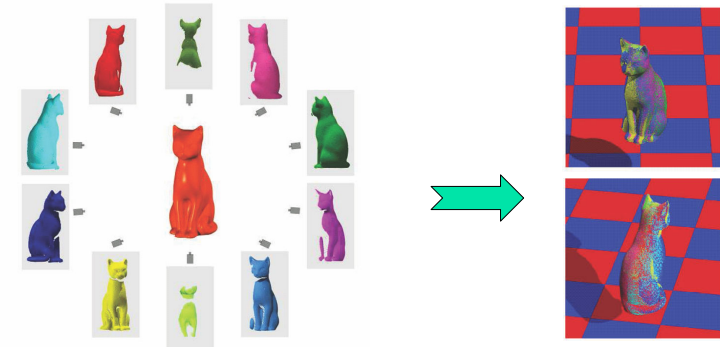


Iterative Closest Point

Motivation

- Align partially overlapping meshes

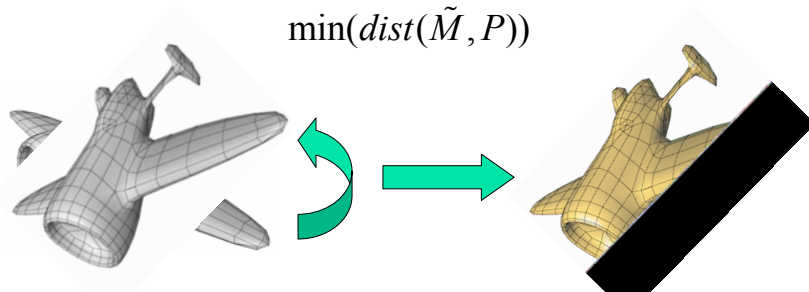


Images from: "Geometry and convergence analysis of algorithms for registration of 3D shapes" by Pottman

The Problem

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

$$\tilde{M} = R * M + T$$
$$\min(\text{dist}(\tilde{M}, P))$$

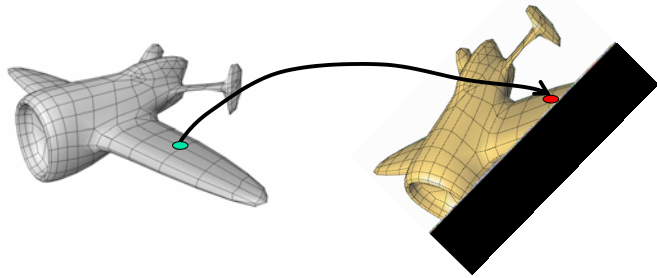


The Challenges

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

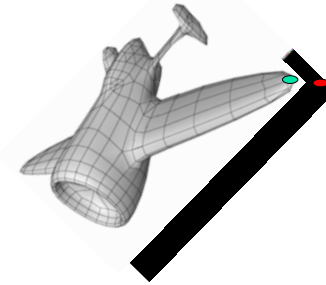
ICP Insight 1

- If correspondance is known, easy to find transformation



ICP Insight 2

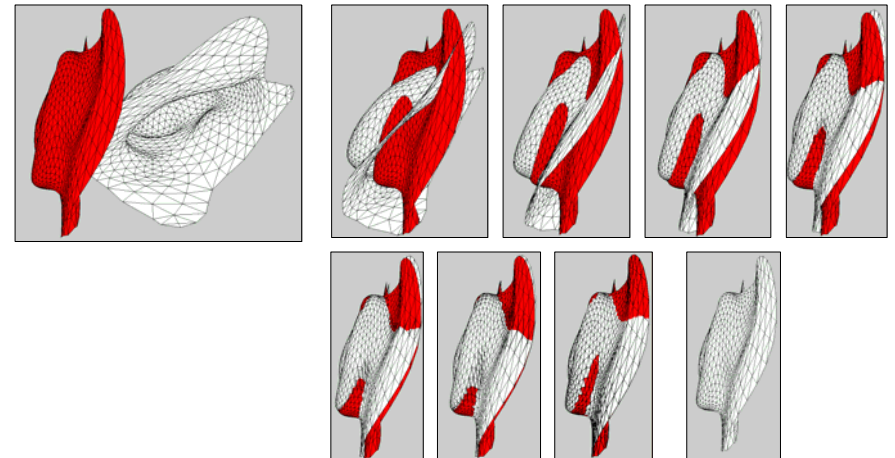
- If transformation is known, easy to find correspondance (closest point)



ICP Algorithm

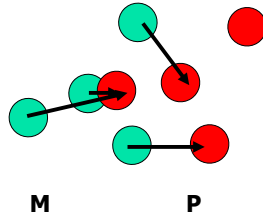
- Start from initial guess
- Iterate
 - For each point on M , find closest point on P
 - Find best transform for this correspondance
 - Transform M

Example



Find Closest Point

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



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

Find Best Transform

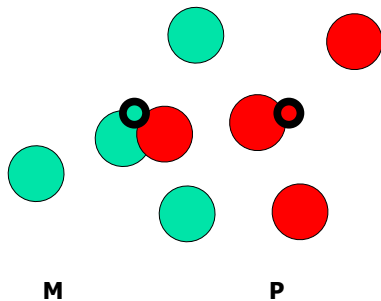
- Find R and T that minimize

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

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

Find Best Transform

- Translation part – from centroids



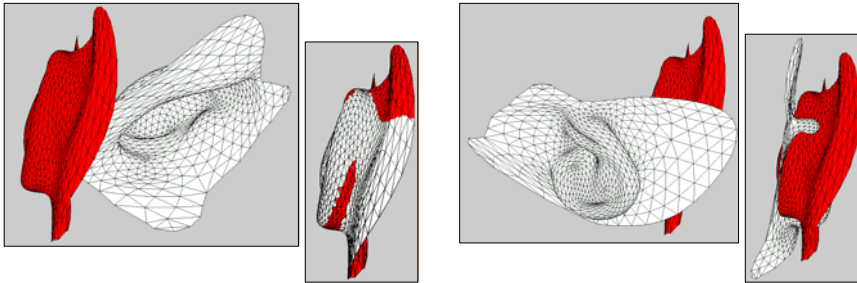
$$T = \text{avg}(P) - R * \text{avg}(M)$$

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

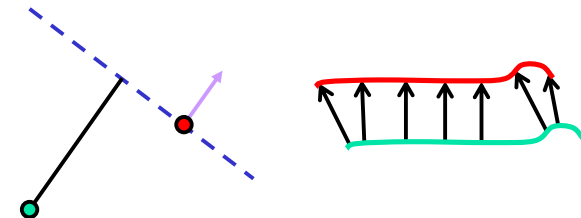
- Speed up correspondance
 - Use spatial subdivision
- Select only sample of points
- Different error metrics
- Change point matching
- Reject outliers

Points Sampling

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

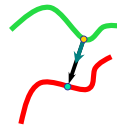
Error Metrics

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



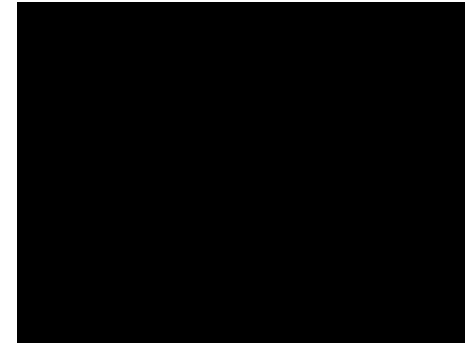
Point Matching

- Standard – closest point
 - Slow
- Normal shooting
 - Bad for noisy meshes
- Consider only compatible points
 - Same curvature, normals, colors



More Extensions

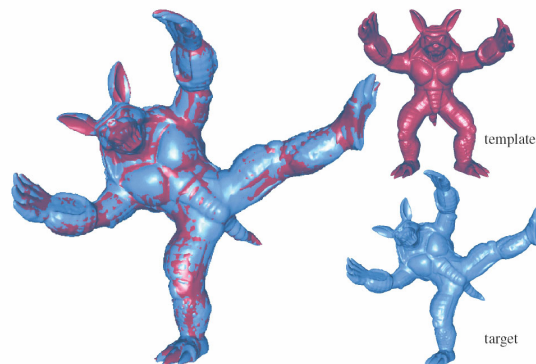
- Can be done in real time
 - Interactive scanning & registration



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