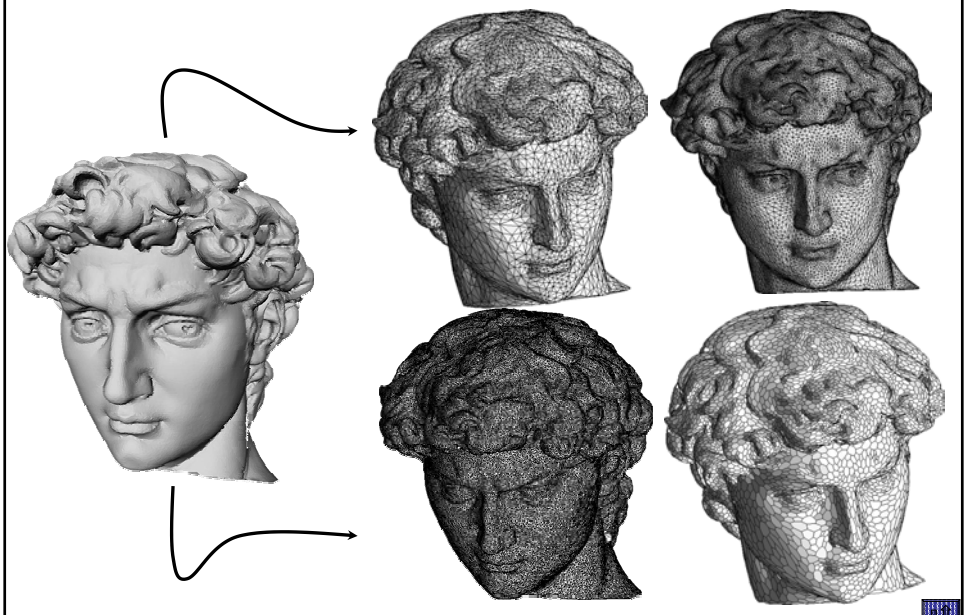


Surface=2-manifold



Representation:
triangle mesh

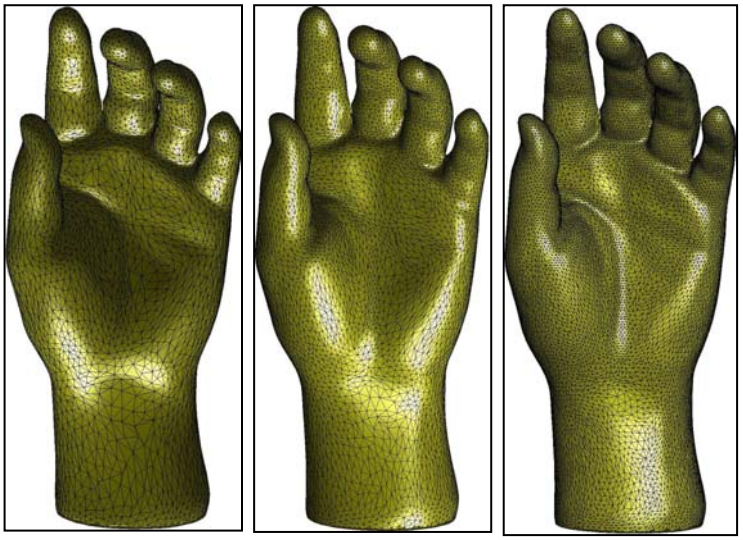
Triangle meshes: equivalent representations?



Analysis and structuring

Objective: to preserve and enhance shape information during geometry processing and to effectively capture the structure of a shape by identifying relevant components and their mutual relationships.

Multi-resolution representations



Three level of details

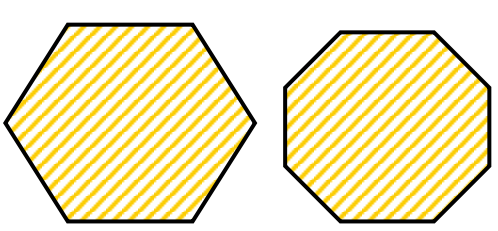
Shape descriptors

- ✓ Structures that describe a shape at high level (abstraction);
- ✓ Decomposition ⇔ Description;
- ✓ Semantics-oriented shape descriptors: describe the object as a collection of parts having a well defined meaning from the morphological point of view.

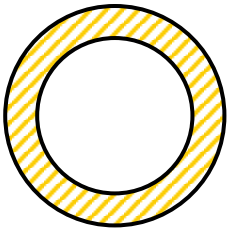
Shape descriptors

In general, descriptors are some set of numbers that are produced to describe a given shape.

Example



edges



area, genus…

Shape descriptors properties

The better the descriptor is,

- ✓ the greater the difference in descriptors of significantly different shapes, and
- ✓ the lesser the difference for similar shapes.

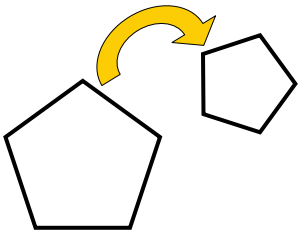
Descriptors attempt to quantify shape in ways that agree with human intuition.

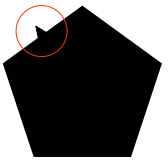
Shape descriptors properties

- ✓ Invariance under (affine) transformations;
- ✓ Uniqueness;
- ✓ Stability to noise;
- ✓ Discrimination between main features and details.

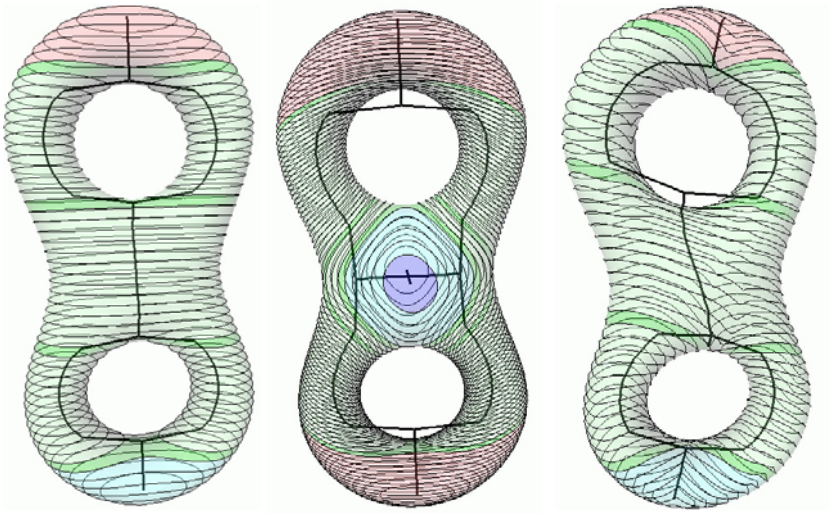
Example

edges





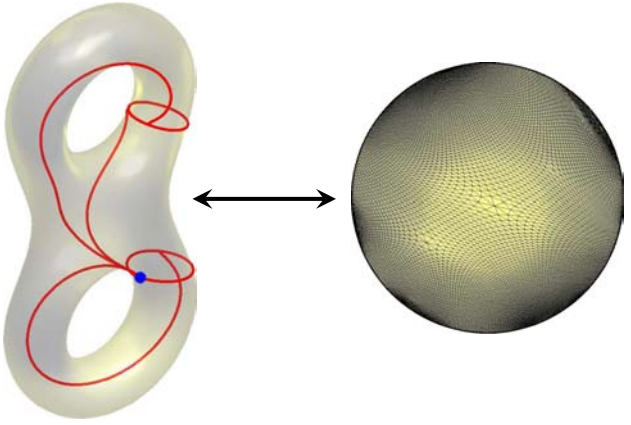
Morse theory and Reeb graph



Iso-contours & Reeb graph w.r.t 3 scalar fields.

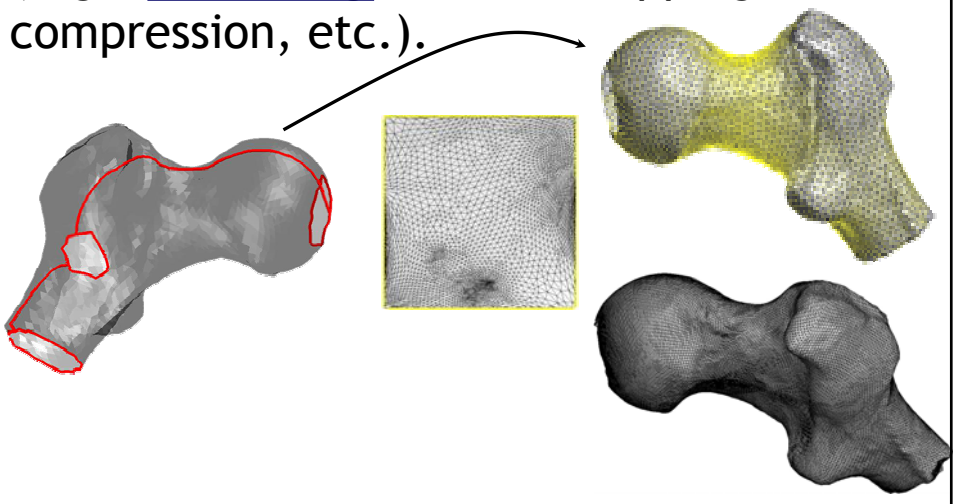
Mesh parameterization

Global Parameterization: continuous and piecewise linear isomorphism between the original surface and a planar region.

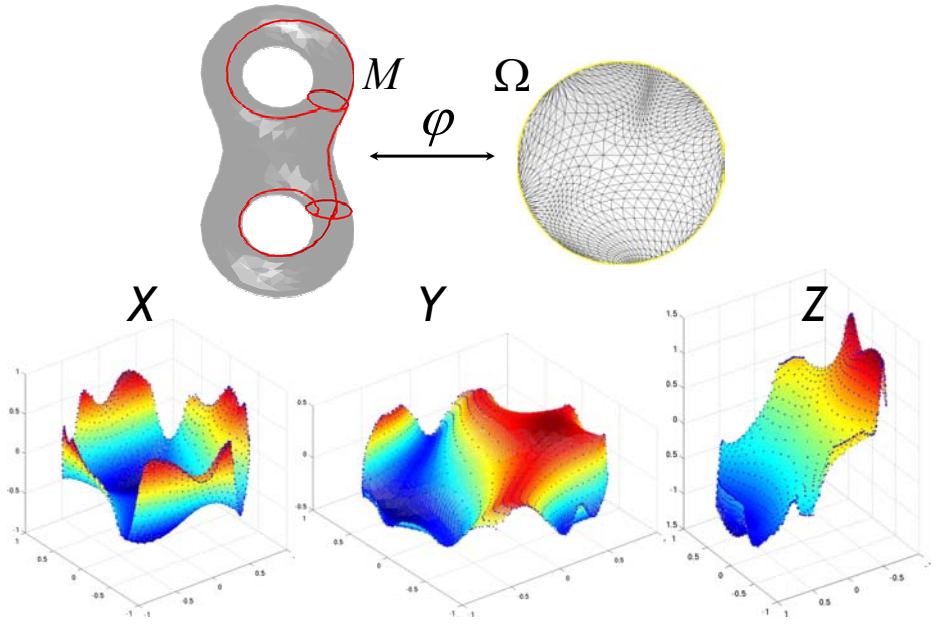


Mesh parameterization

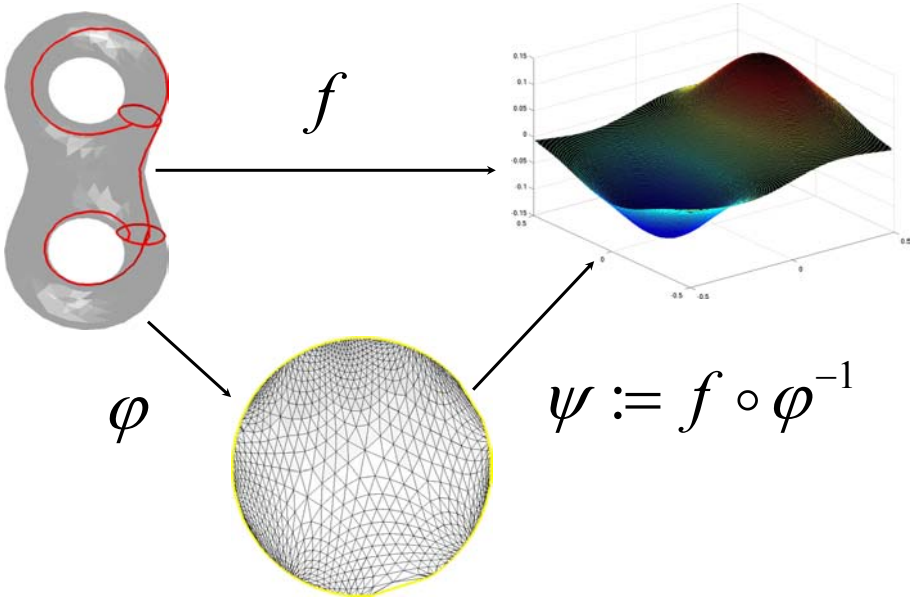
Surface approximation and sampling (e.g., remeshing, texture mapping, compression, etc.).



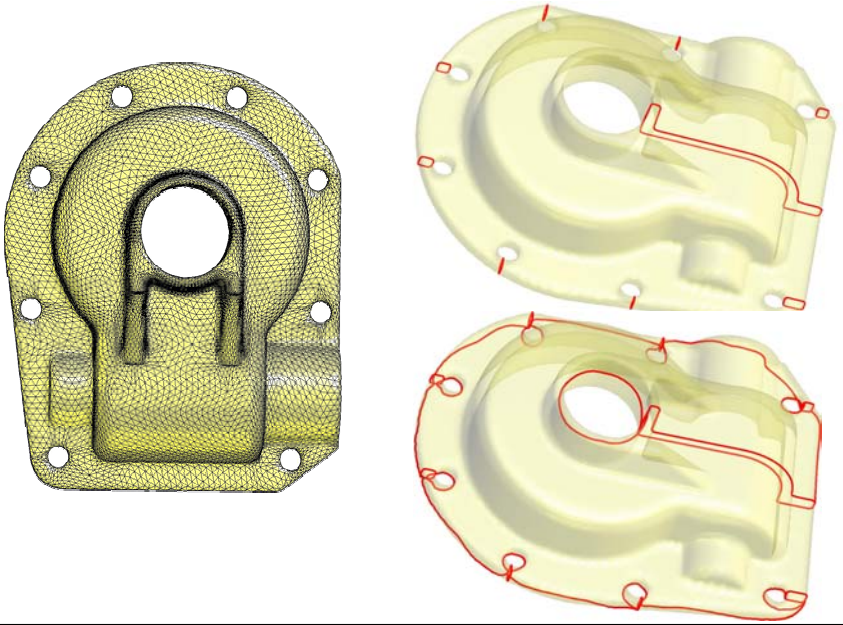
Surface interpolation



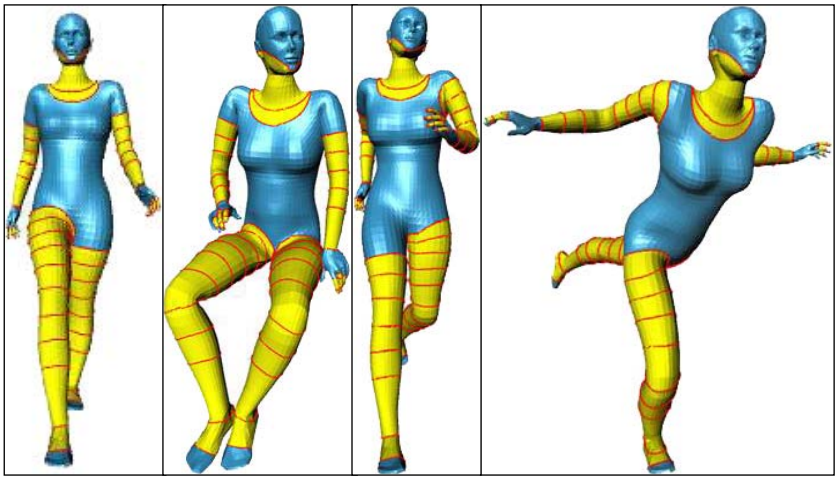
Analysis & modelling of scalar fields



Mesh parameterization

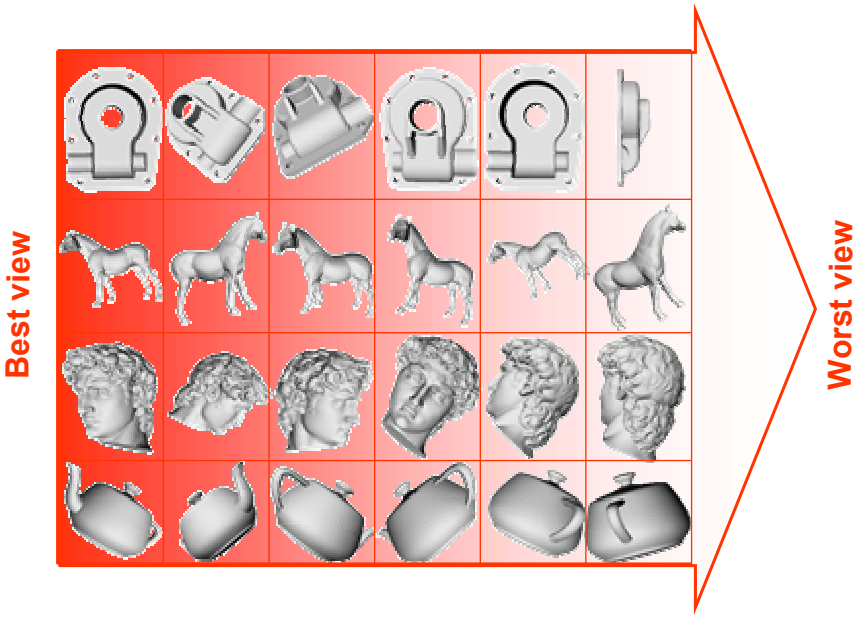


Shape segmentation & semantic annotation

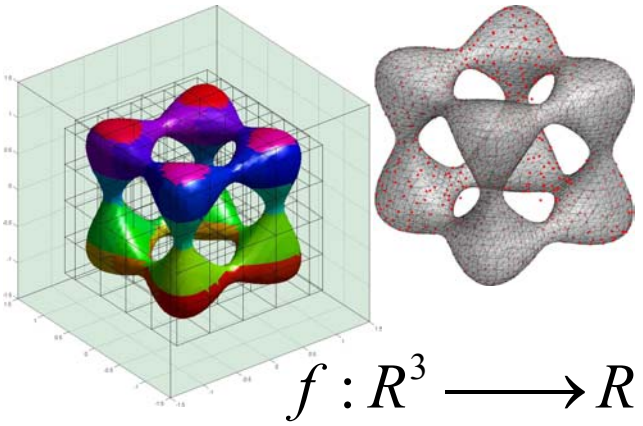


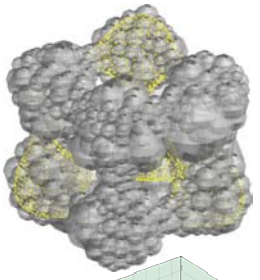
Identification & abstraction of features: generalized cone, cylinders, and bodies.

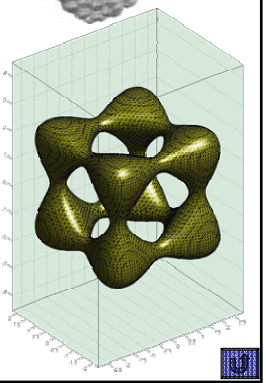
Shape entropy



Implicit modeling







$$f : R^3 \longrightarrow R$$

$$f(p) := \sum_i \alpha_i \varphi(\| p - c_i \|_2)$$

$$\varphi(t) := \exp(-t^2), \varphi(t) = t^3, \ldots$$

AIM@SHAPE NoE

Network of Excellence AIM@SHAPE: Advanced and Innovative Models And Tools for the development of Semantic-based systems for Handling, Acquiring, and Processing knowledge Embedded in multidimensional digital objects (Contract number FP6 IST NoE 506766)

www.aimatshape.net