Computer Graphics
-**Geometry Processing**

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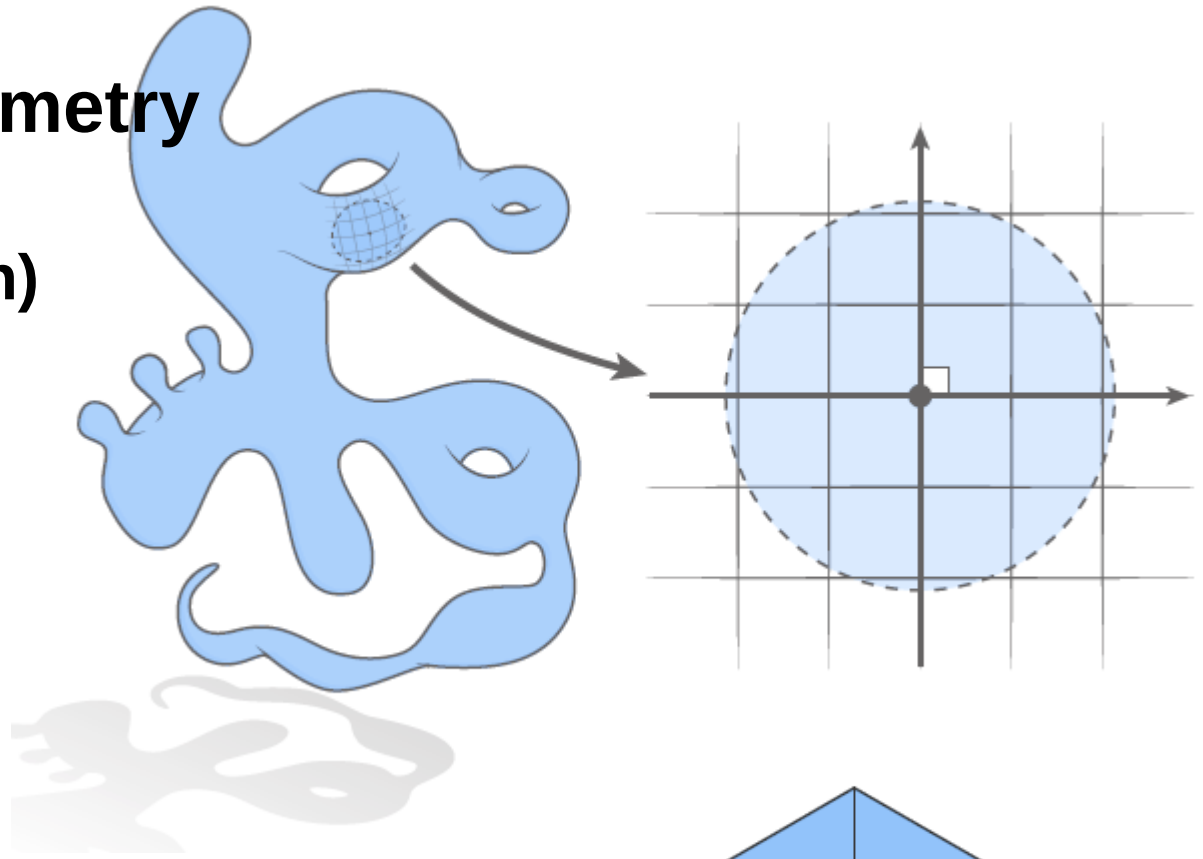
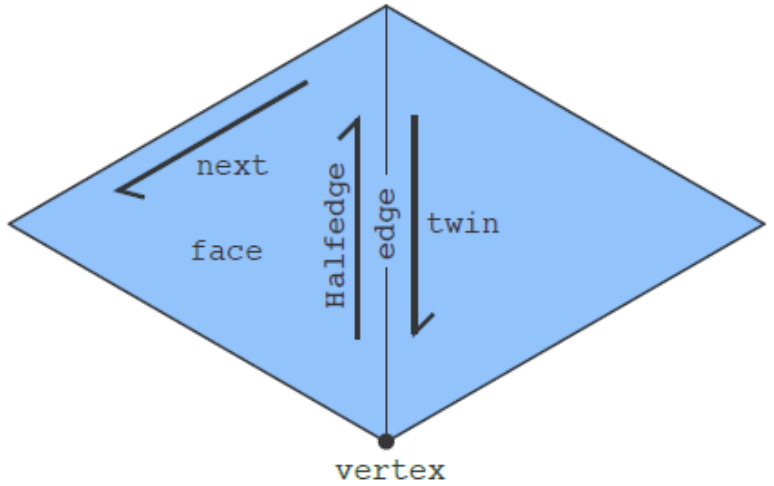
http://jjcao.github.io/ComputerGraphics/

Last time: Curves, Surfaces & Meshes

- **Mathematical description of geometry**
  - **simplifying assumption: *manifold***
  - **gives local coordinates (Manhattan)**
- **Data structures for surfaces**
  - **polygon soup**
  - **halfedge mesh**
  - **storage cost vs. access time, etc.**
- **Today:**
  - **how do we manipulate geometry?**
  - **geometry processing / resampling**





Comparison of Polygon Mesh Data Structures

	Polygon Soup	Incidence Matrices	Halfedge Mesh
storage cost*	~3 x #vertices	~33 x #vertices	~36 x #vertices
constant-time neighborhood access?	NO	YES	YES
easy to add/remove mesh elements?	NO	NO	YES
nonmanifold geometry?	YES	YES	NO

Conclusion: pick the right data structure for the job!

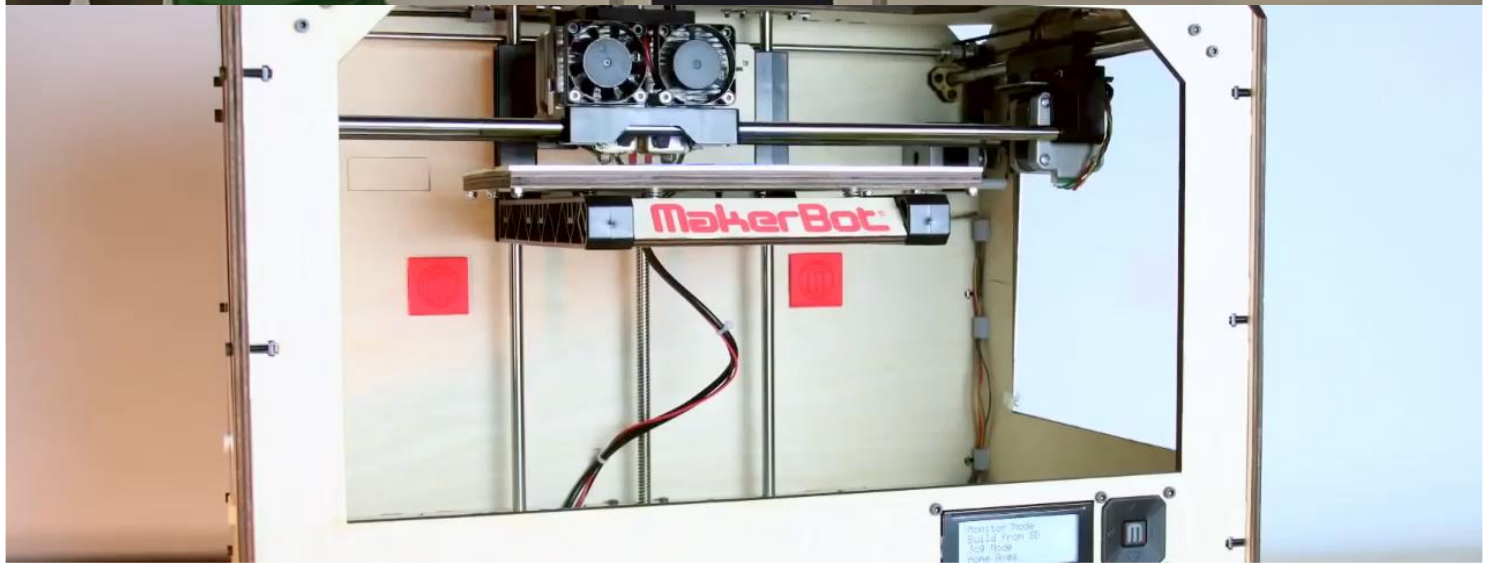
Digital Geometry Processing

- **Extend traditional digital signal processing (audio, video, etc.) to deal with *geometric* signals:**
  - **upsampling / downsampling / resampling / filtering ...**
  - **aliasing (reconstructed surface gives “false impression”)**
- **Also some new challenges (very recent field!):**
  - **over which domain is a geometric signal expressed?**
  - **no terrific sampling theory, no fast Fourier transform, ...**
- **Often need new data structures & new algorithms**

Digital Geometry Processing: Motivation

- 3D Scanning

- 3D Printing



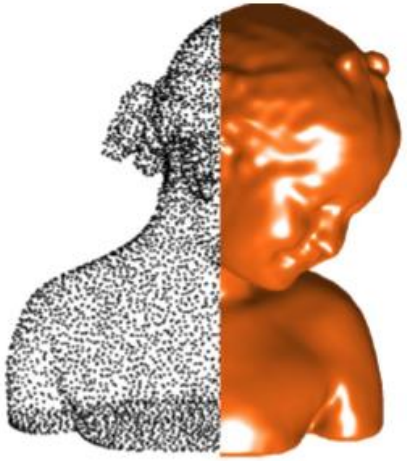
Geometry Processing Pipeline

scan

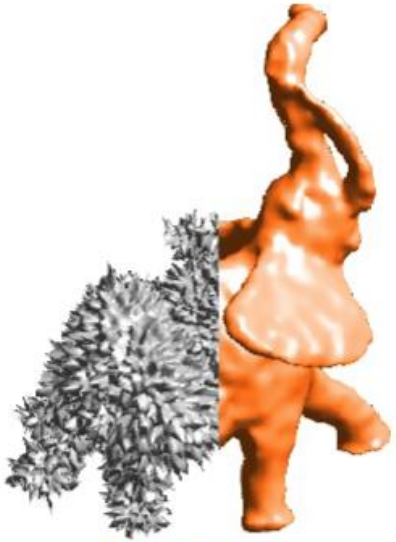
process

print

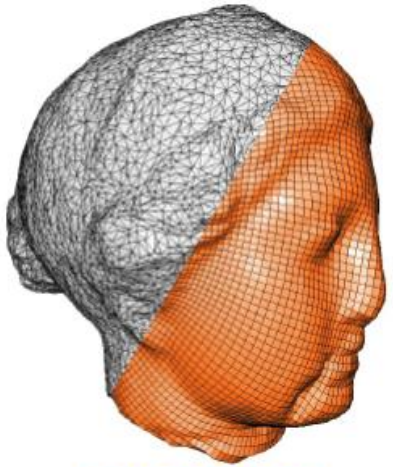
Geometry Processing Tasks



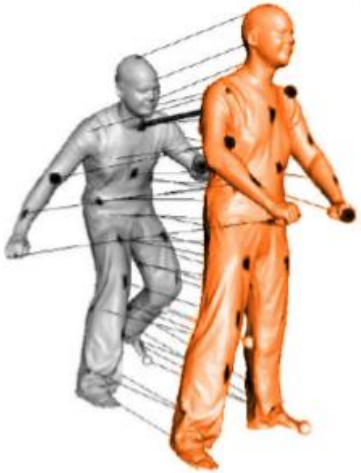
reconstruction



filtering

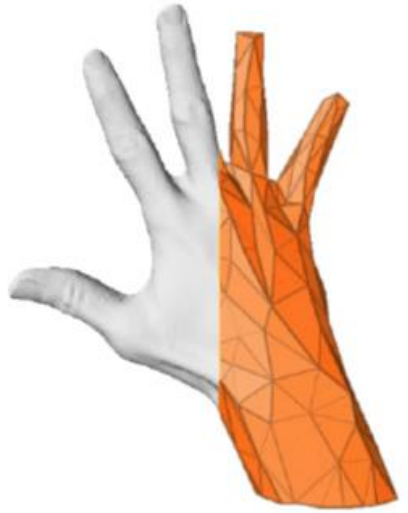


remeshing



shape analysis

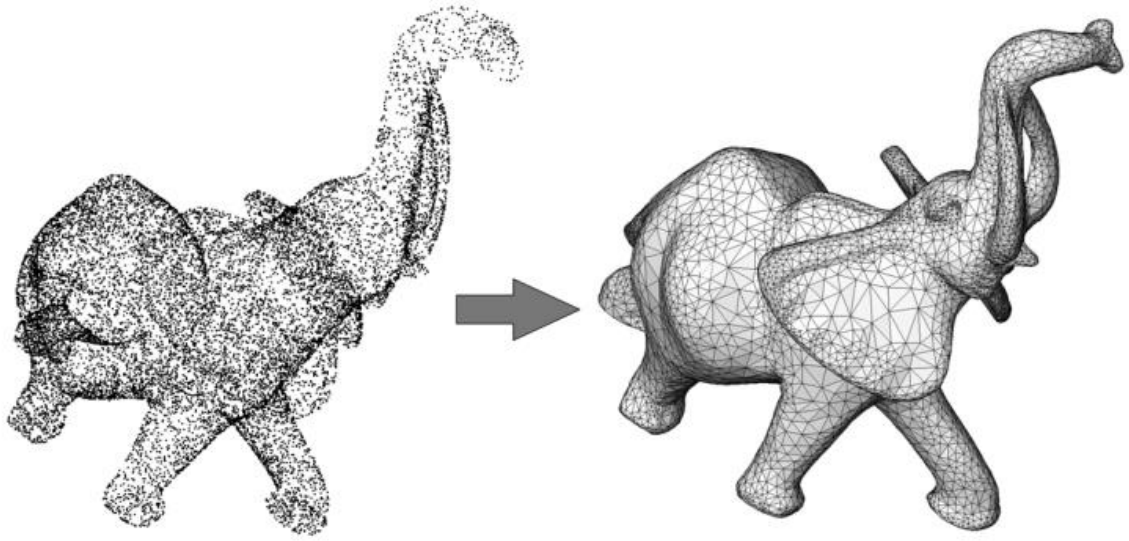
parameterization



compression

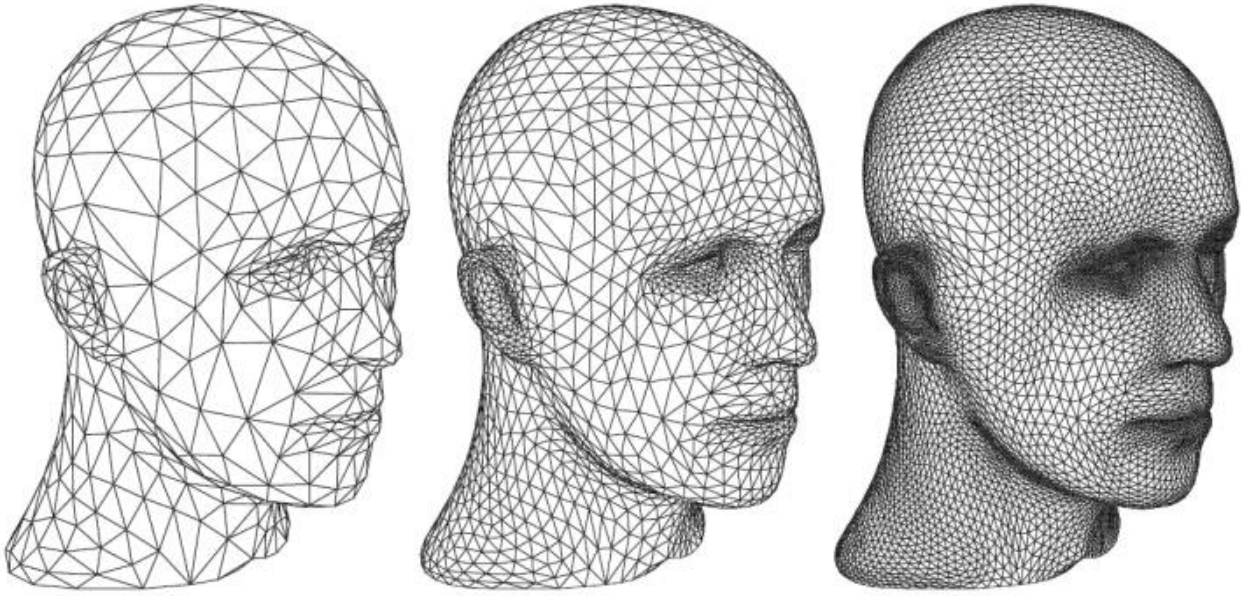
Geometry Processing: Reconstruction

- Given samples of geometry, reconstruct continuous surface
- What are “samples”? Many possibilities:
  - points, points & normals, ...
  - image pairs / sets (multi-view stereo)
  - line density integrals (MRI/CT scans)
- How do you get a surface? Many techniques:
  - PDE-based (e.g., Poisson reconstruction)
  - Voronoi-based (e.g., power crust)
  - silhouette-based (visual hull)
  - Radon transform / isosurfacing (marching cubes)



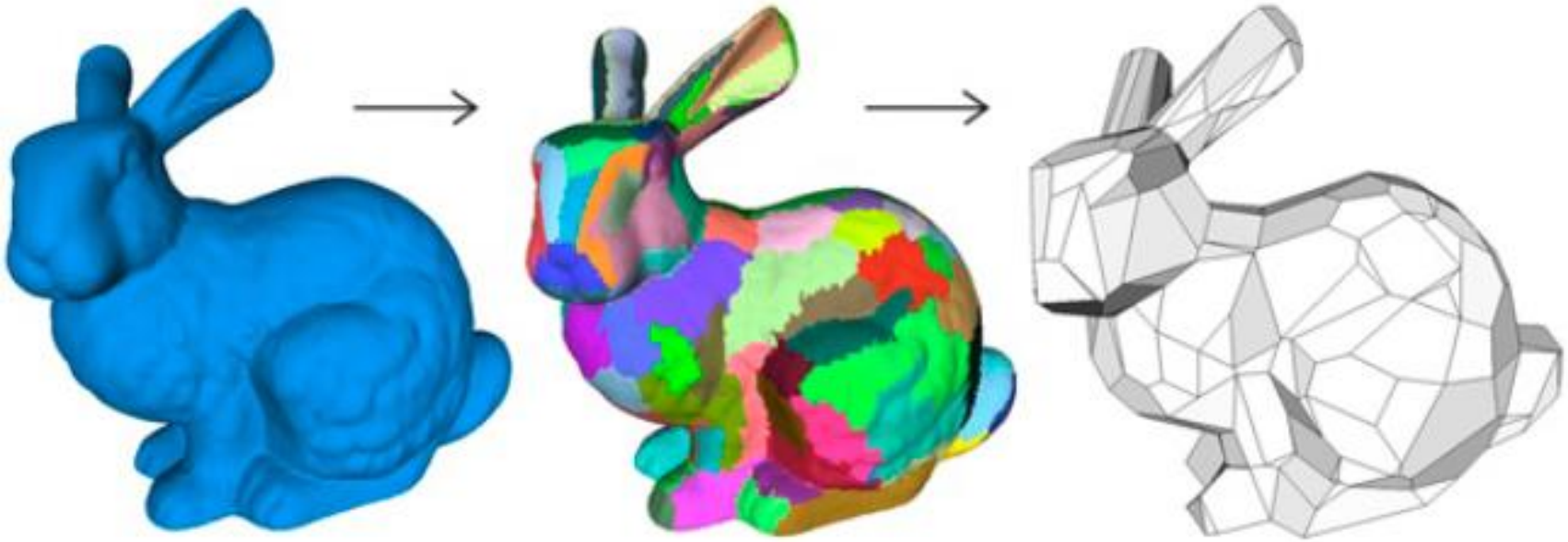
Geometry Processing: Upsampling

- Increase resolution via interpolation
- Images: e.g., bilinear, bicubic interpolation
- Polygon meshes:
  - subdivision
  - bilateral upsampling
  - ...



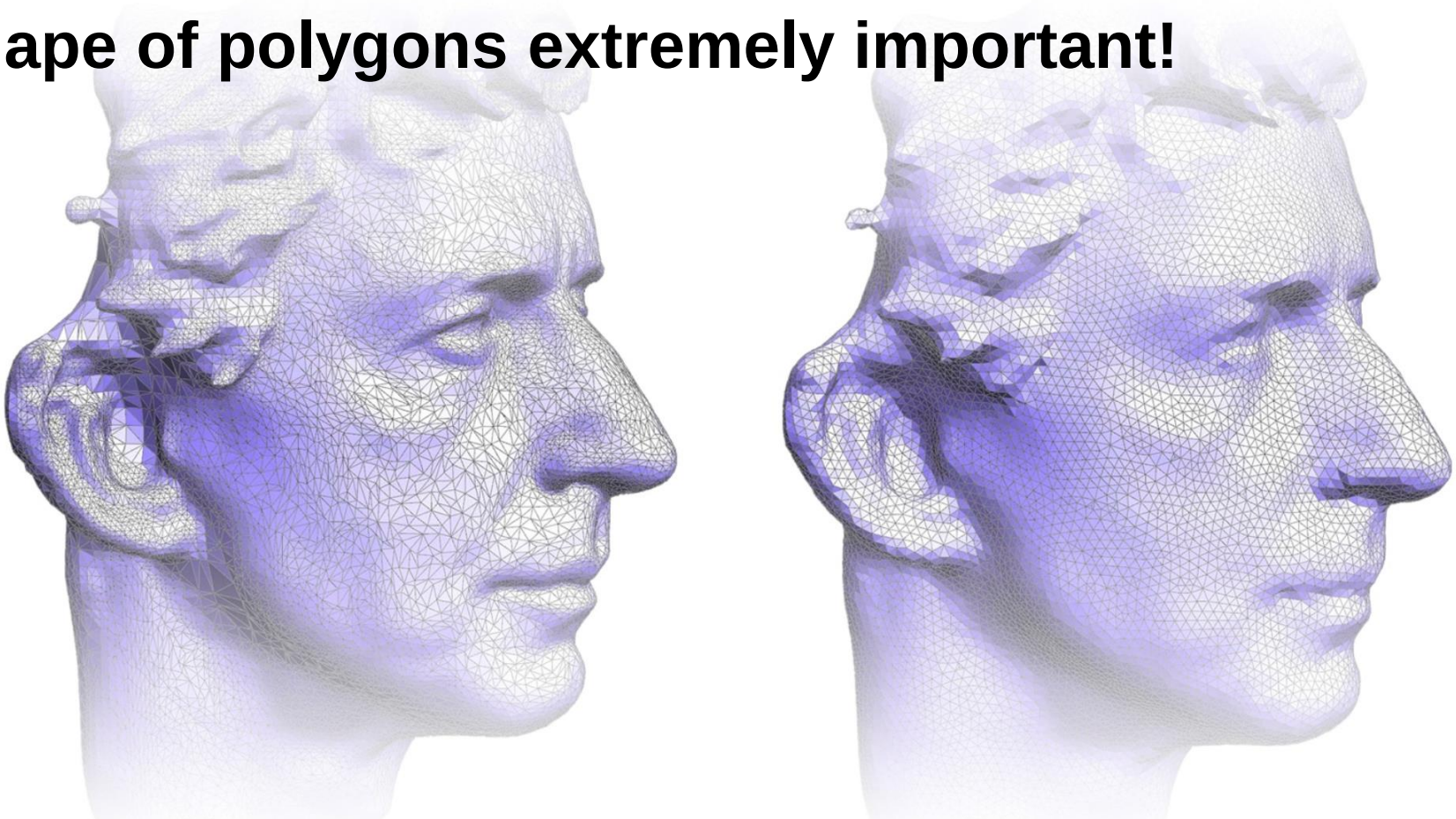
Geometry Processing: Downsampling

- Decrease resolution; try to preserve shape/appearance
- Images: again, bilinear, bicubic interpolation (again)
- Polygon meshes:
  - iterative decimation
  - variational shape approximation
  - ...



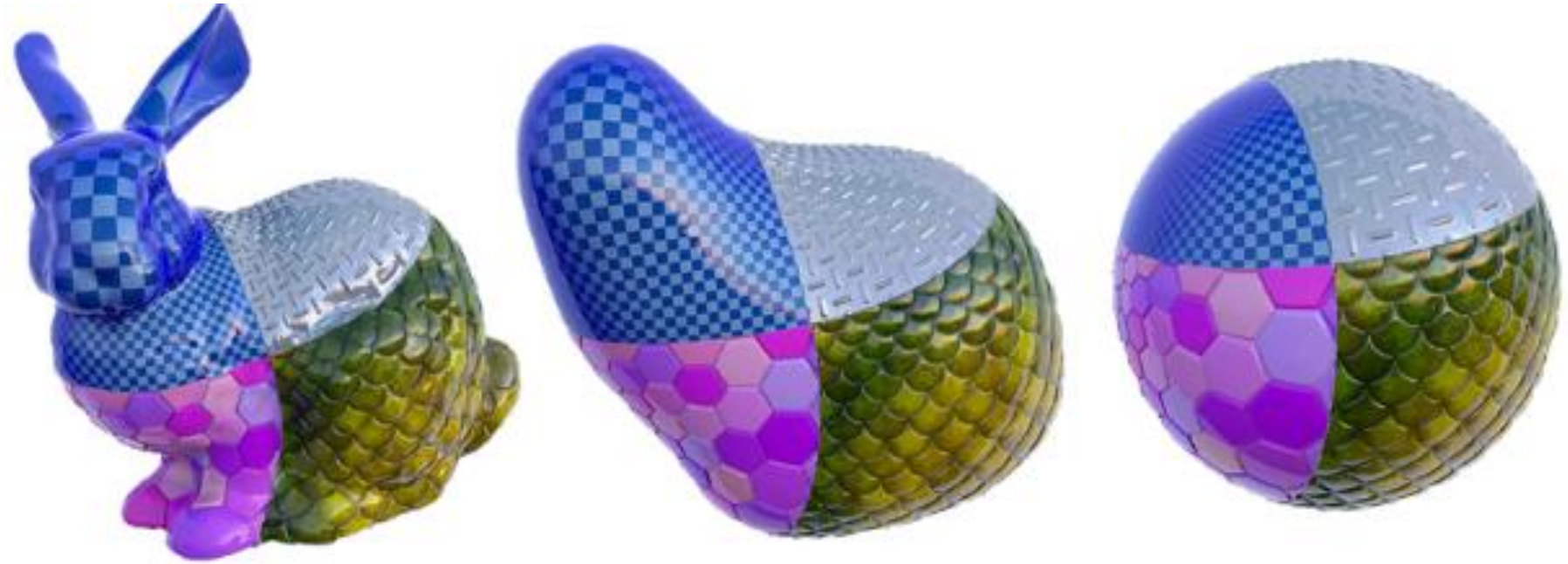
Geometry Processing: Resampling

- Modify sample distribution to improve quality
- Images: ...not usually an issue!
  - pixels are always stored on a regular grid
- Polygon meshes: shape of polygons extremely important!
  - approximation
  - simulation
  - further processing



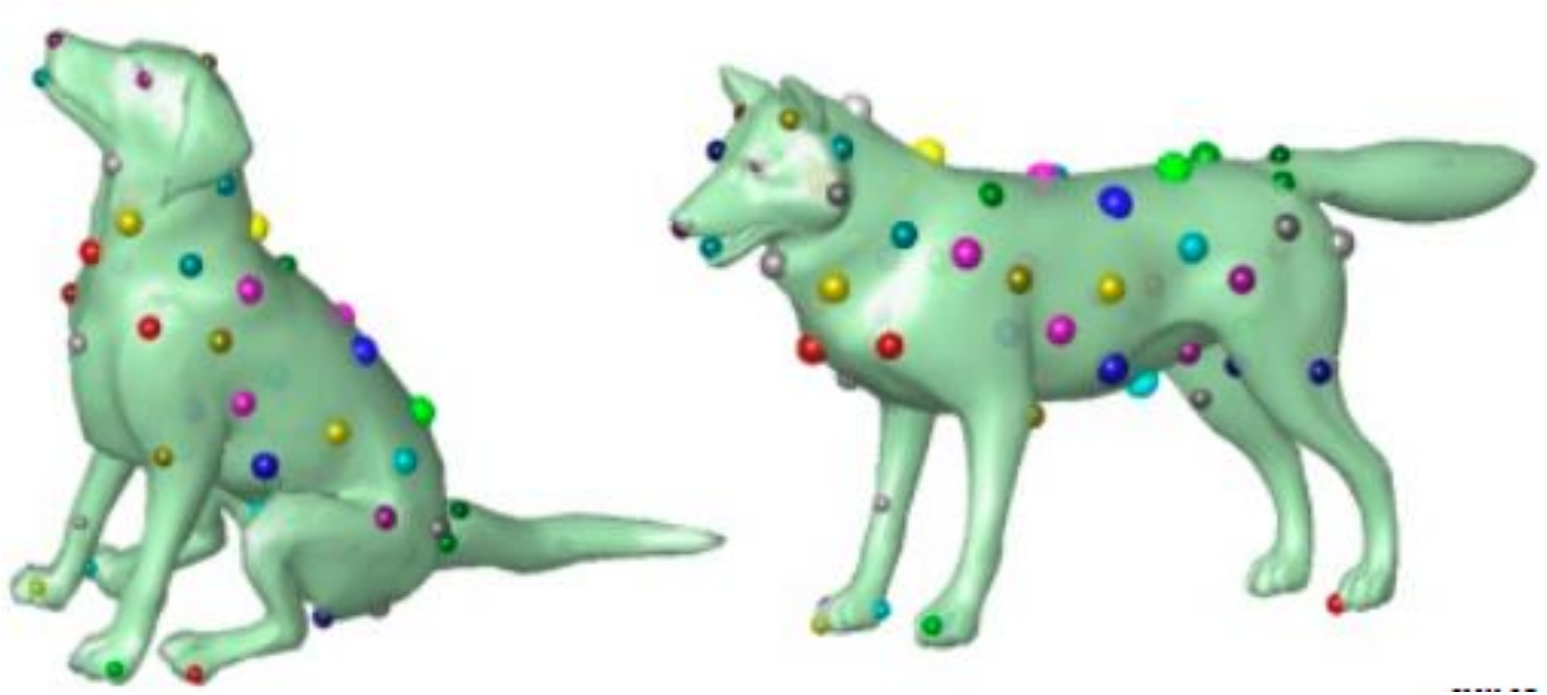
Geometry Processing: Filtering

- Remove noise, or emphasize important features (e.g., edges)
- Images: blurring, bilateral filter, compressed sensing, ...
- Polygon meshes:
  - curvature flow
  - bilateral filter
  - ...



Geometry Processing: Shape Analysis

- Identify/understand important semantic features
- Images: computer vision, segmentation, face detection, ...
- Polygon meshes:
  - segmentation
  - correspondence
  - symmetry detection
  - ...



Ok, enough! Let’s process some geometry!