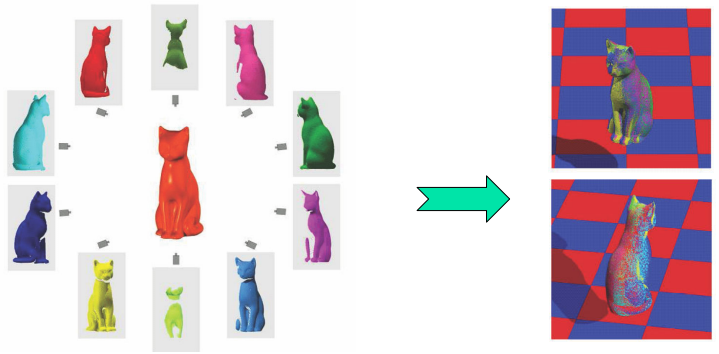
Iterative Closest Point

Motivation

- Align partially overlapping meshes



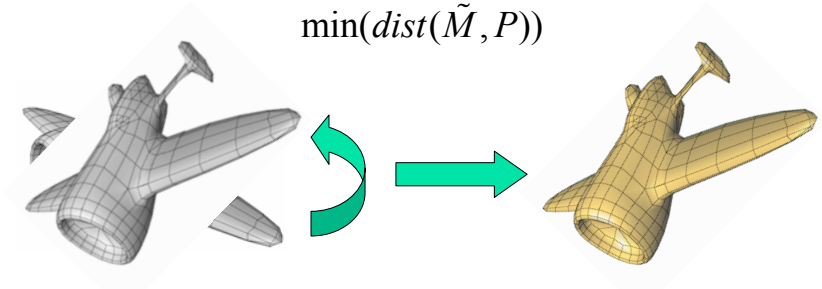
Images from: "Geometry and convergence analysis of algorithms for registration of 3D shapes" by Pottman

The Problem

- Input: Meshes *M*,*P*
- Output: Rotation *R* , translation *T*, s.t.

$$\tilde{M} = R * M + T$$

$$\min(dist(\tilde{M}, P))$$

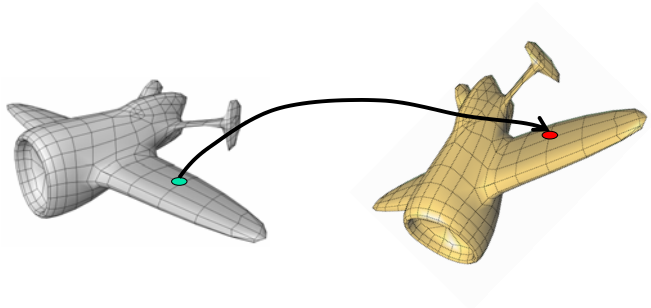


The Challenges

- Should support partial matching
- Should be robust to noise
- Should be efficient

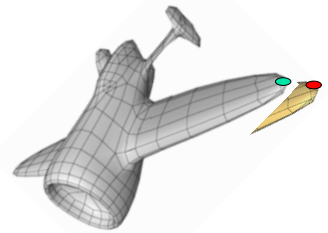
ICP Insight 1

- If correspondance is known, easy to find transformation



ICP Insight 2

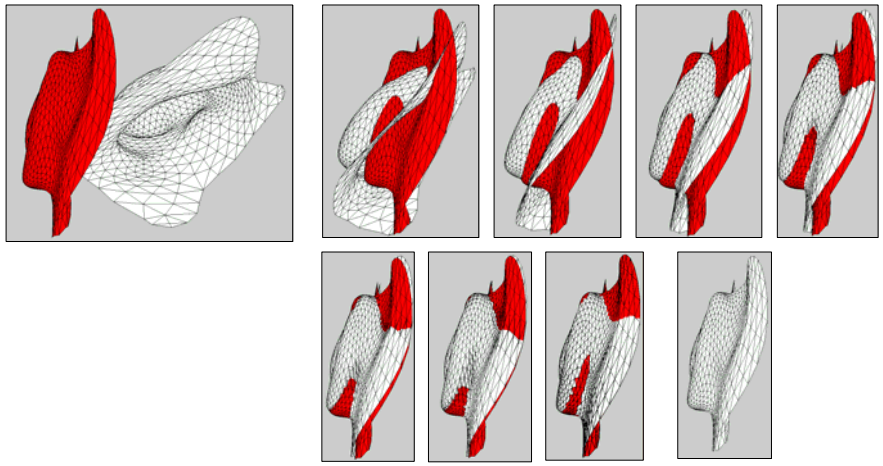
- If transformation is known, easy to find correspondance (closest point)



ICP Algorithm

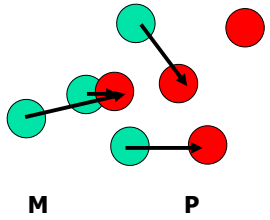
- Start from initial guess
- Iterate
  - For each point on *M*, find closest point on *P*
  - Find best transform for this correspondance
  - Transform *M*

Example



Find Closest Point

- For each point in *M*
  - Choose closest point (Euclidean) from *P*



  - Minimizes $\frac{1}{|M|}\sum_{v\in M}\|v - match_P(v)\|_2^2$

Find Best Transform

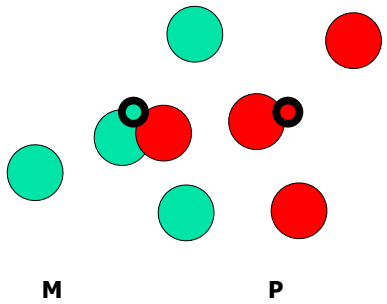
- Find R and T that minimize

$$\frac{1}{|M|}\sum_{v\in M}\|match_P(v) - (R*v+T)\|_2^2$$

- R – 3D rotation
- T – 3D translation

Find Best Transform

- Translation part – from centroids



$$T = avg(P) - R*avg(M)$$

Find Best Transform

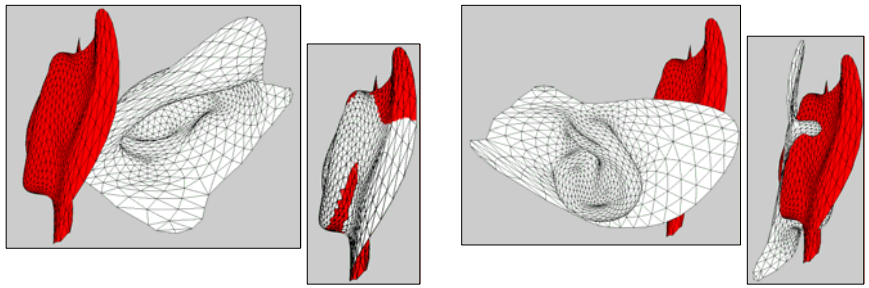
- Rotation part
  - Closed form solution – solve a cubic equation

  or

  - (Easier, but not equivalent)
  - Find best matrix Q
    - Linear least squares system
  - Find best approximating rotation
    - SVD

Converges?

- Errors decrease monotonically
- Converges to local minimum
- Good initial guess → Converges to global minimum



Extensions

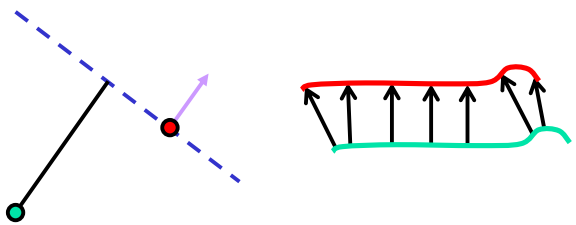
- Speed up correspondance
  - Use spatial subdivision
- Select only sample of points
- Different error metrics
- Change point matching
- Reject outliers

Points Sampling

- All points
- Uniform sampling
- Random sampling
- Uniform normal distribution

Error Metrics

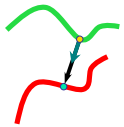
- Point-to-plane distance instead of point to point



Point Matching

- Standard – closest point
  - Slow

- Normal shooting
  - Bad for noisy meshes



- Consider only compatible points
  - Same curvature, normals, colors

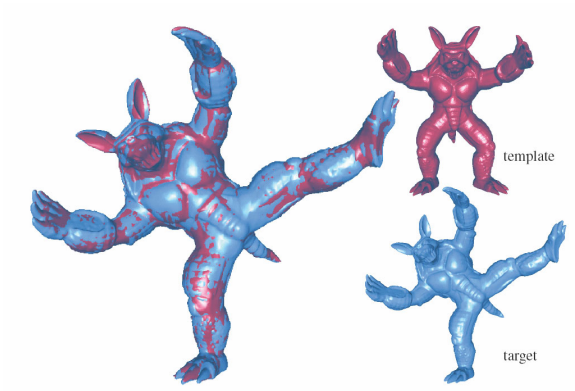
More Extensions

- Can be done in real time
  - Interactive scanning & registration

Movie from: "Efficient Variants of the ICP Algorithm" by Rusinkiewicz et al.

More Extensions

- Non rigid deformations



Images from: "Generalized Surface Flows for Mesh Processing" by Eckstein et al