Applications of Manifolds and Research Challenges

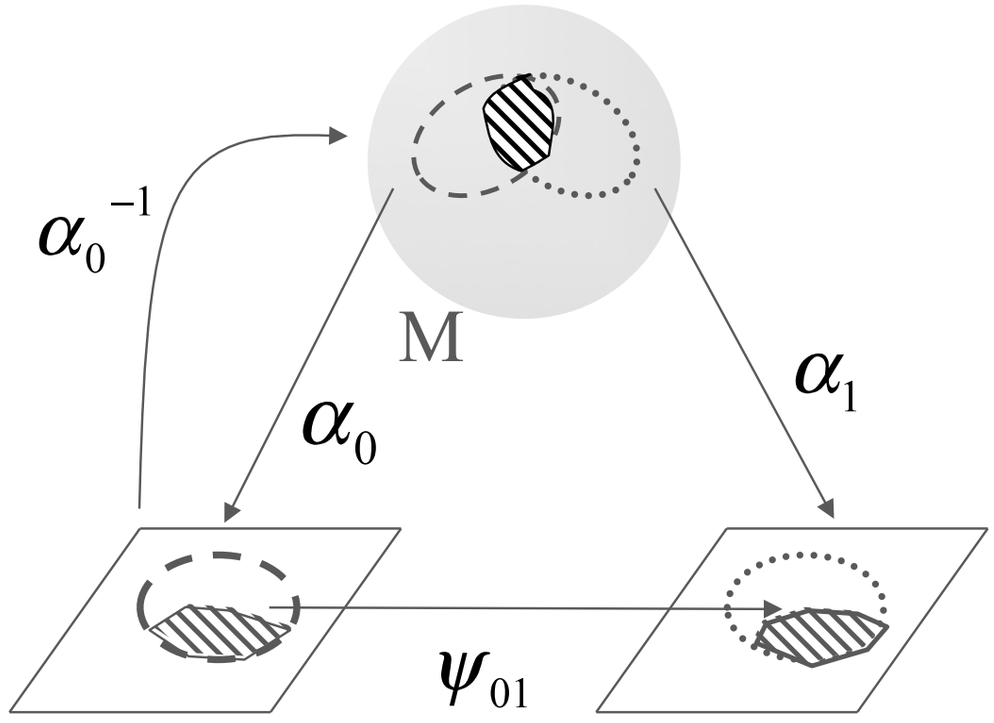
Luiz Velho
IMPA

Outline

- Concepts
- Illumination
- Appearance
- Simulation
- Faces
- Manifold Learning
- Wrap-up

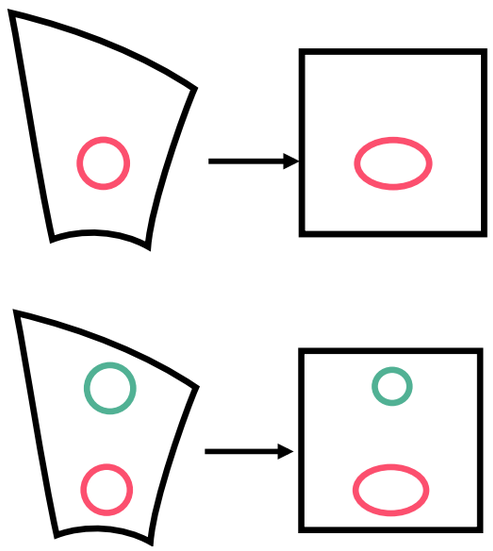
Manifolds & Parametrization

- Two Points of View
  - Functions on surfaces
  - Functions defining surfaces

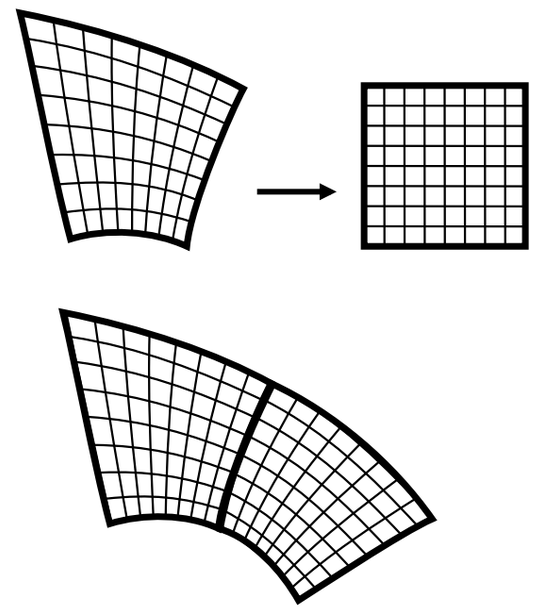


Desirable Properties

- Minimal Distortion
  - Angle
  - Area

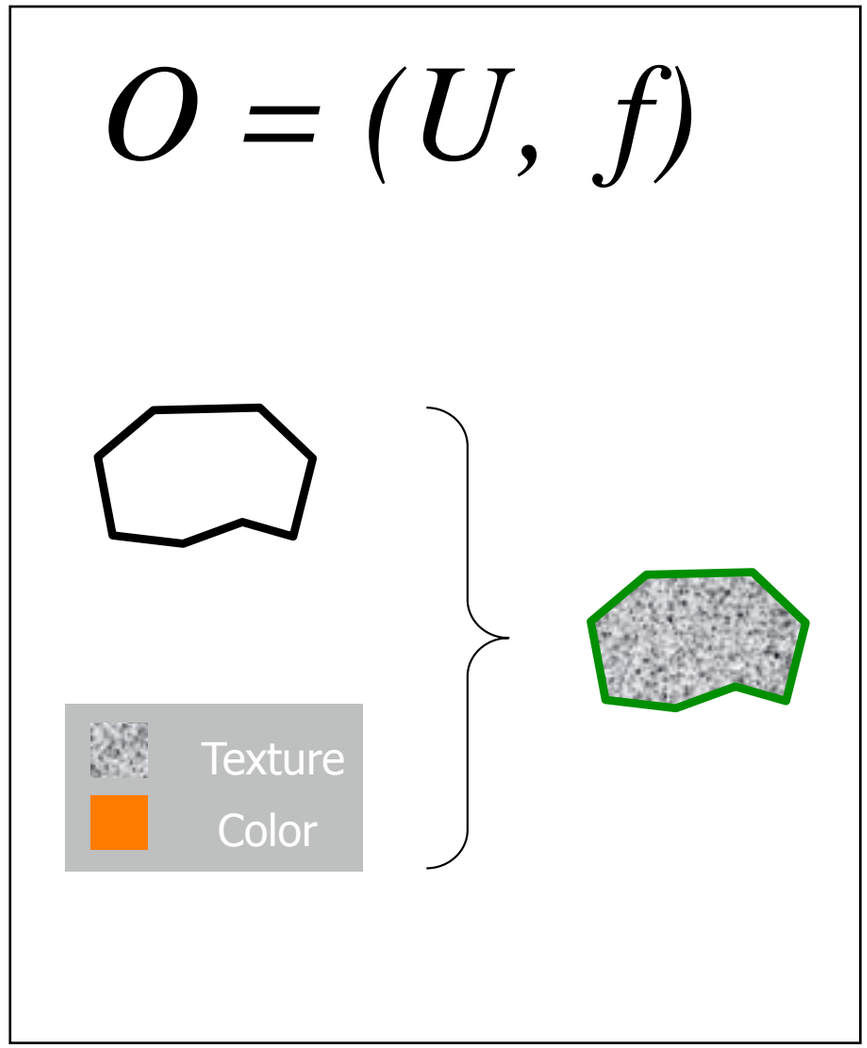


- Smoothness
  - Differentiability
  - Continuity



Graphical Objects

- Shape U
  - Topology (*domain*)
    - Abstract Manifold
  - Geometry (*function*)
    - Embedding
- Attributes f
  - Functions (*co-domain*)



G.O. Manifold Setting

- Canonical Surfaces
  - Fixed Shape (defined *apriori*)
  - Variable Functions (complex)
    - *ex: Sphere*
- Arbitrary Surfaces
  - Complex Shape
  - Computation on Surfaces (attributes)
  - Building / Transforming (shape)
    - *ex: Triangle Meshes*

Applications

- Illumination
  - Canonical Manifold + Functions
- Appearance and Simulation
  - Pseudo-Manifold + Attributes
- Faces
  - Manifold + Geometric Deformation
- Surface Reconstruction
  - Pseudo-Manifold / Topology Estimation

The Sphere

- Construction [Grimm 2002]

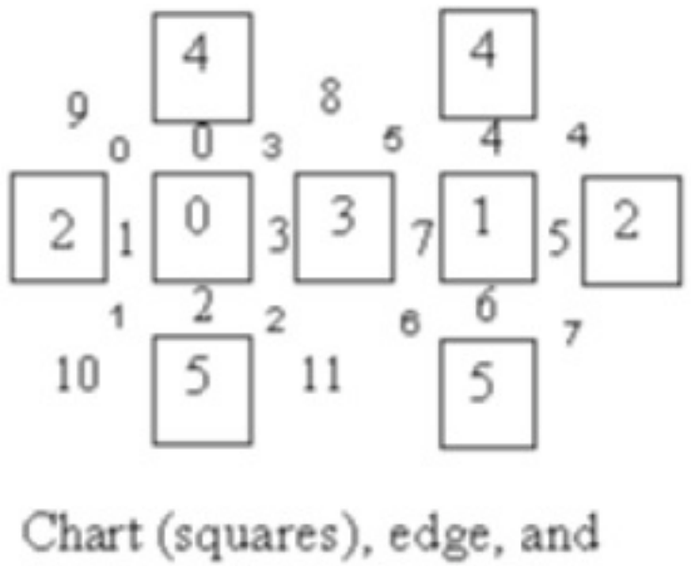
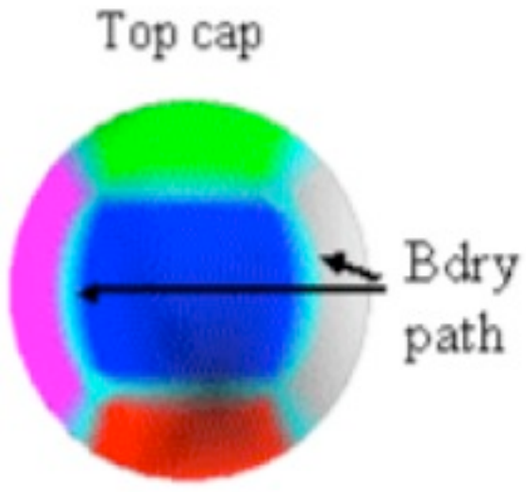
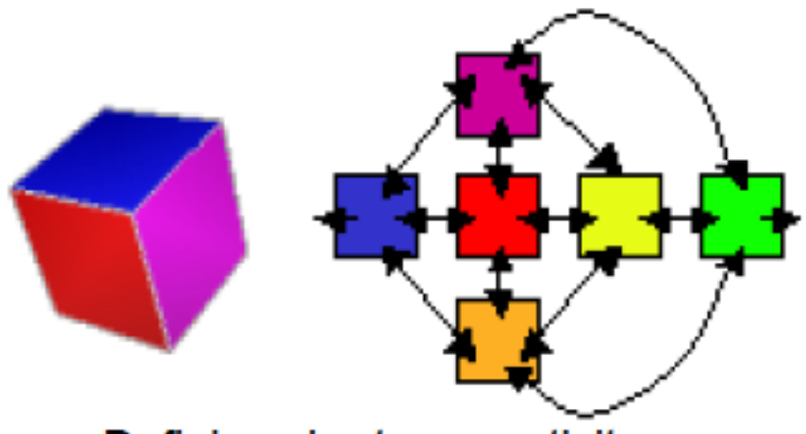


Chart (squares), edge, and

A single chart on the sphere

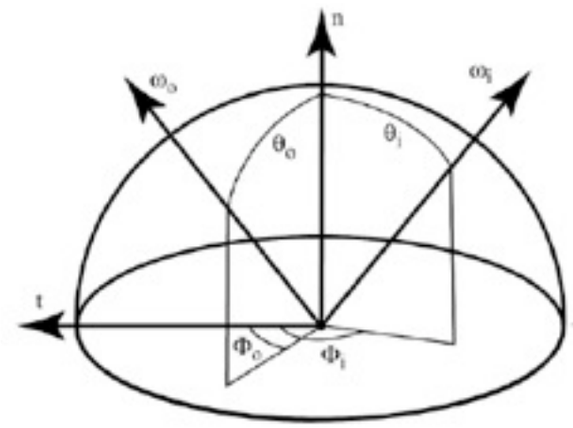


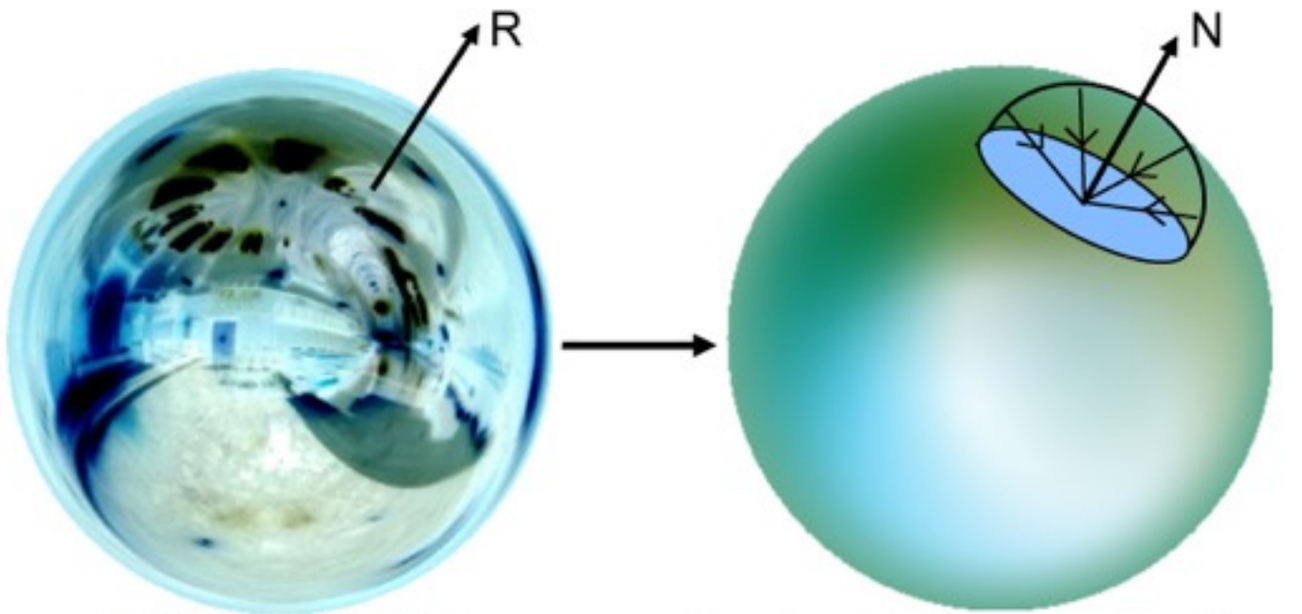


Defining chart connectivity

Illumination

- Functions on the Sphere
  - Light Fields / BRDFs
- Applications
  - Capture / Synthesis



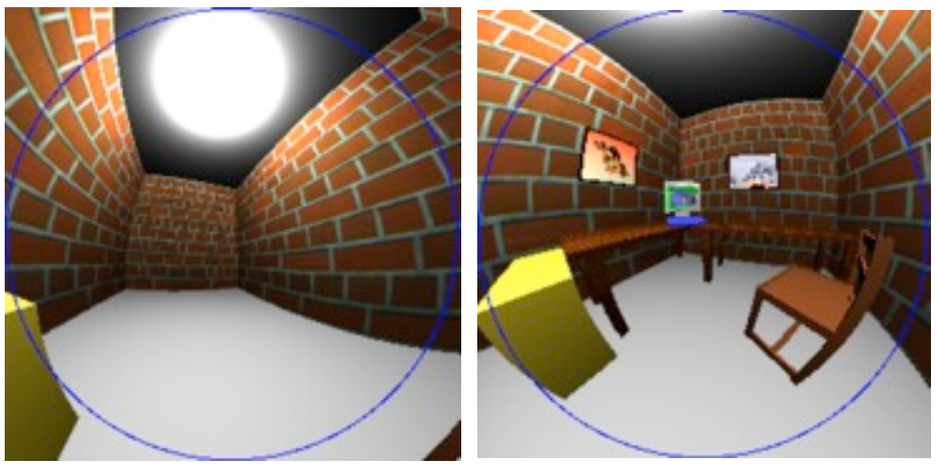


Incident Radiance
(Illumination Environment Map)

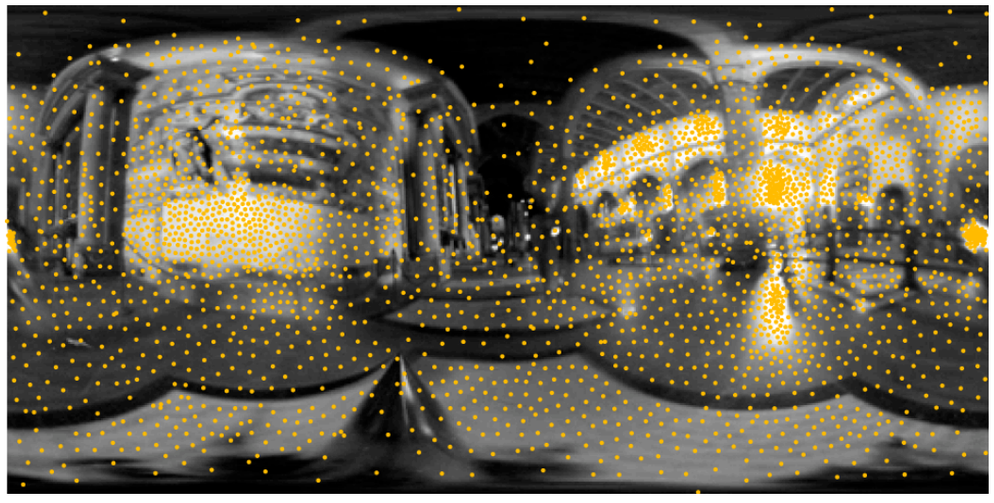
Irradiance Environment Map

Illumination Maps

- Environment Maps
  - Area Sampling

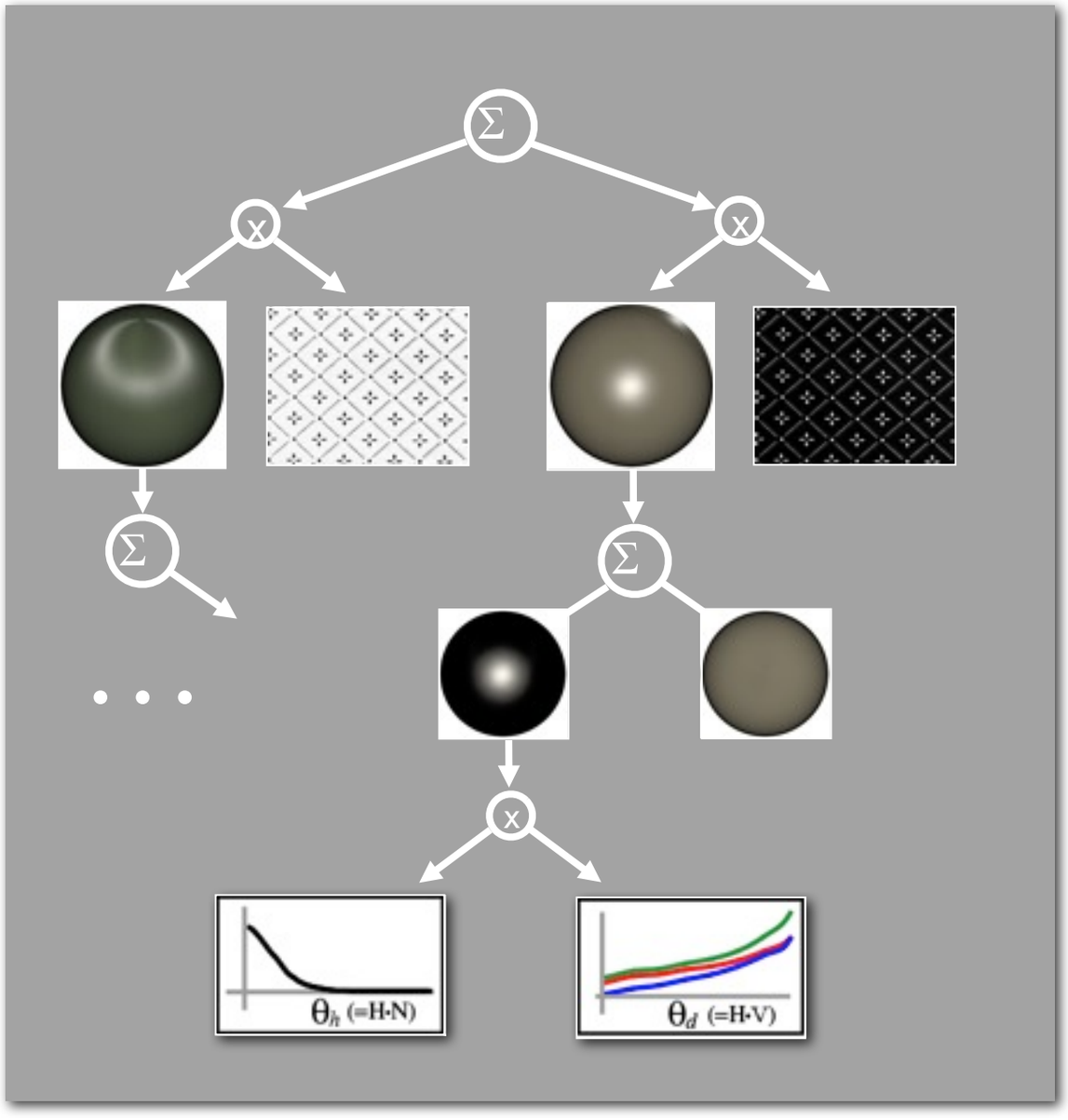


- Light Maps
  - Stratification



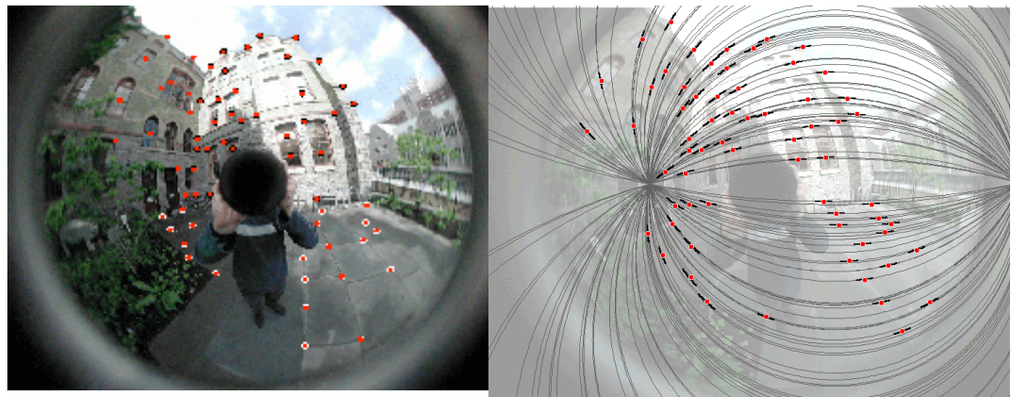
Material Properties

- Spatially Varying BRDFs

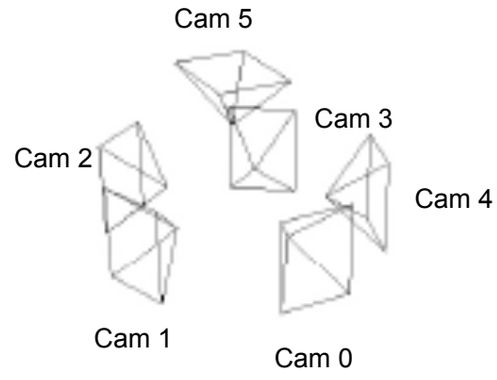


Spherical Panoramas

- Panoramic Cameras
  - Processing



- Multi-Camera Assembly
  - Stitching / Blending



Omnidirectional Images

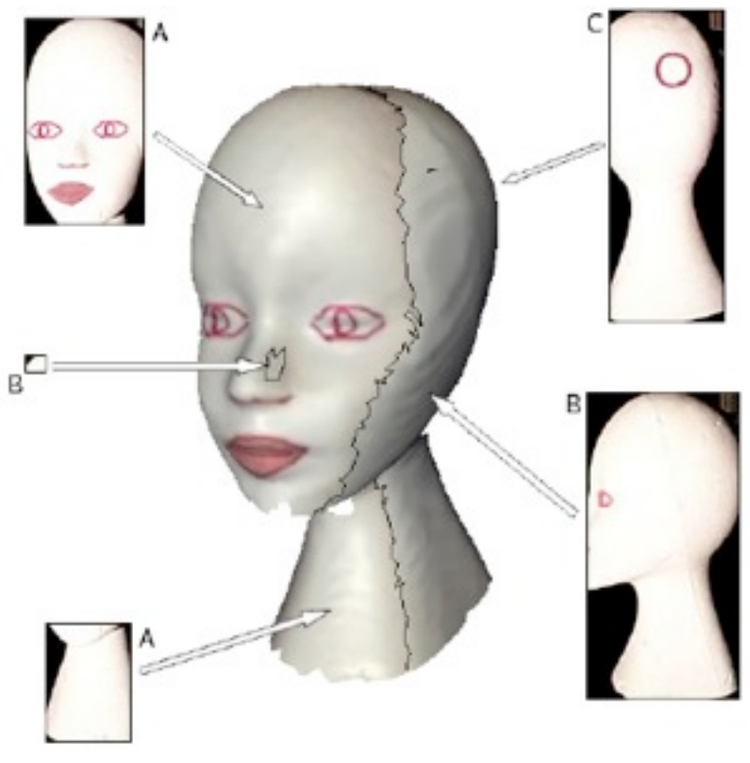
- Processing Large Spherical Imagery
  - Example: Sharpening

Obs: *Metric Aware Operators*

Polygonal Surfaces

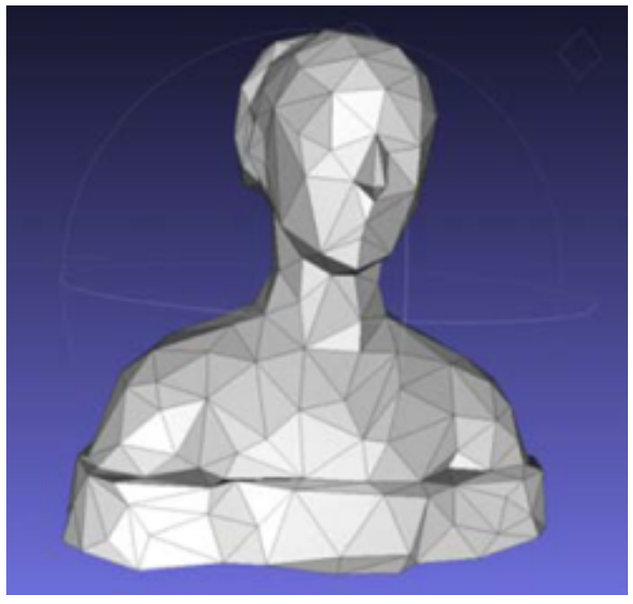
- Building from Images

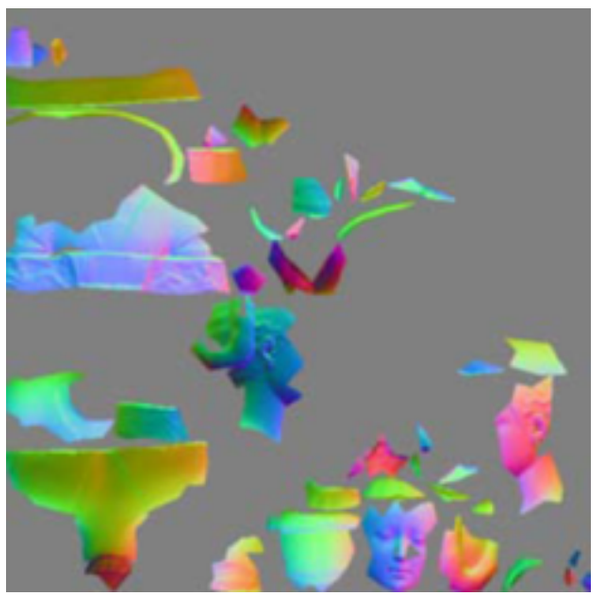
- Projective Map



Surface Properties

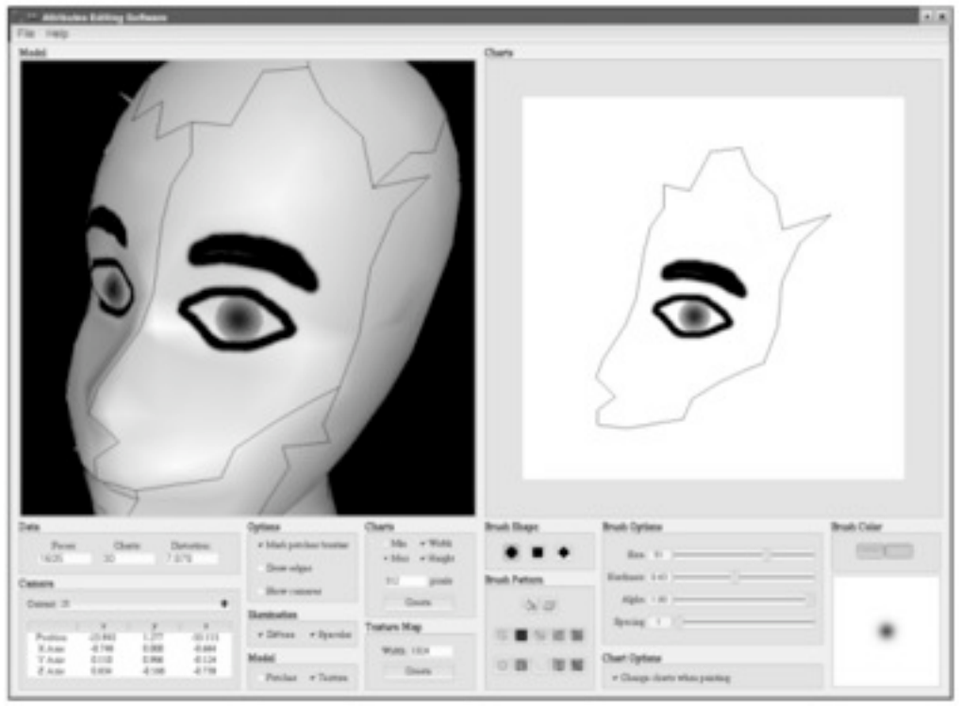
- Texture Atlas
  - Albedo
  - Normal Field
  - etc...

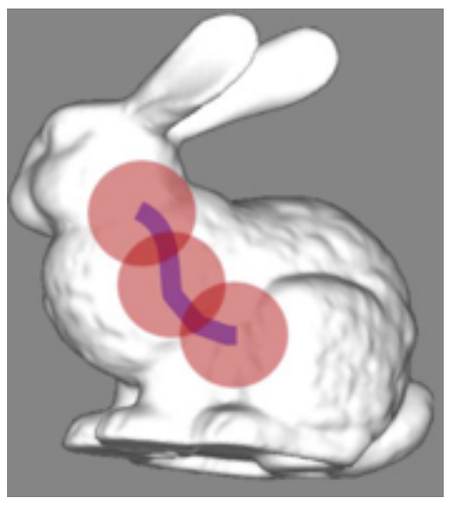


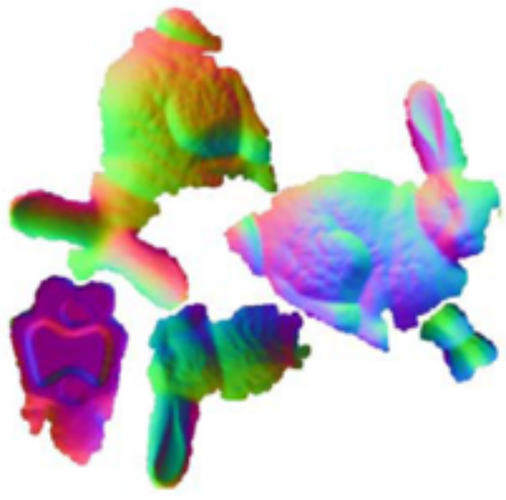


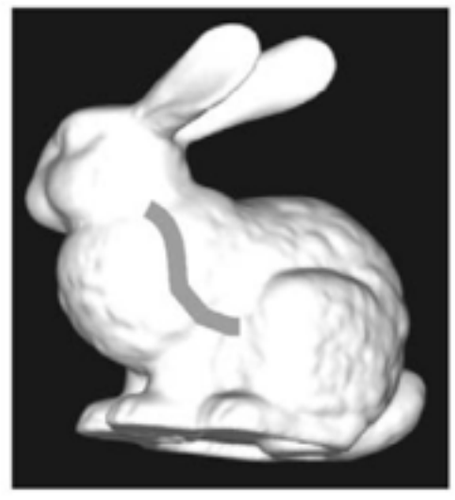
Painting

- Editing Ops
  - Color
  - Normals



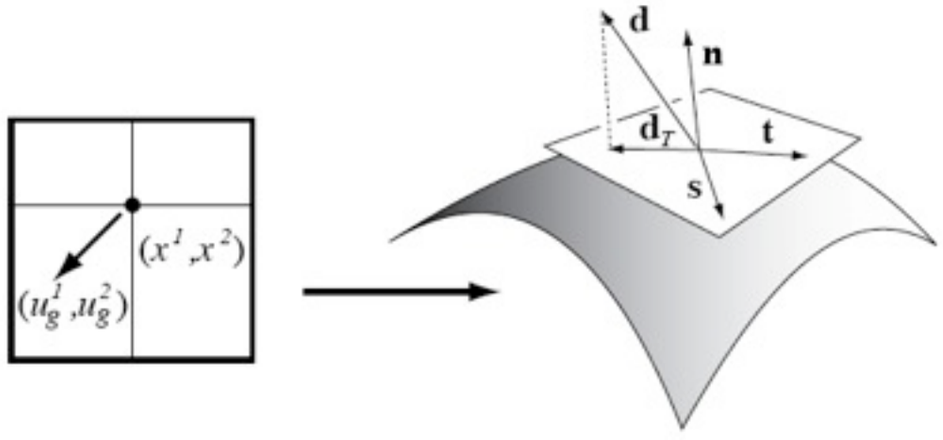


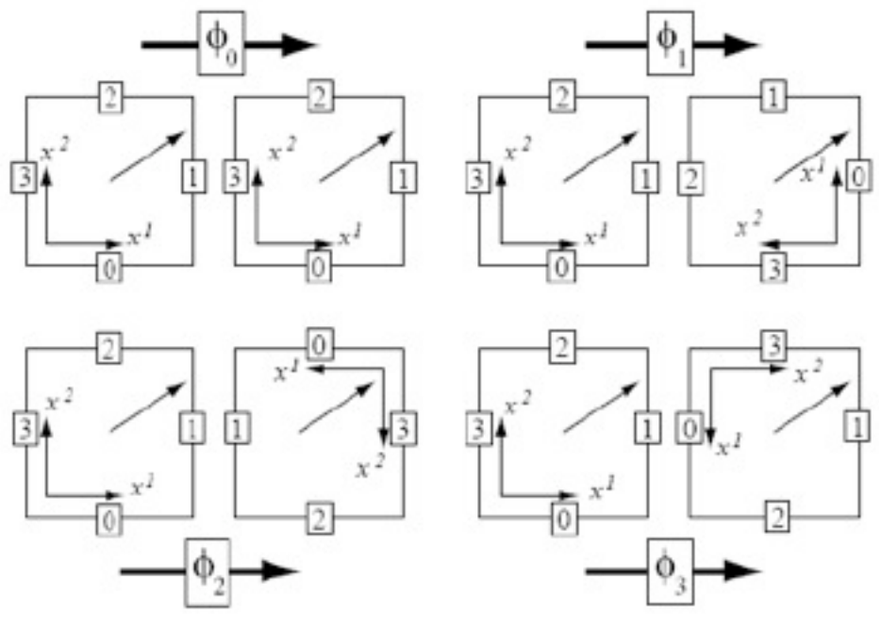




Solving Equations on Manifolds

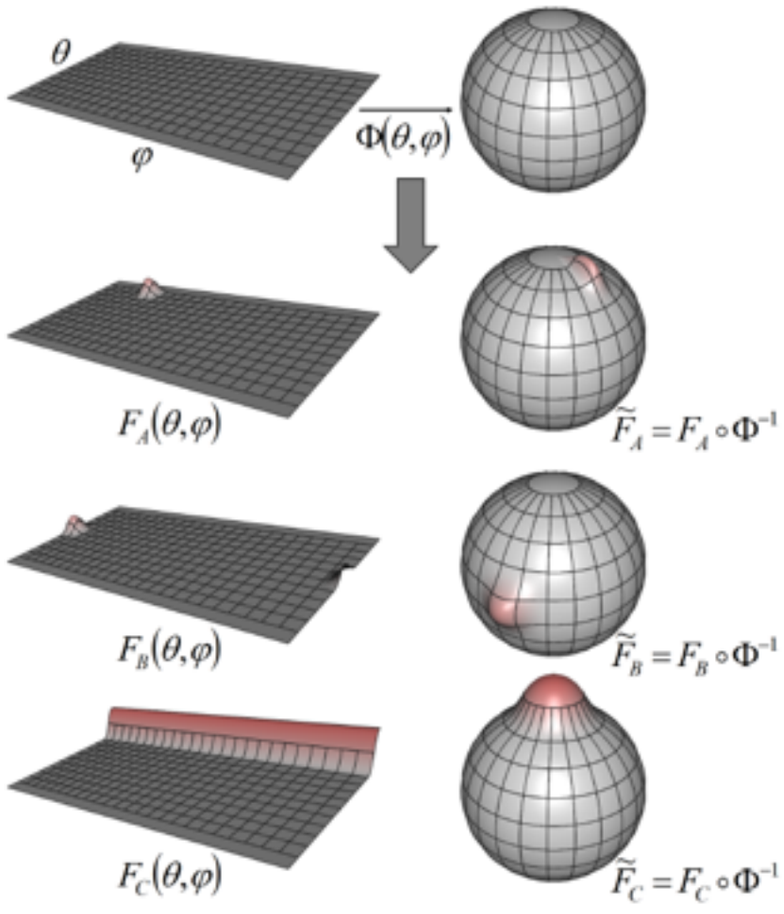
- Global Structure
  - Surface Points
  - Local Neighborhoods

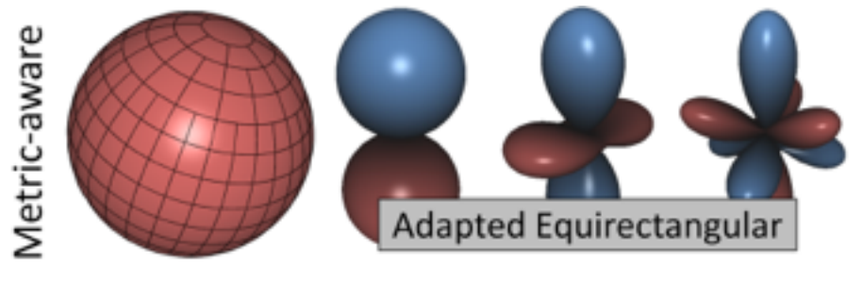


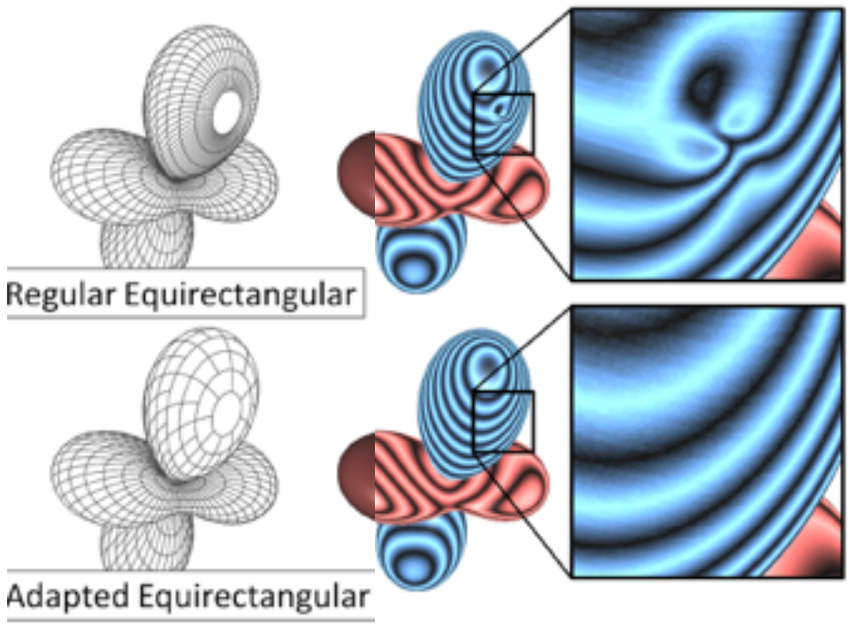


Simulation

- Metric Aware Operators

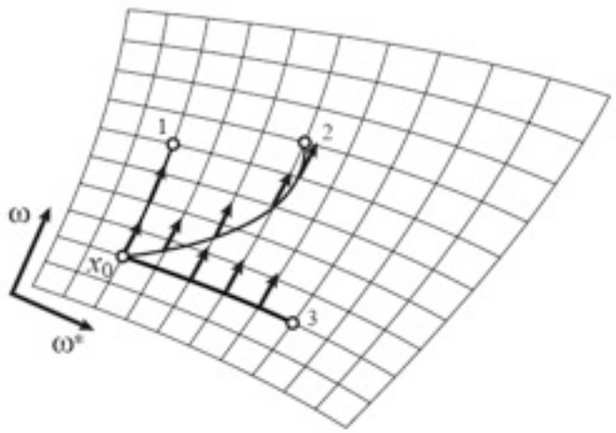


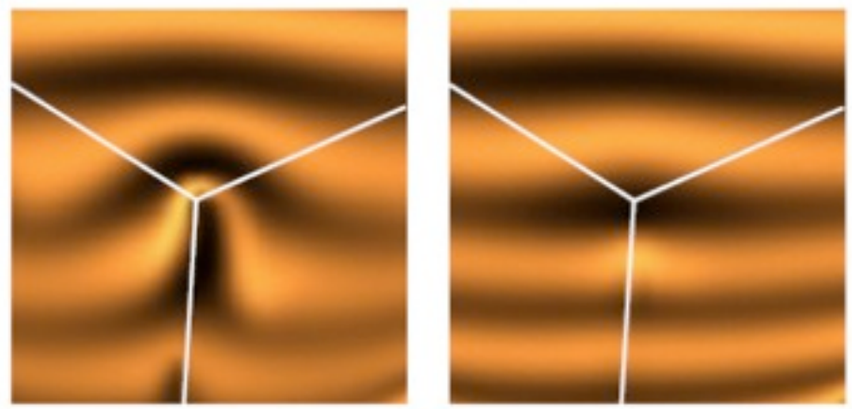


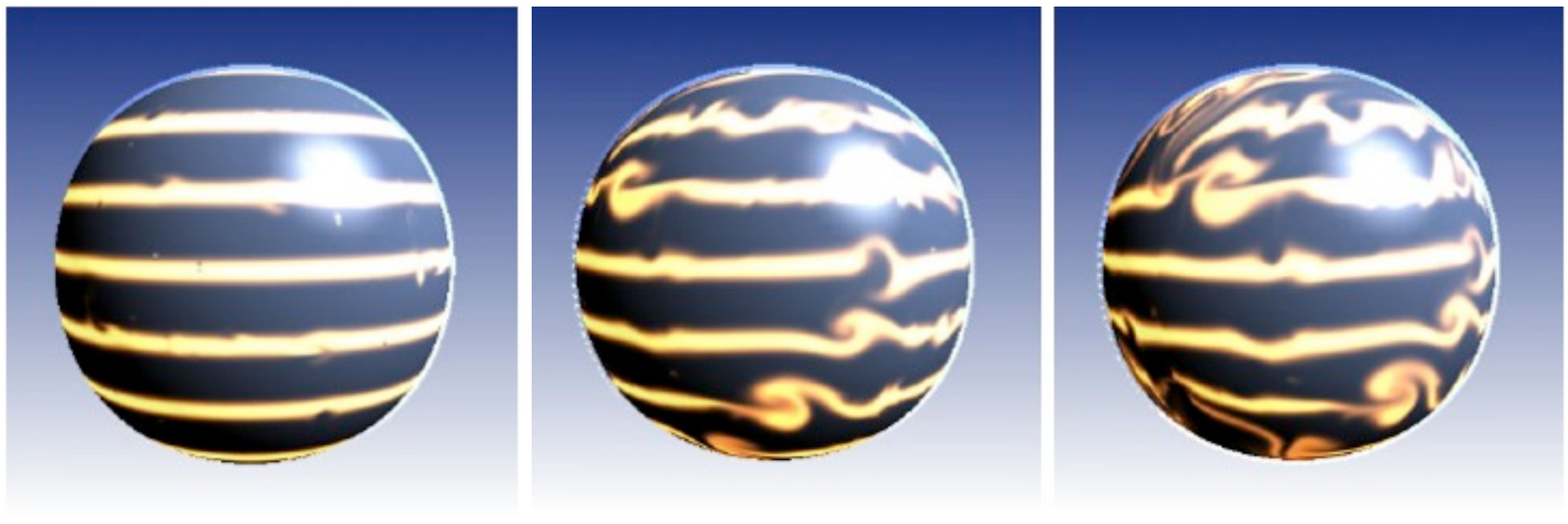


Fluids

- Vector Fields on Surfaces

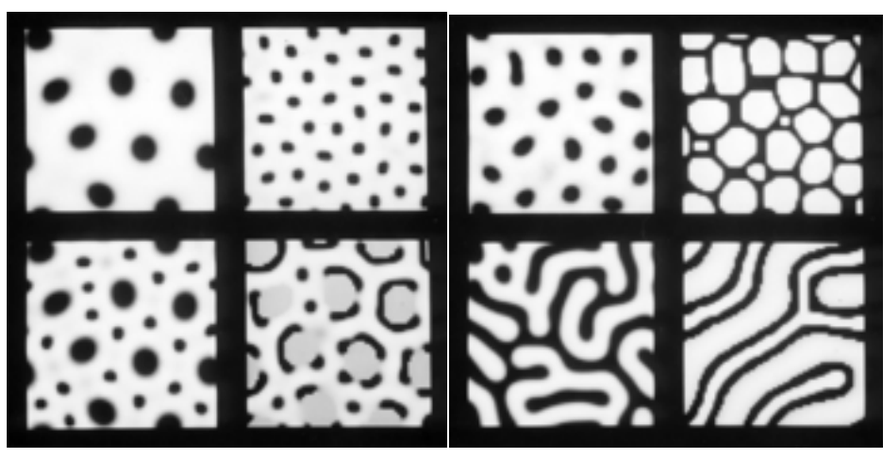




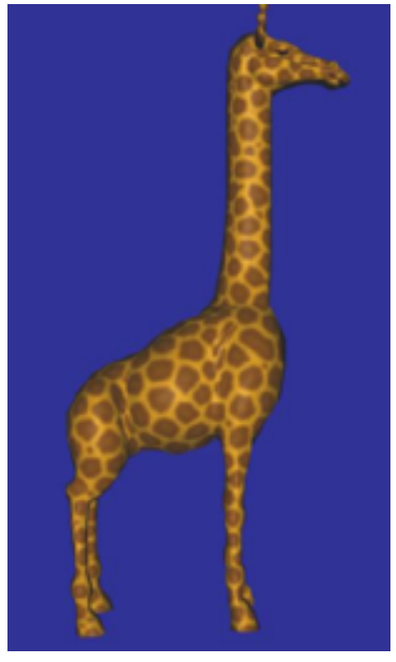


Biological Processes

- Reaction Diffusion

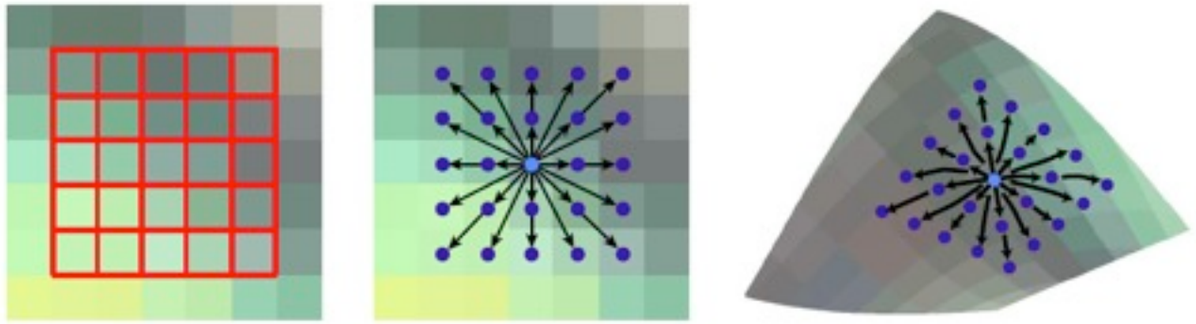


- Examples:



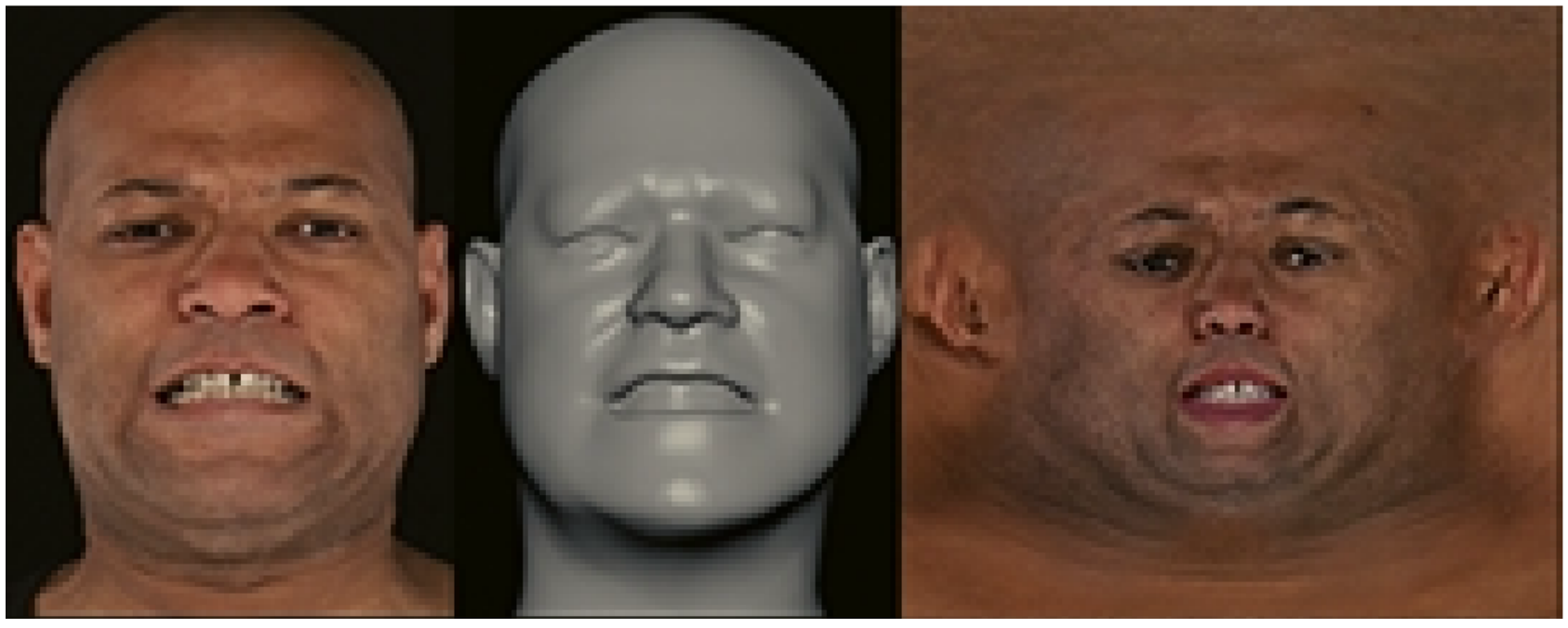
Texture Synthesis

- Stationary / Quasi Stationary



Faces

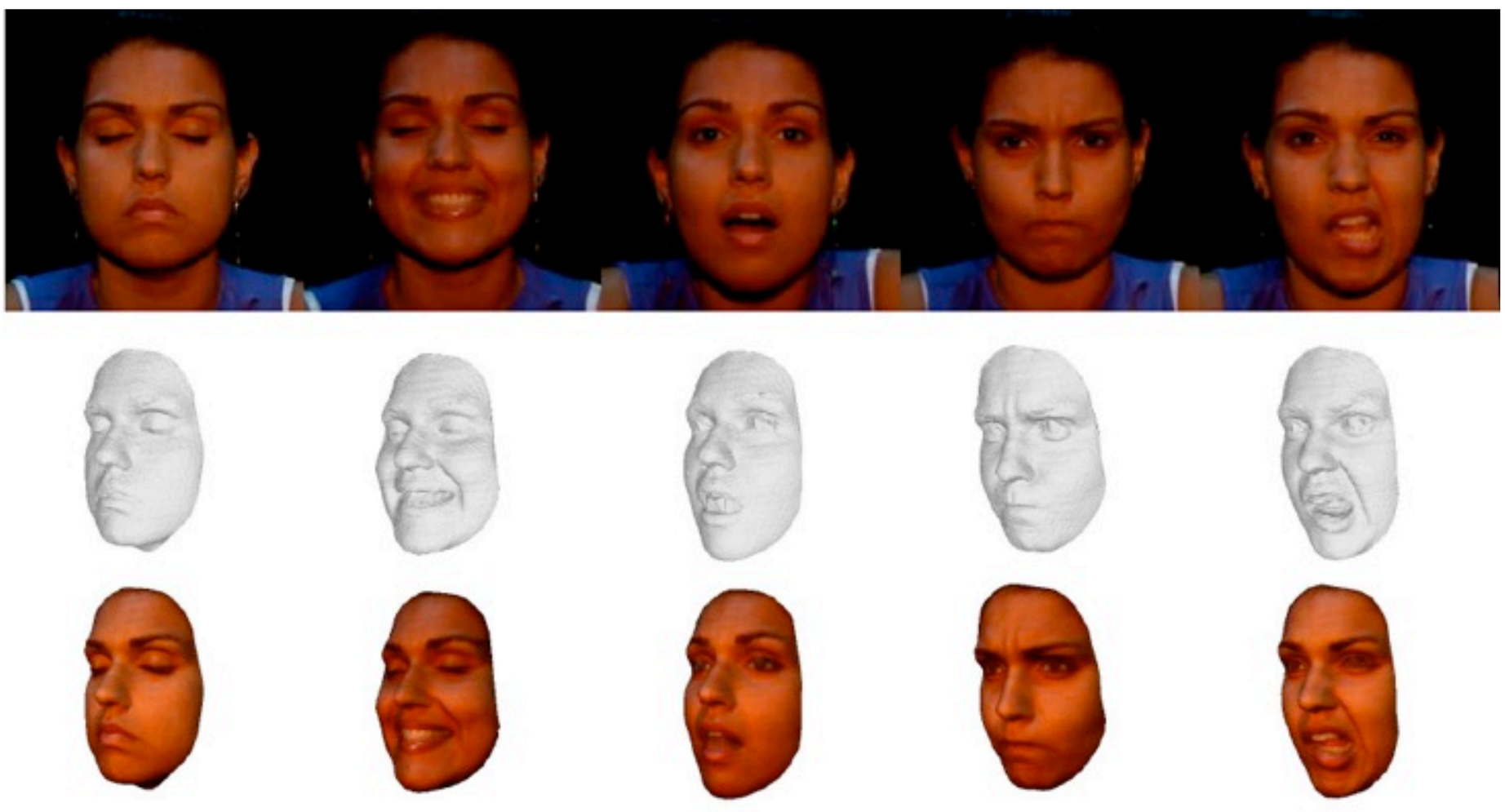
- Geometry + Appearance



[G. Borshukov et al SIGGRAPH 2003]

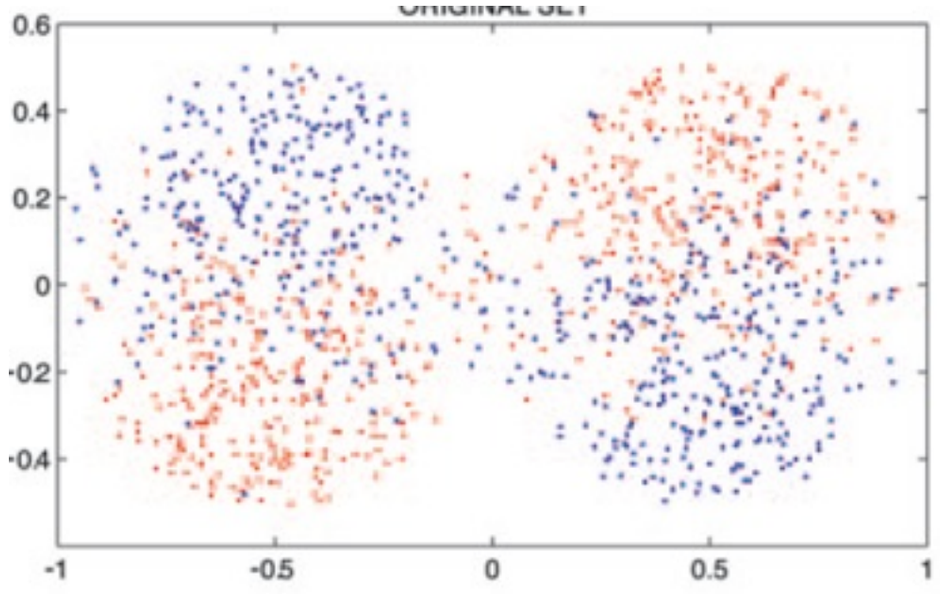
Facial Expressions

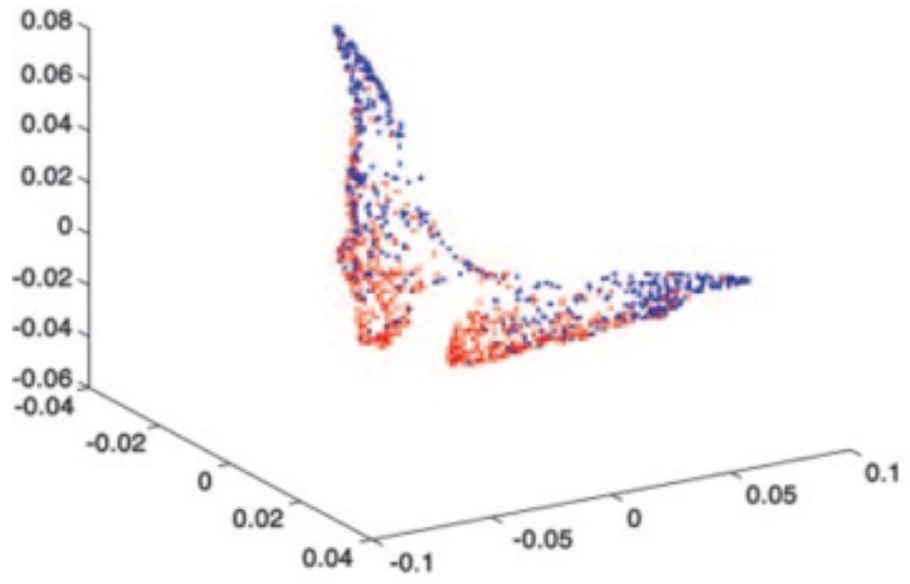
- Deformations



Manifold Learning

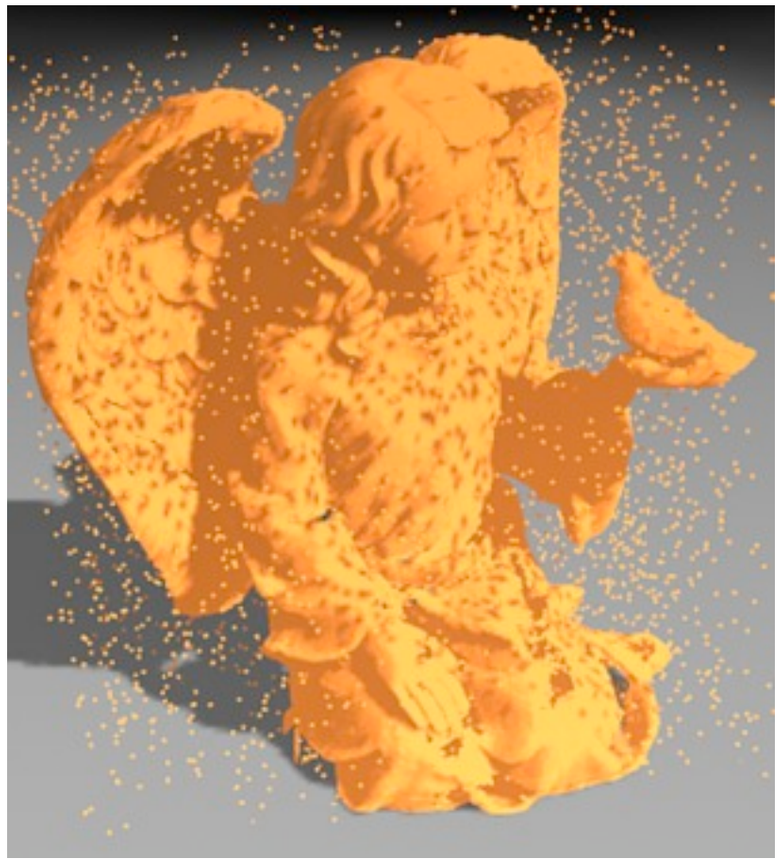
- Estimate from Data Samples
  - Topology
  - Geometry





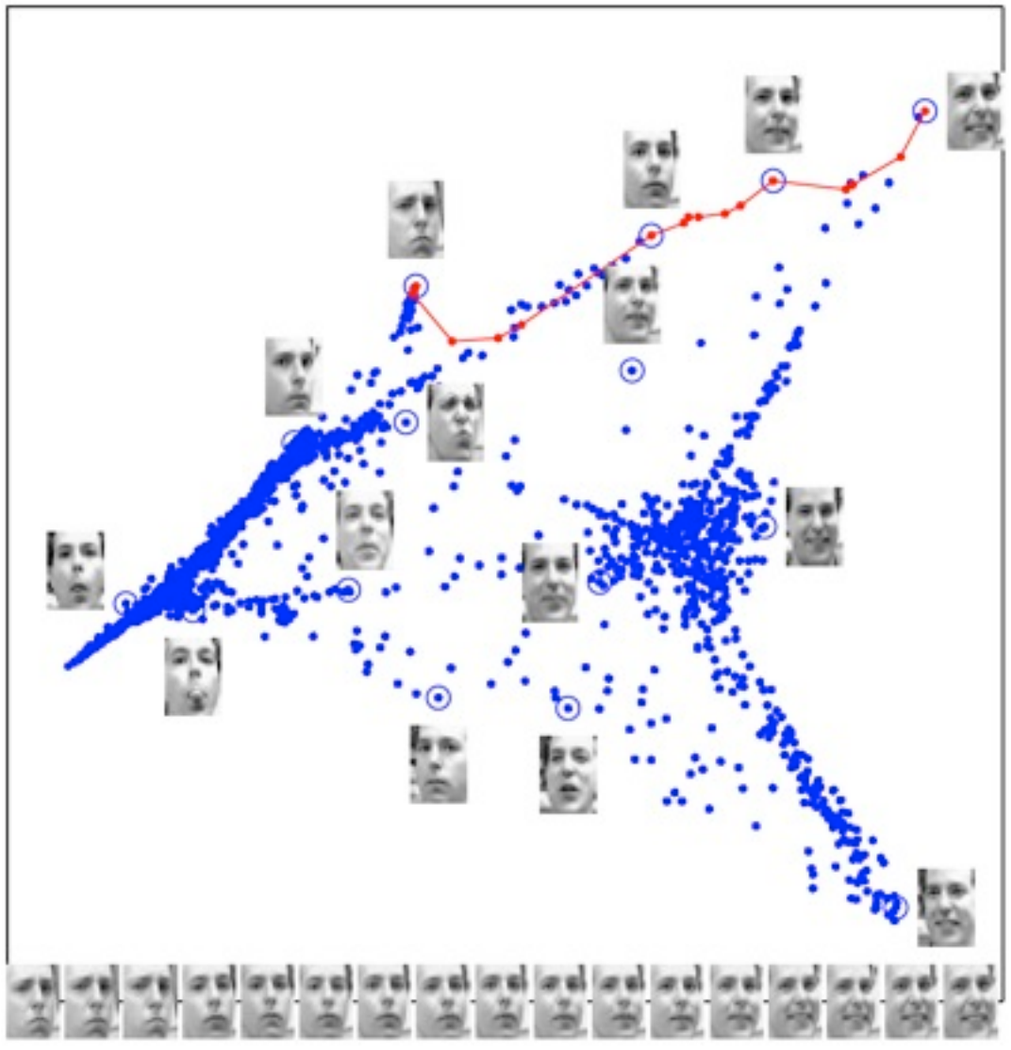
Surfaces

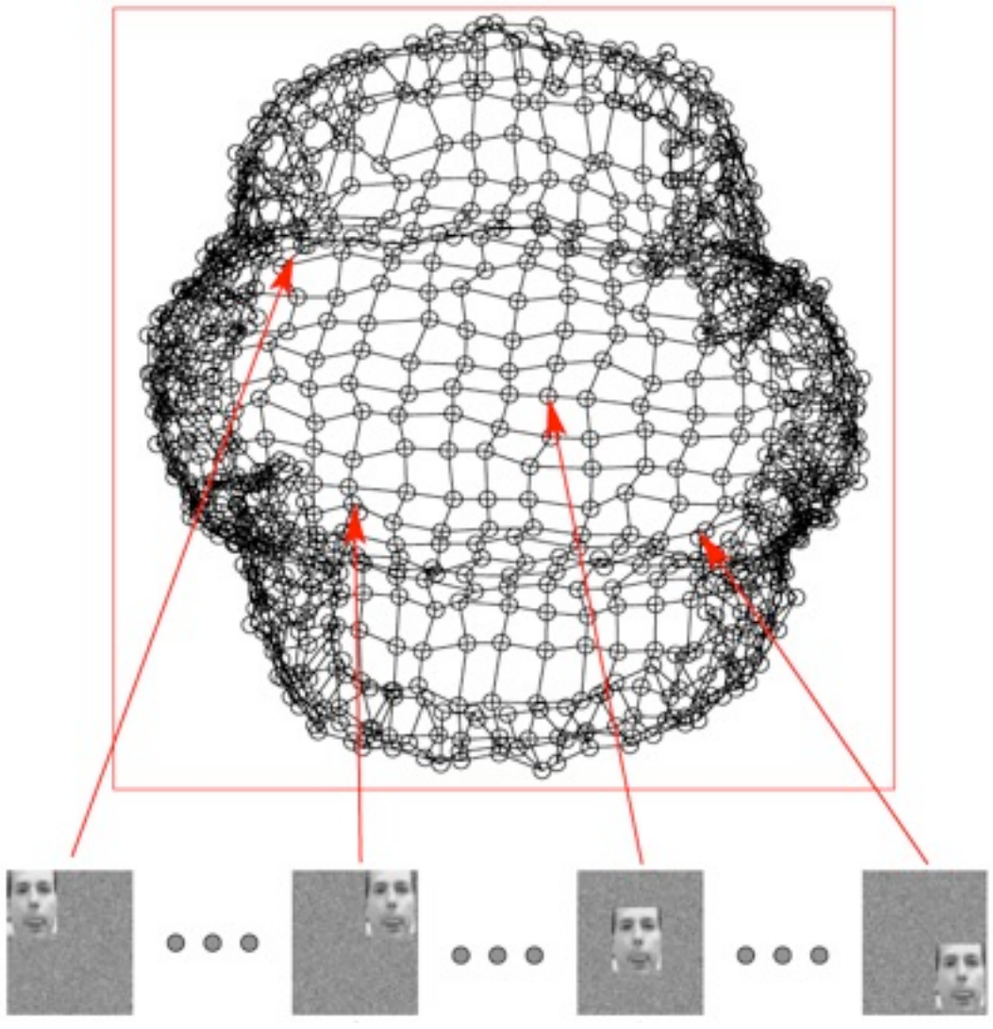
- Point Sets



N-Dimensional Case

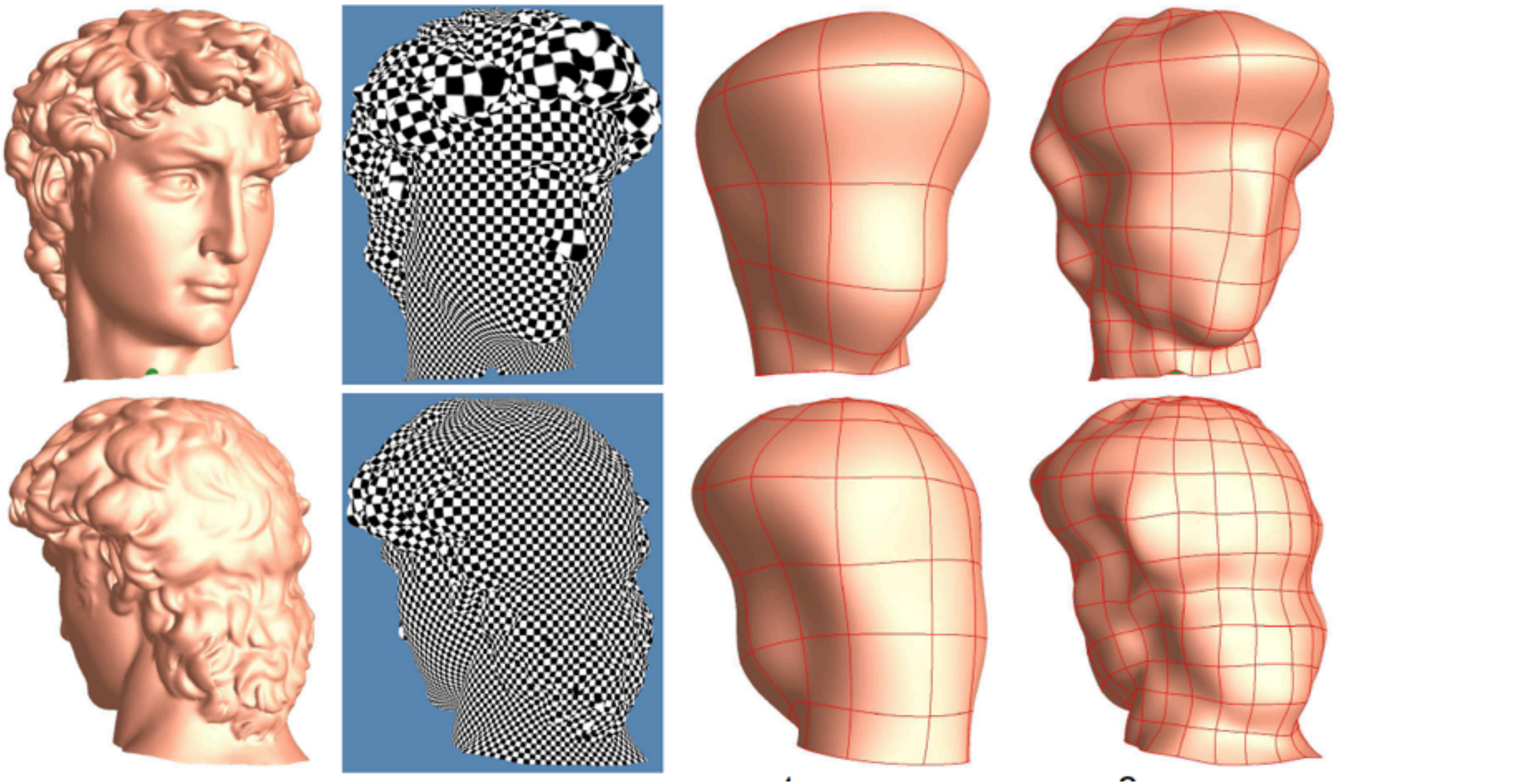
- ex: Facial Expressions





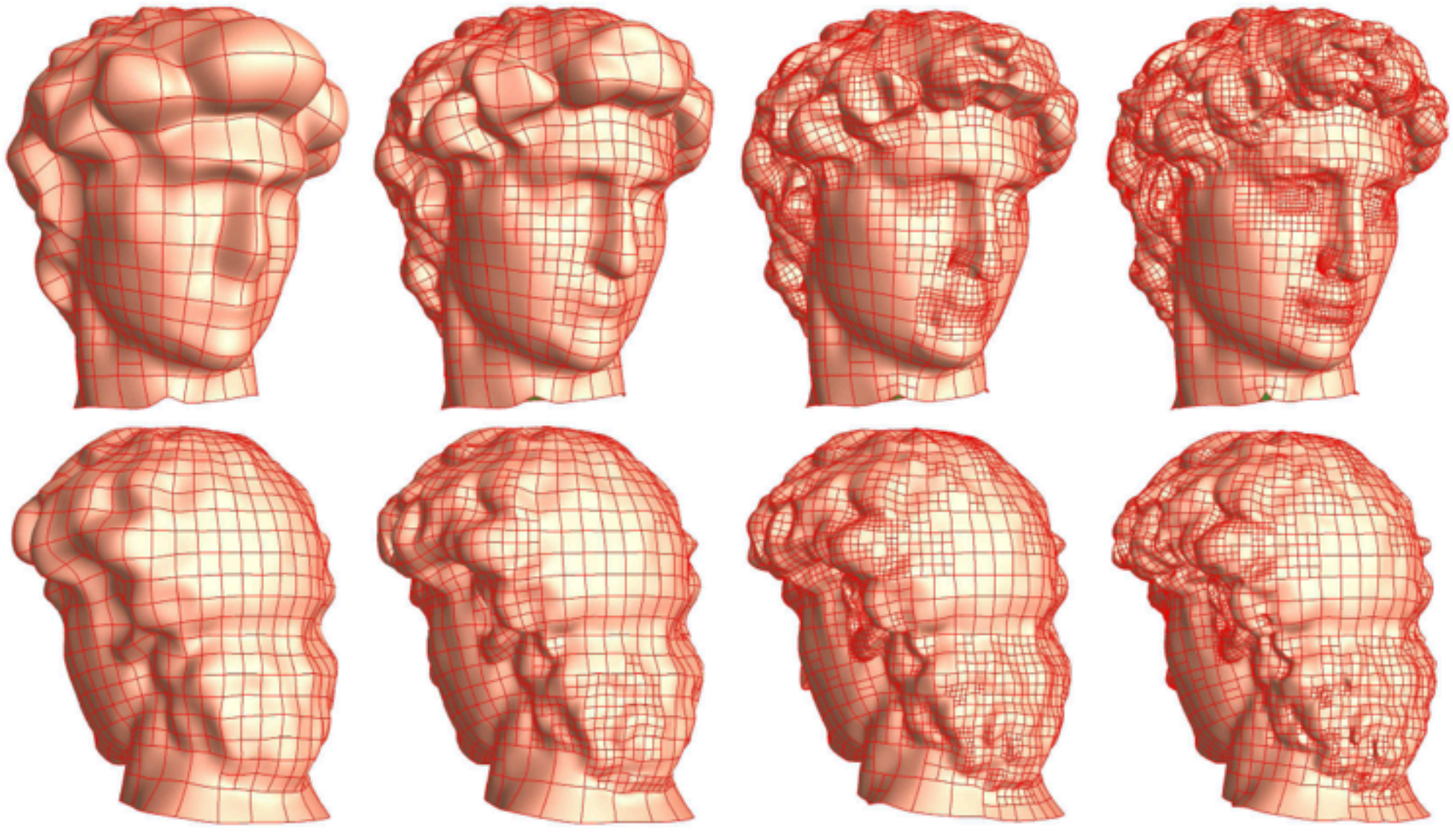
Multiresolution

- Manifold T-Spline (Gu, et al)



Adaptation

- Hierarchical Surface Reconstruction



Challenges

- Representation
  - Simple / Emcompassing
- Operators
  - Efficient / Accurate
- Multi-Resolution
  - Hierarchical Atlas / Dynamic Setting
- API
  - Intuitive / General

Questions ?