Overview

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Analyzing Skeletons

Analysis and processing needed to use skeletons

- 4.1 Comparing skeletons
- 4.2 Building the skeletal structure
- 4.3 Garbing

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Comparing skeletons (1/3)

Skeletonizations widely differ in many aspects:

- definition, approximation, computation…
- compliance with desired properties

➡ **must compare to choose**

Properties assessment:

- **can** be done quantitatively
  - invariance, centeredness [SJT14], thinness, speed & scalability, reconstruction [ASS11]
- **must** be done qualitatively
  - homotopy, detail preservation, smoothness, regularization

[JKT13] [RvWT08a] [JBC07] [LCLJ10] [ASS11] [PK99a] Input shapes (512^3 voxels)

dino

dragon

fertility

rockerarm

casting

horse

elephant

frog

Comparing skeletons (3/3)

Comparing skeletons is a difficult challenge:

- hard to obtain full implementations of methods
- lack of accepted property definitions
- lack of ground truth (especially for curve skeletons)
- lack of benchmark shapes
- sheer amount of algorithms (+ regularizations / parameters)

➡ still needed for both practitioners and researchers

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Building skeletal structure (1/4)

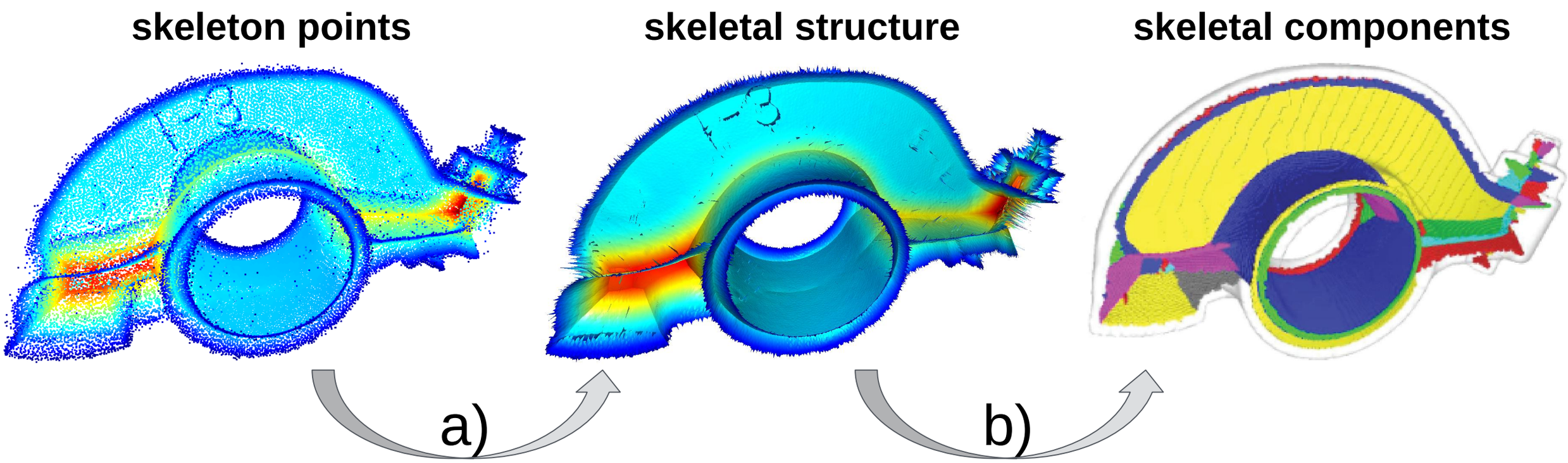
MAT produces a set of balls:

only useful for garbing & thickness estimation [JKT13]

For other applications, we need to:

a) approximate the skeletal structure

b) segment the skeletal structure into curves or surfaces



Building skeletal structure (2/4)

Relatively simpler for Image Skeletons (IS)

- for a), IS are already sets of connected voxels
- for b), finding component bounders/junctions efficiently done by
  - templates in image morphology [BM94,SC94,PK99a]
  - using cardinality of voxel-based feature transform [RT08c]

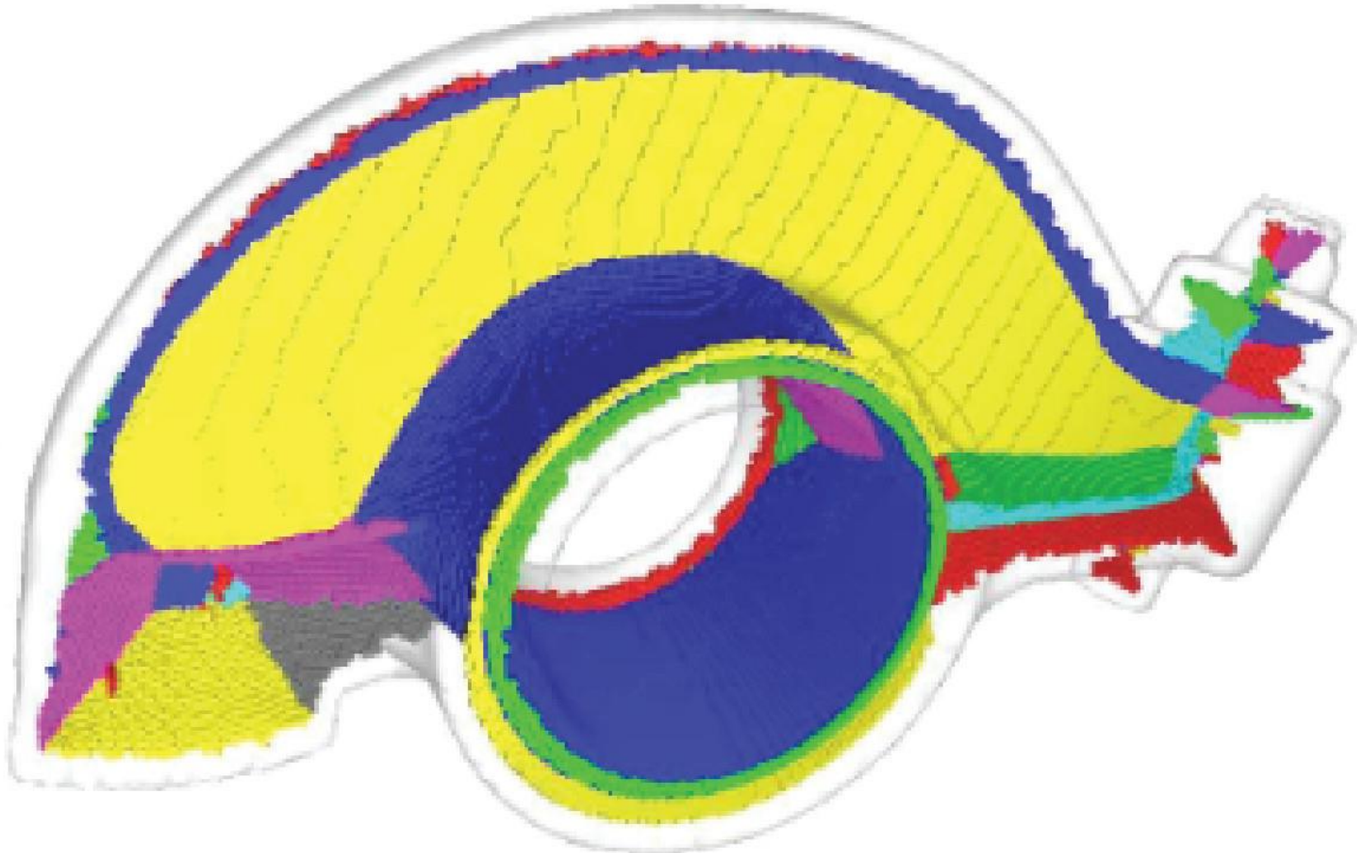
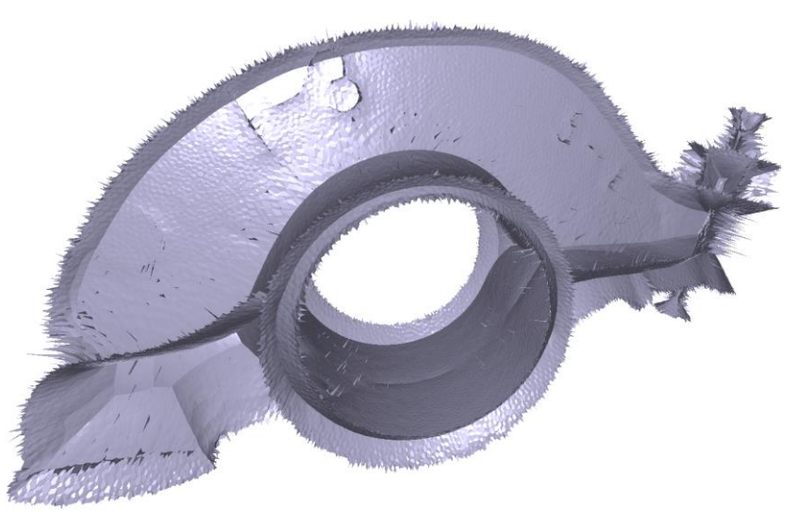


Image Surface Skeleton components segmentation [RT08c]

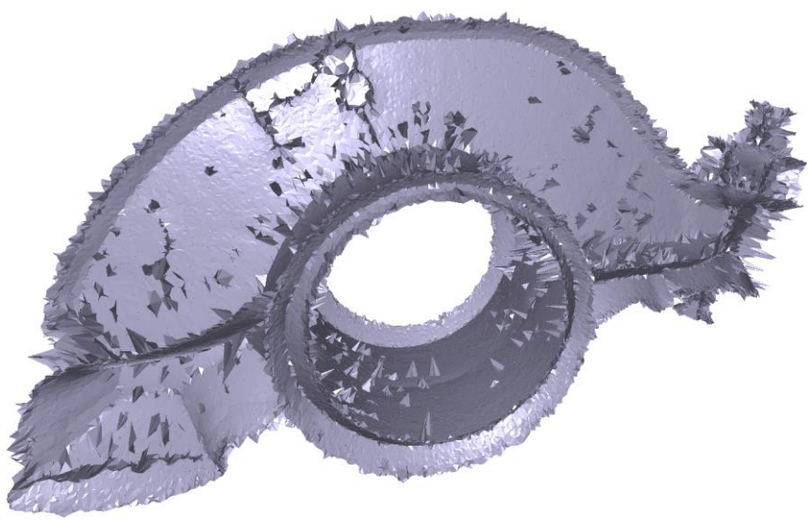
Building skeletal structure (3/4)

Approximating skeletal structure for analytic skeletons:

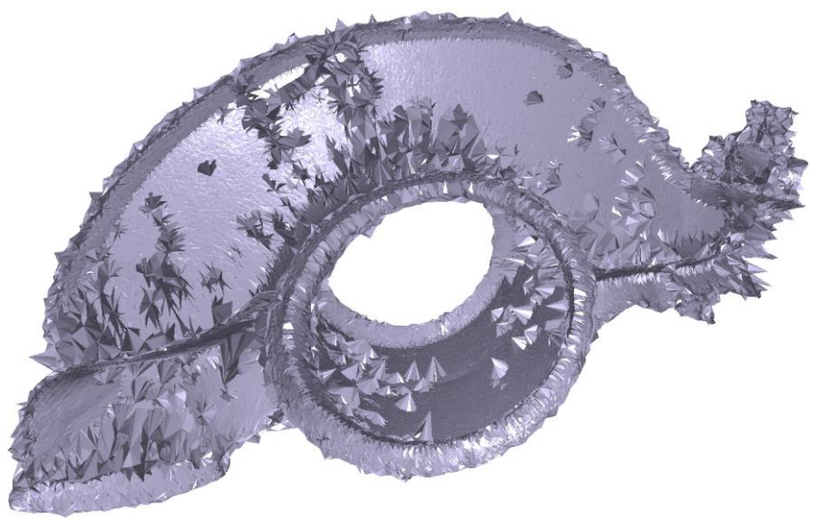
- similar to Point Cloud Reconstruction (PCR) methods [BTS*14]
- few PCR can handle multiply intersecting noisy manifolds [CLK09,KJT14a]
- other popular methods: Voronoi diagram, weighted alpha shape and Delaunay reconstruction [JT12]



Voronoi Diagram



Weighted Alpha Shape



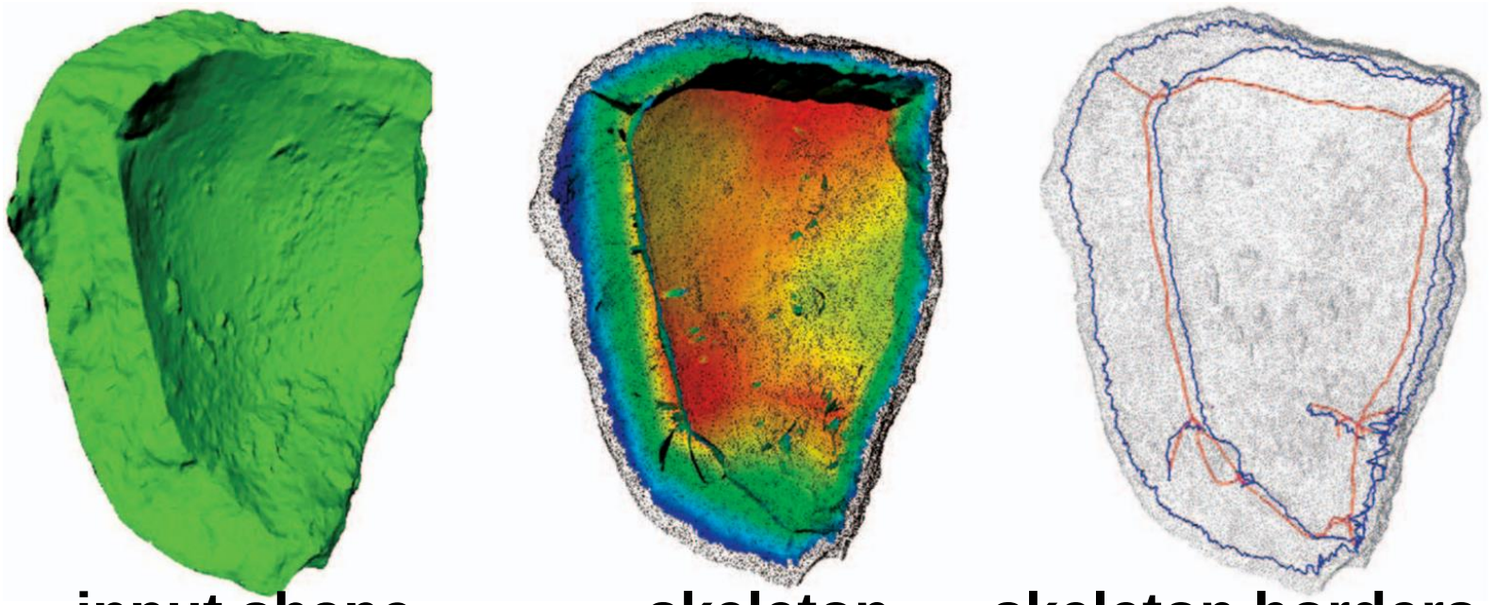
Delaunay Reconstruction

Building skeletal structure (4/4)

Segmenting analytic surface skeletons into components

- classifying medial points [GK04]: find borders & junctions
- medial scaffold classification [LK07]
  - slower & complex to implement
  - delivers **also a segmentation** into manifolds
- classification by cardinality of feature transform [KJT15]
  - faster & simpler to implement but gives only a classification
  - after, cluster medial points into manifolds and reconstruct them [KJT14a]

[LK07]



input shape **skeleton** **skeleton borders & junctions**

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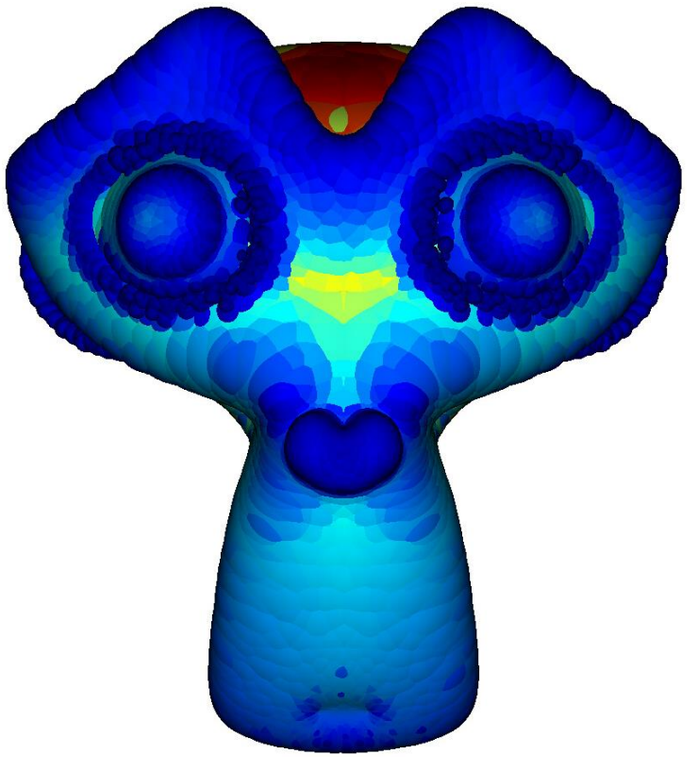
Garbing (1/2)

Approximating the shape from its skeleton by a surface mesh

- implicit surfaces [Bli82,JLW10]: smooth but costly
- meshing the union of balls
  - Regular triangulation methods [AE96]: quite efficient
  - Skin surfaces methods [Ede99]: **more for molecules** than dense skeletons



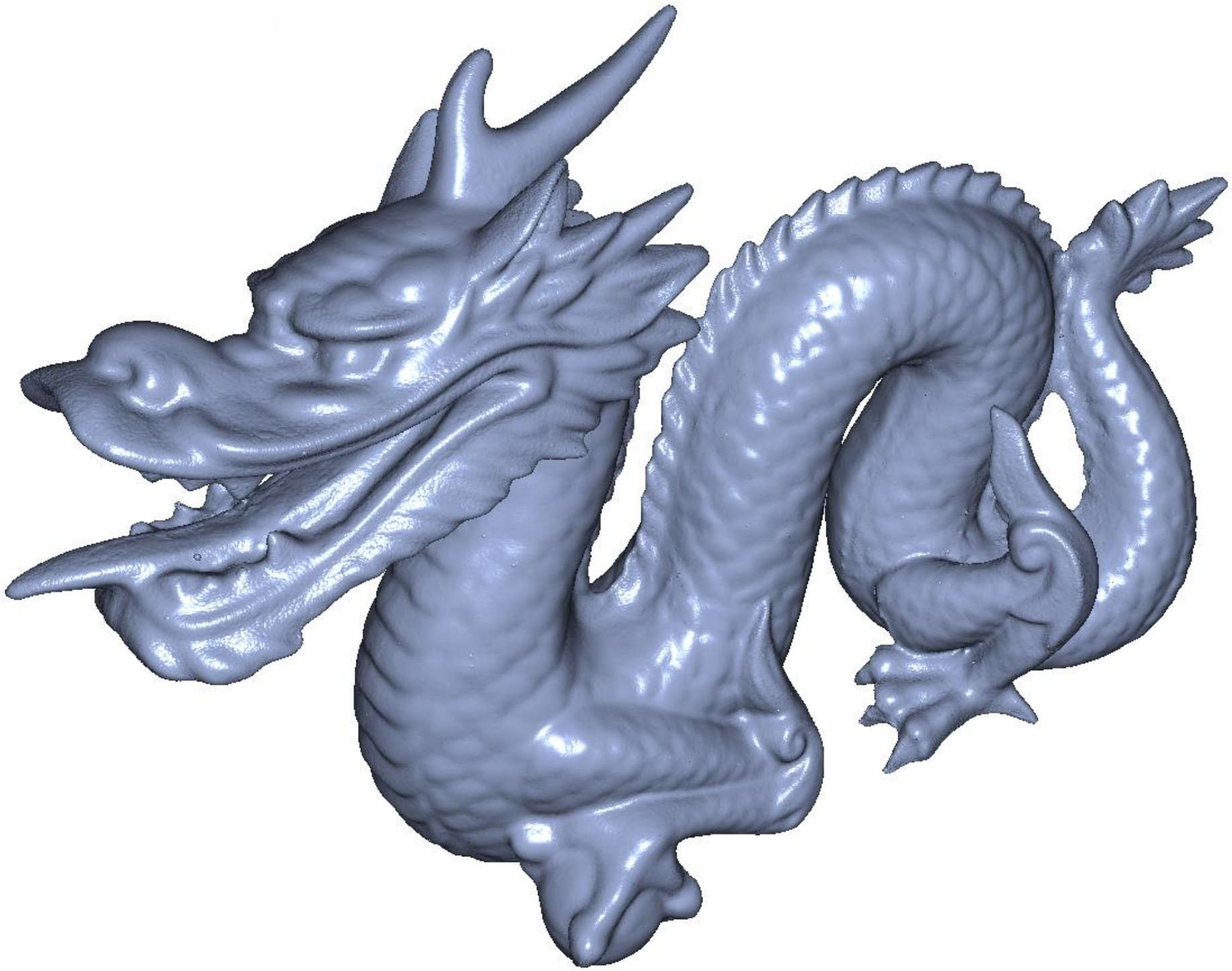
Union of balls

Implicit Surface

Skin Surface

Garbing (2/2)

Approximating the shape from its skeleton by splatting & impostors



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Applications

Curve skeletons

- most present in applications (easy / fast to compute)

Surface Skeletons

- Increasingly being used (due to recent efficient computation)

Applications

- Computer animation & shape synthesis
- Shape processing and analysis

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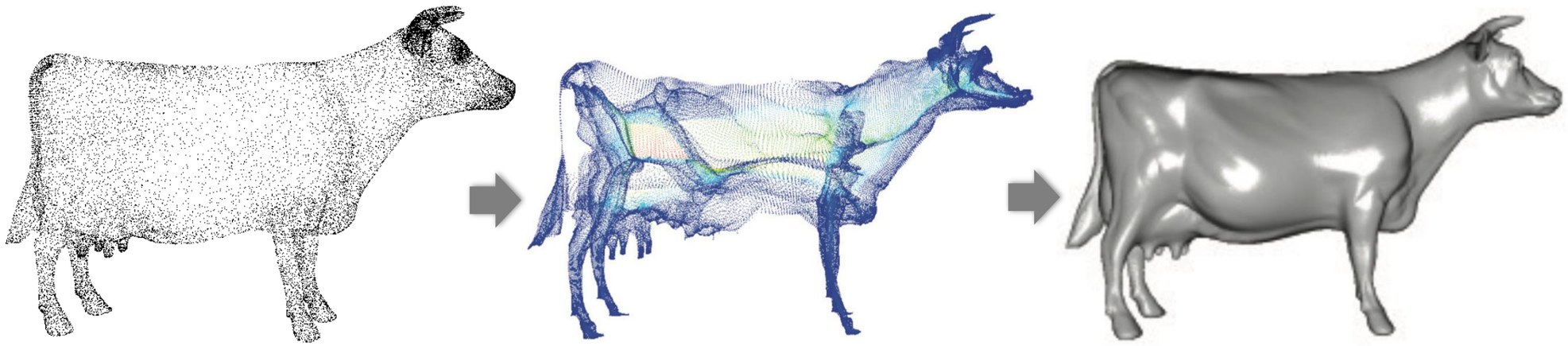
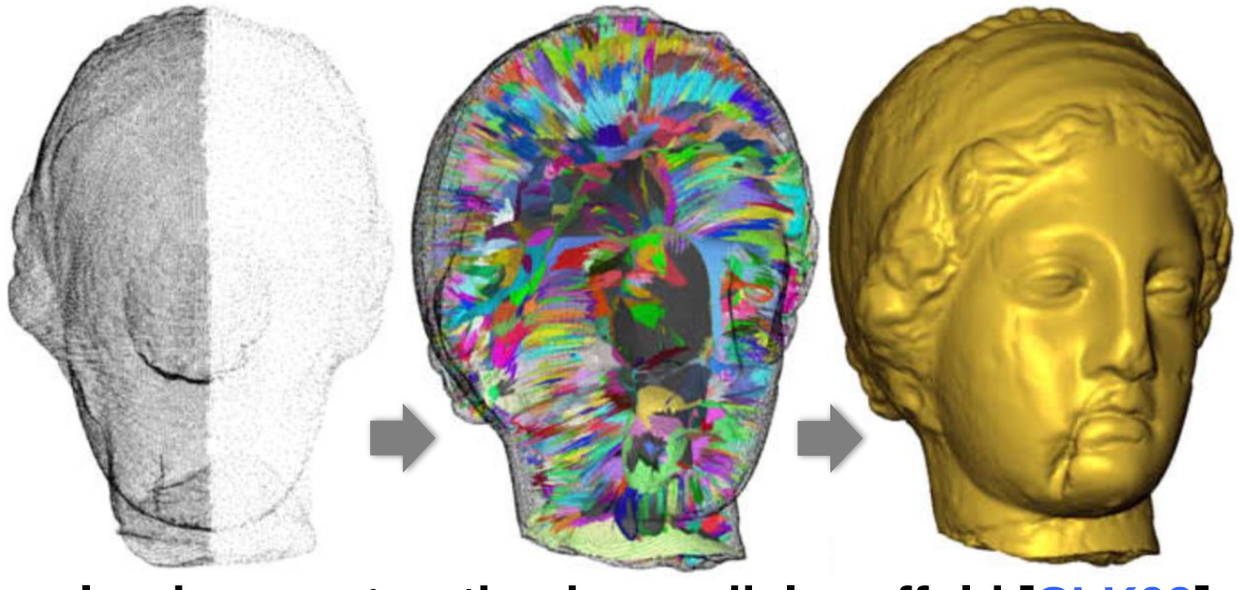
Surface reconstruction

Goals

- we have a (dense) point-sampling of some 3D surface
- we want to reconstruct a compact surface representation



cloud reconstruction by ball splatting [JKT13]

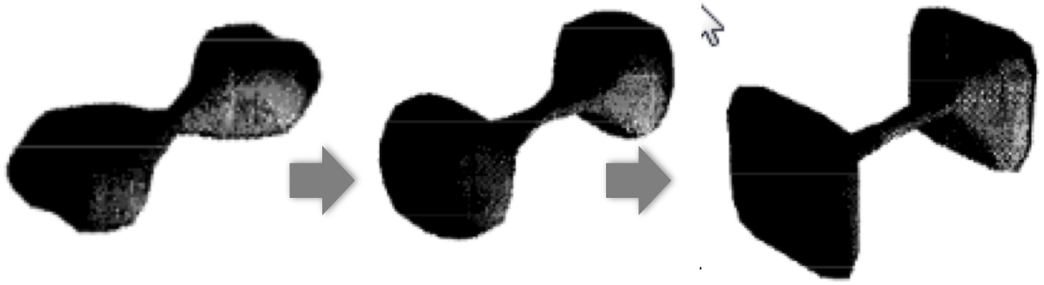


cloud reconstruction by medial scaffold [CLK09]

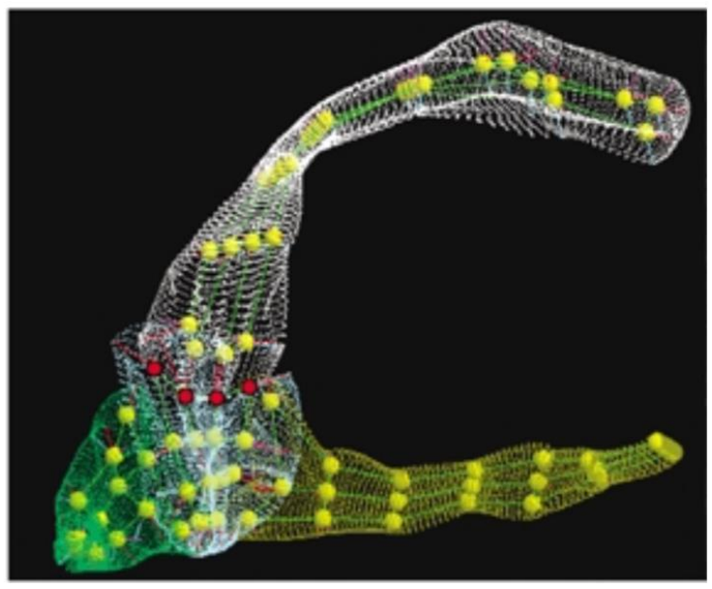
Shape Animation & Synthesis

Goals

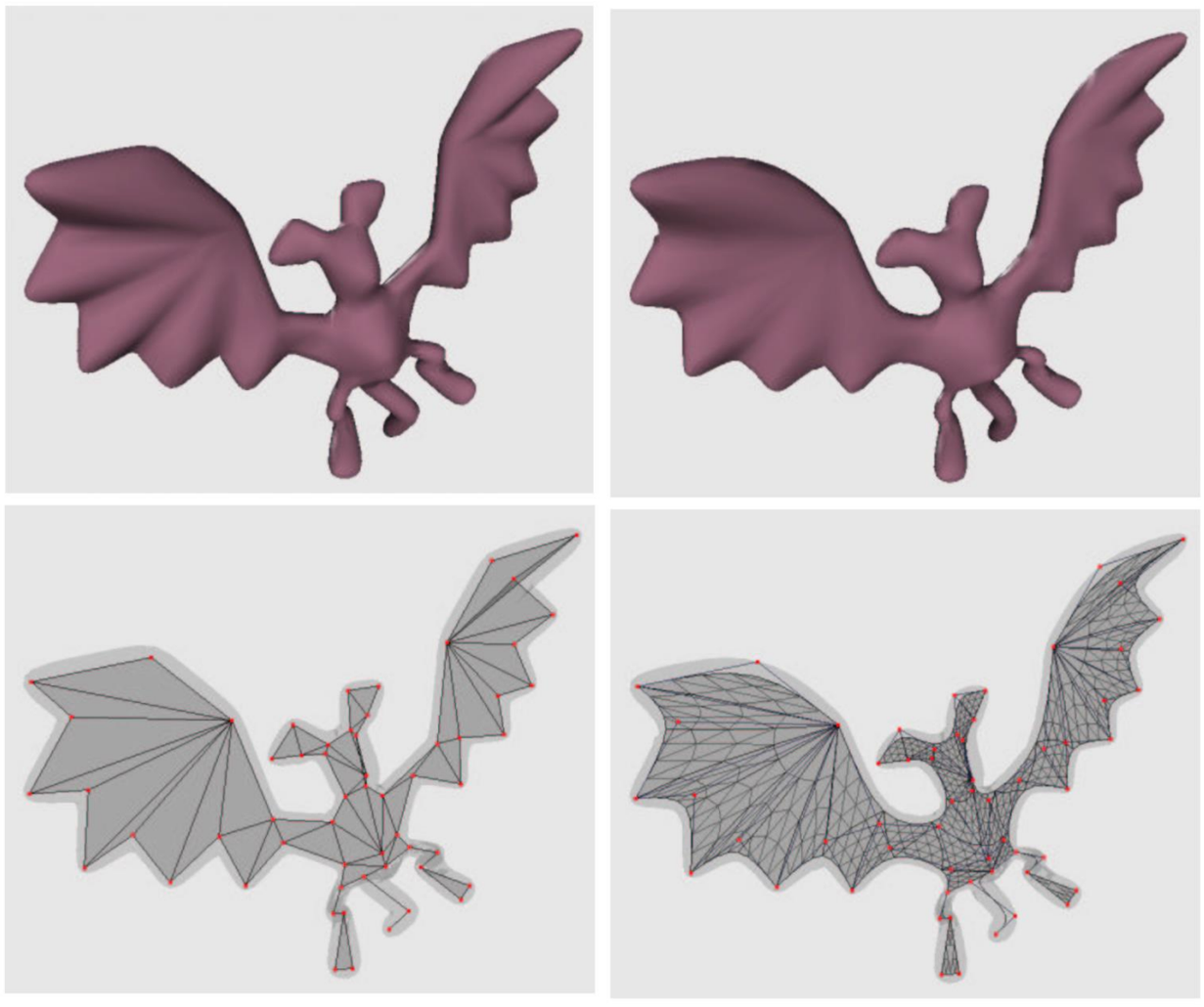
- we have a high-level shape (modification) description
- we want to create (modify) a shape along that description



medial atom-based editing [STG*97]



***m*-reps[PFJ*03]**



skeleton-based modeling [AC02]

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Shape Segmentation

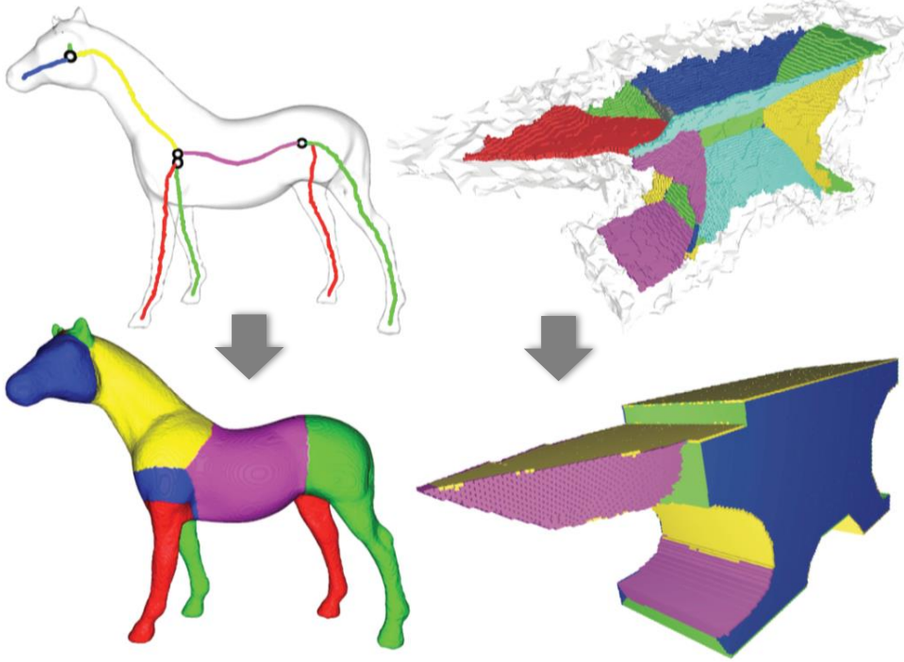
Part-based segmentation

- find the ‘natural’ parts of organic shapes

Patch-based segmentation

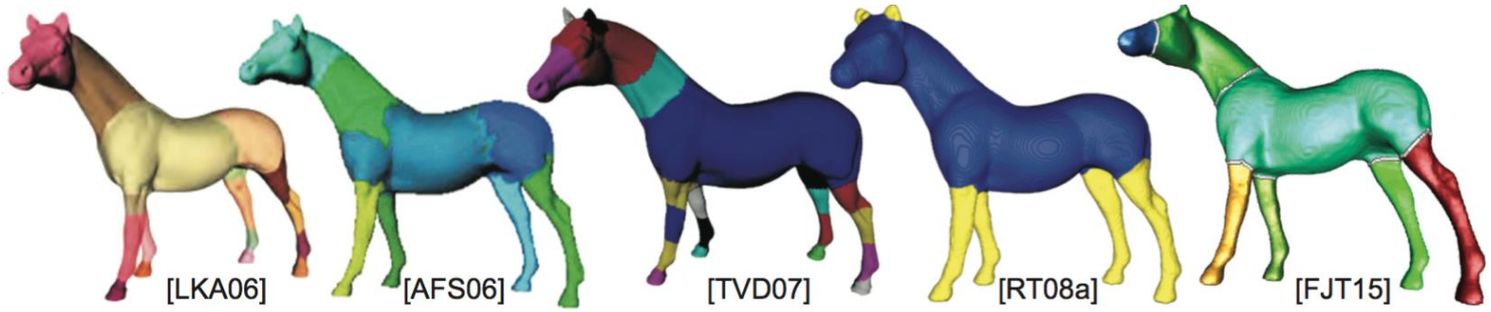
- find the ‘quasi-flat’ parts of surfaces of synthetic shapes

curve skeleton… **surface skeleton…**

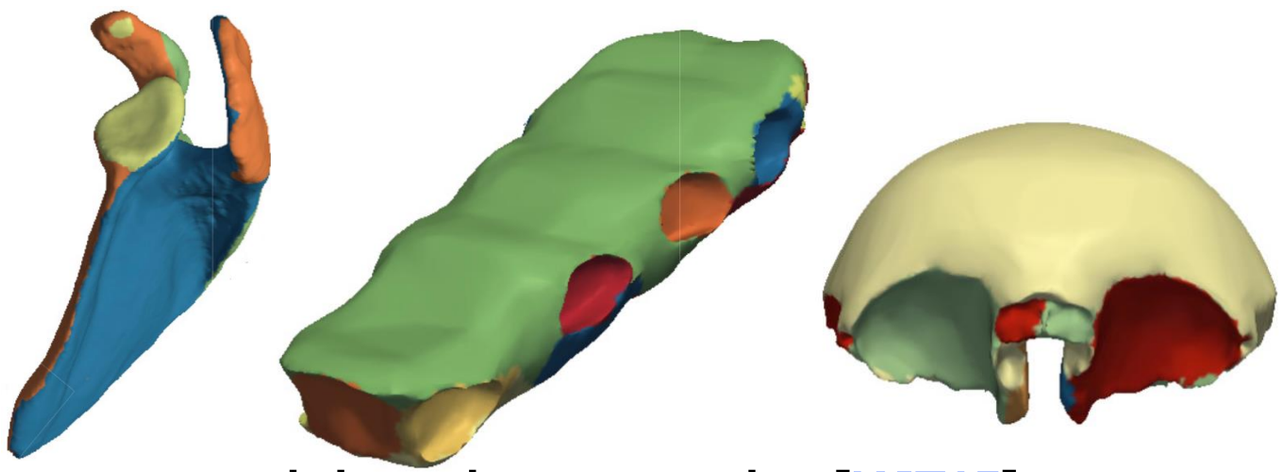


…gives parts **…gives patches**

[RT08a] **[RT08b]**



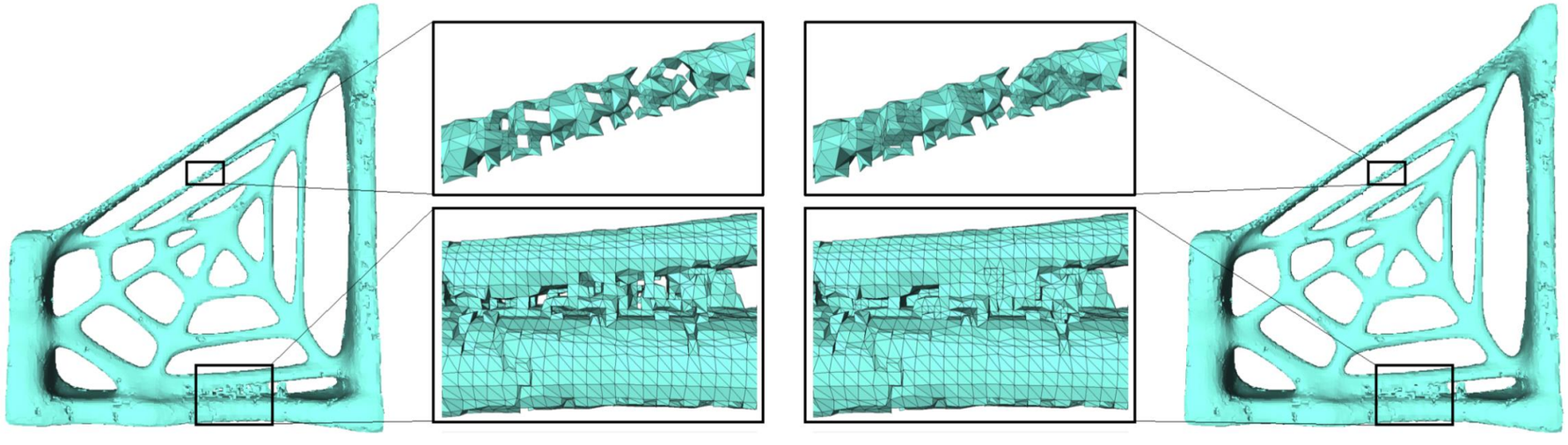
part-based segmentation



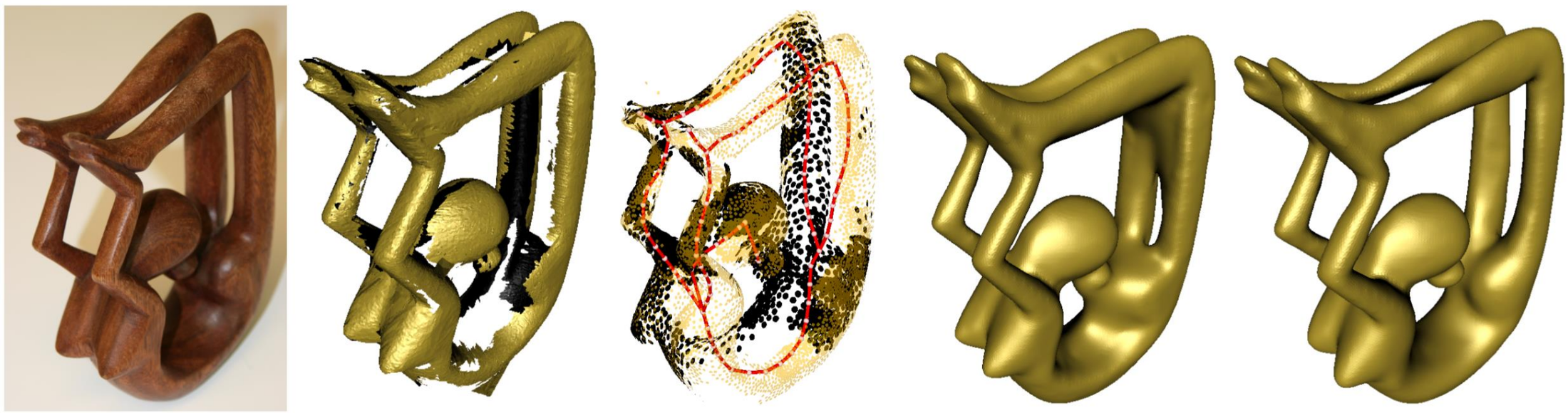
patch-based segmentation [KJT15]

Shape Repairing

Automatically fix various problems in (acquired) shapes



automatic topology repair in scanned shapes [ZJH07]

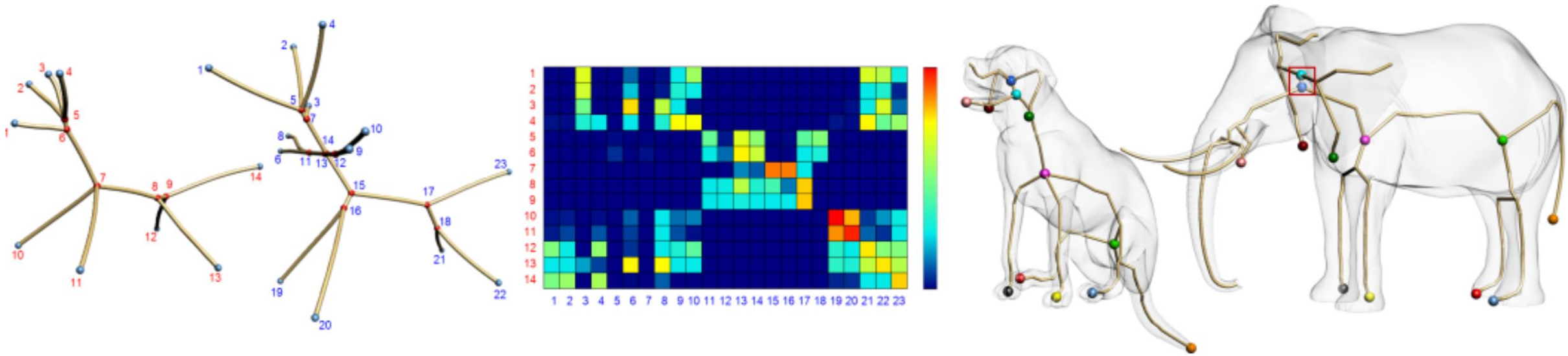


skeletonization and reconstruction of incomplete point clouds [TZCO09]

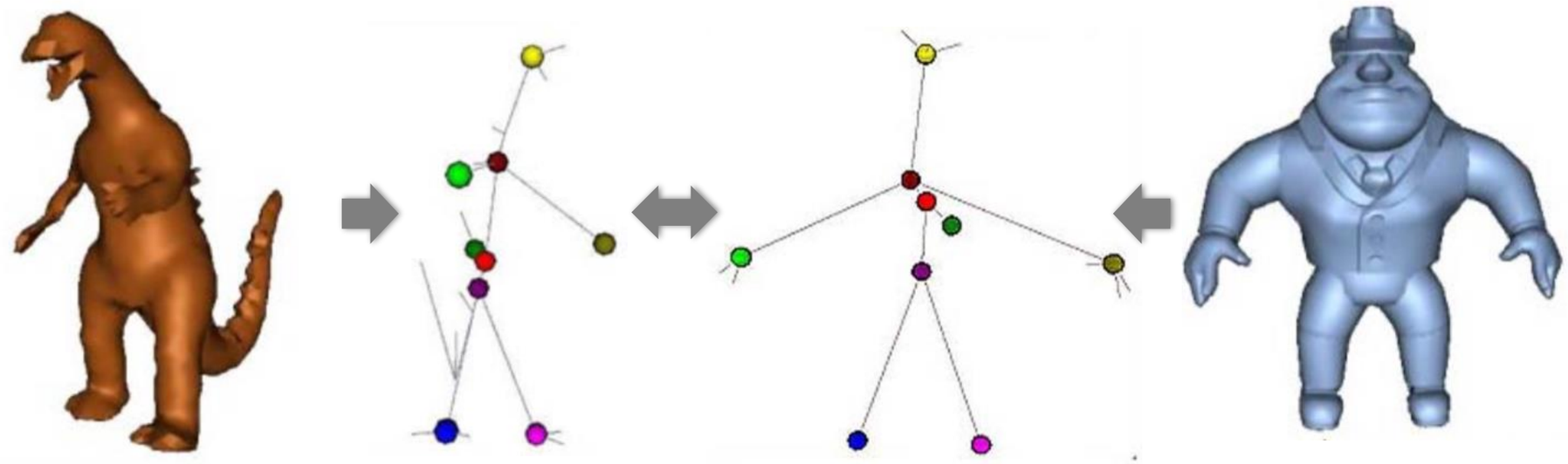
3D Shape Matching

Fundamental problem in shape retrieval, computer vision

Hard part: finding *correspondences* between 2 shapes



fast automatic shape correspondence using curve skeletons [ATCO*10]



skeleton-based shape retrieval [SSGD03]

Shape Metrology

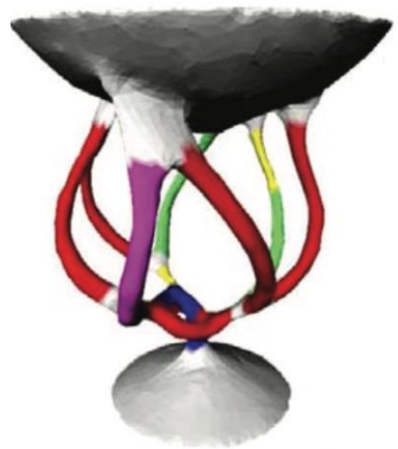
Estimate various properties of 3D shapes

- genus, local tubularity, local thickness, local eccentricity, …
- important for many applications (3D printing, manufacturing)

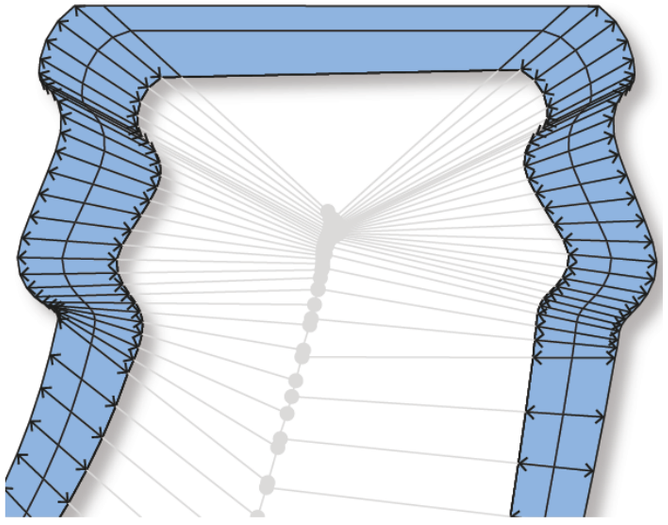
curve skeletons [SSCO08]

surface skeletons [JKT13]

local shape thickness computation



finding tubular parts [MPS*04]
(Plumber method)

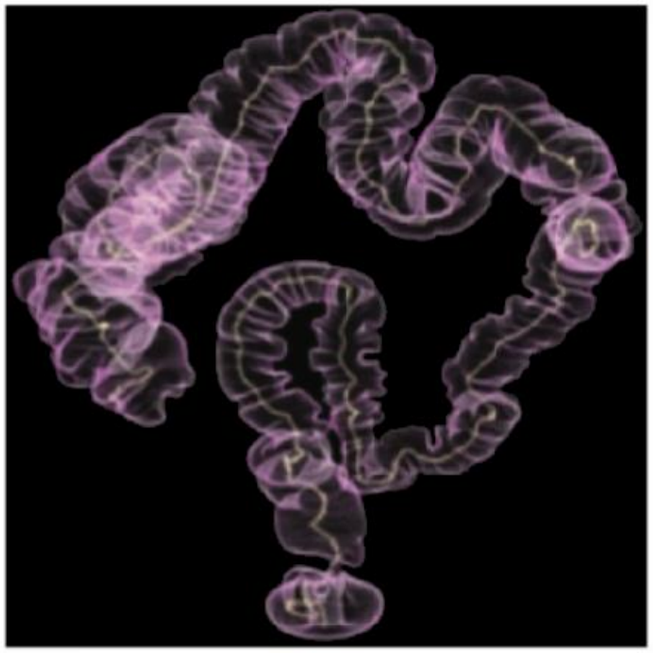


offset surface computation

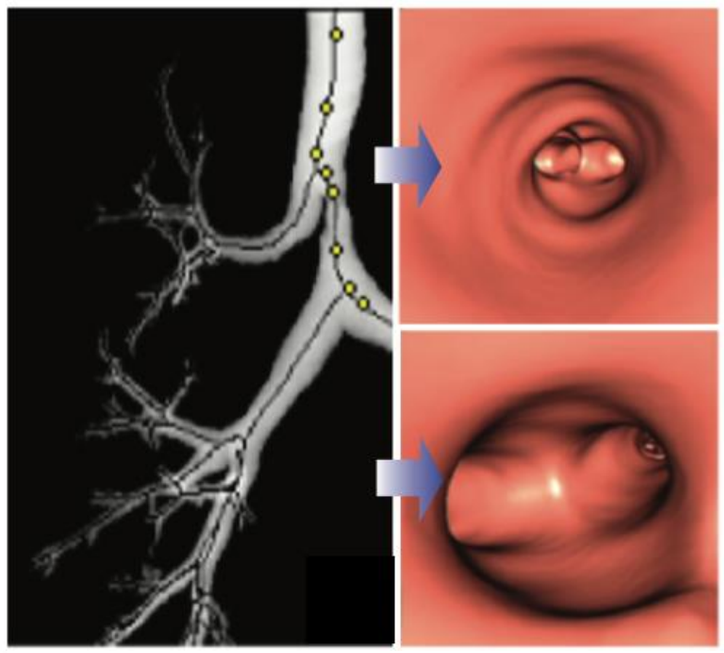
[Musialski et al. SIGGRAPH'15]
Reduced-Order Shape Optimization Using Offset Surfaces

Medical image visualization

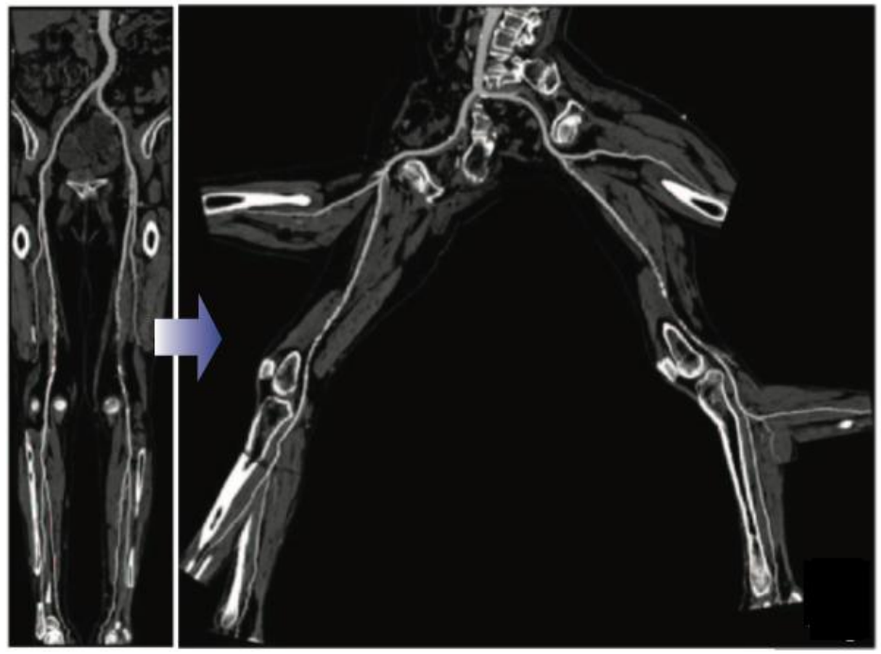
Use curve skeletons to facilitate 3D navigation/inspection



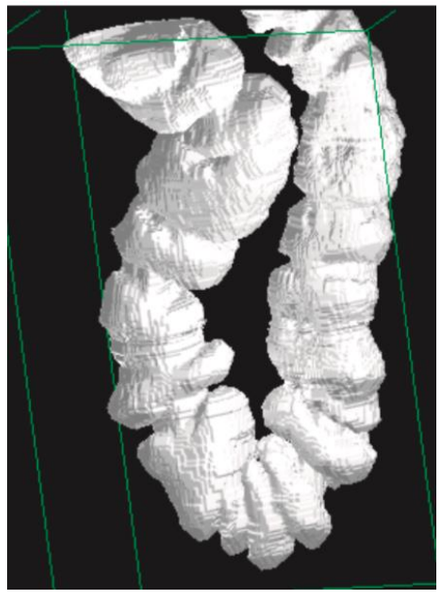
virtual colonoscopy [WDK01]



virtual bronchoscopy [PFP04]



vessel planar reformation [KWFG03]



virtual colon unfolding [VWKG01]