3D Pose Estimation from Planes

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Pose Estimation

Like 2D case, estimate rotation first, then translation

Assume:

- N paired planes $\{(M_i, D_i)\}_{i=1}^{N}$
- model and data normals $\{\vec{m}_i\}$ and $\{\vec{d}_i\}$
- a point on each model patch $\{\vec{a}_i\}$
- a point on each data patch $\{\vec{b}_i\}$ (need not correspond to $\vec{a}_i$)

Rotation Estimation

Want R such that $\mathrm{R}\vec{m}_i \doteq \vec{d}_i$

A least square problem, minimizing

$$\sum_i \| \mathrm{R}\vec{m}_i - \vec{d}_i \|^2$$

Form matrix $\mathrm{M} = [\vec{m}_1 \vec{m}_2 \ldots \vec{m}_N]$

Form matrix $\mathrm{D} = [\vec{d}_1 \vec{d}_2 \ldots \vec{d}_N]$

Compute singular value decomposition (SVD):

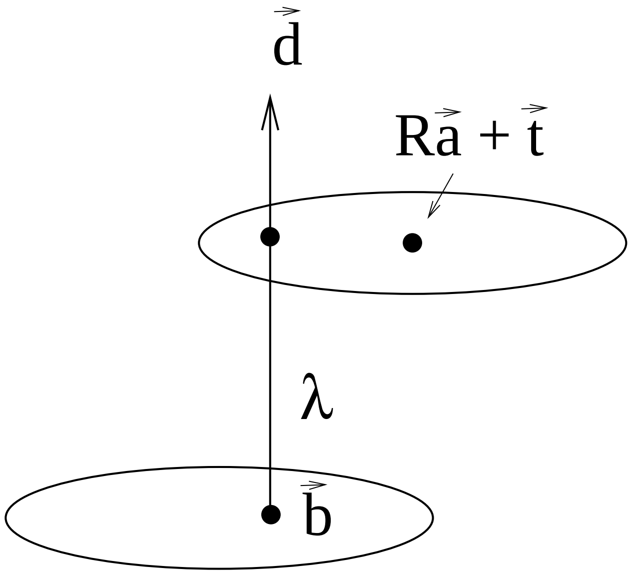
svd(DM') = U*S*V'

Compute rotation matrix: R = V*U'

Assumes at least 3 non-coplaner vectors (caution 1 special case)

Translation Estimation

Minimize the perpendicular separation λ_i between rotated model patch and data patch:



Goal: find $\vec{t}$ that minimizes $\sum_i \lambda_i^2$

Form matrix: $\mathrm{L} = \sum_i \vec{d}_i \vec{d}_i'$

Form vector: $\vec{n} = \sum_i \vec{d}_i \vec{d}_i' (\mathrm{R}\vec{a}_i - \vec{b}_i)$

Compute translation $\vec{t} = -(\mathrm{L})^{-1} \vec{n}$

Verification

Multiple possible matching solutions:

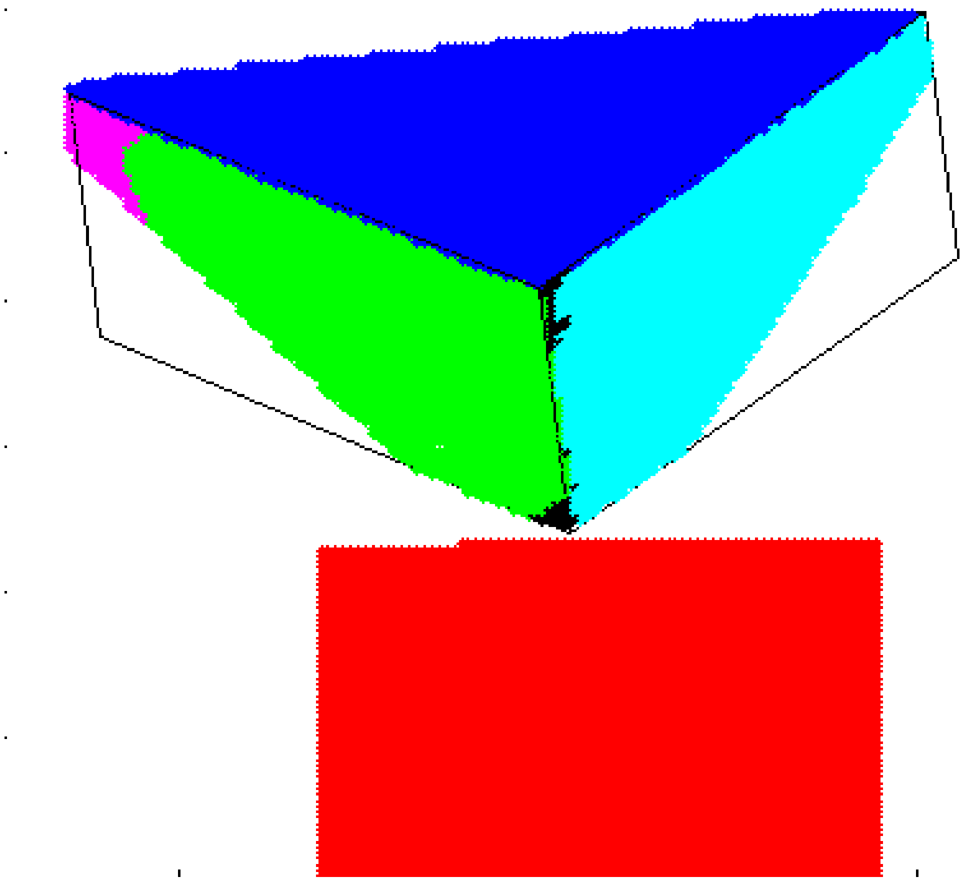
globally invalid pairings, alternative pose hypotheses

Use verification to find correct one

1. Rotated model normals $\vec{m}_i$ close to data normals $\vec{d}_i$:
   $acos(\vec{d}_i' \mathrm{R} \vec{m}_i) < \tau_1$
2. Transformed model vertices $\vec{e}_i$ lie on the data plane
   $\vec{n}'\vec{x} + d = 0$: $\mid \vec{n}'\vec{e}_i + d \mid < \tau_2$

Matching Results

Object recognized but three pose solutions as verification didn't check overlap areas



Accurate model-data alignment!

What We Have Learned

- A least squares pose estimation algorithm using planes
- Constraints to verify 3D model matches