3D Model Matching and Verification

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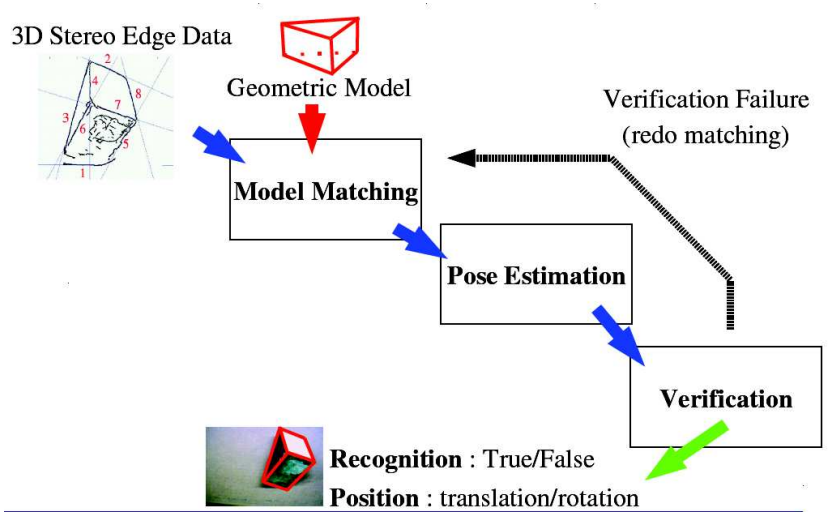
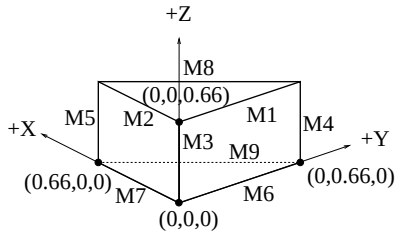
3D Edge Based ? Pipeline



3D Wireframe Part Model

Match 3D data edges to 3D ? model edges



Model =
(0,0,0)-(0.66,0,0)
(0,0,0)-(0,0.66,0)
(0,0,0)-(0,0,0.66)
(0.66,0,0)-(0.66,0,0.66)
(0,0.66,0)-(0,0.66,0.66)
(0,0,0.66)-(0.66,0,0.66)
(0,0,0.66)-(0.66,0.66,0.66)
(0.66,0,0)-(0,0.66,0)
(0.66,0,0.66)-(0,0.66,0.66)

3D Model Matching

Use ? algorithm: match edges,
Limit = 5

Unary test: similar length $\mid l_m - l_d \mid < \tau_l(l_m + l_d)$
(No effect as all edges about same length)

Binary test: similar angle between pairs:
$\mid \theta_m - \theta_d \mid < \tau_a (= 0.5)$

3D Pose Estimation

Given: matched line directions $\{(\vec{m}_i, \vec{d}_i)\}$ and points on corresponding lines (but not necessarily same point positions) $\{(\vec{a}_i, \vec{b}_i)\}$

Rotation (matrix R): estimate rotation from matched ?

except:

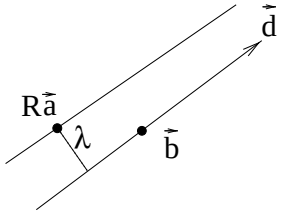
1) Use line directions instead of surface normals
2) Don't know which $\pm$ direction for edge correspondence: try both for each matched segment
3) If $det(\mathrm{R}) = -1$ then need to flip symmetry

3D Translation Estimation

Given N paired model and data segments, with point $\vec{a}_i$ on model segment i and $\vec{b}_i$ on data segment i

Direction $\vec{d}_i$ of data segment i

Previously estimated rotation R



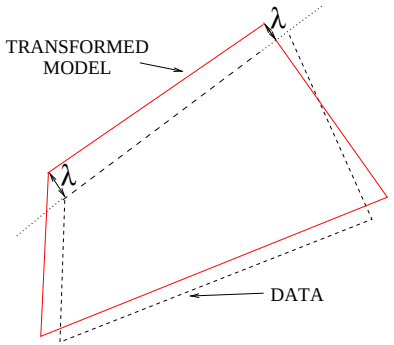
$\vec{\lambda}_i = \mathrm{R}\vec{a}_i + \vec{t} - \vec{b} - \vec{d}_i(\vec{d}_i'(\mathrm{R}\vec{a}_i + \vec{t} - \vec{b}))$ is ? error to minimize

Goal: find $\vec{t}$ that minimizes $\sum_i \vec{\lambda}_i'\vec{\lambda}_i$

How: $\mathbf{L} = \sum_i (I - \vec{d}_i\vec{d}_i')'(I - \vec{d}_i\vec{d}_i')$

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

$\vec{t} = \mathrm{L}^{-1}\vec{n}$



3D Match Verification

Like 2D match ? except measure 3D quantities:

1. Rotated 3D model line similar orientation to estimated 3D scene line
2. Rotated & translated model line endpoints near infinite 3D scene line
3. Rotated & translated model midpoint near estimated 3D scene line midpoint

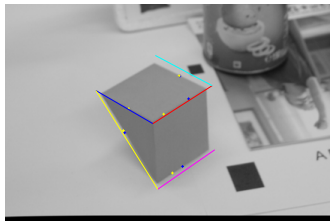
Matching ?

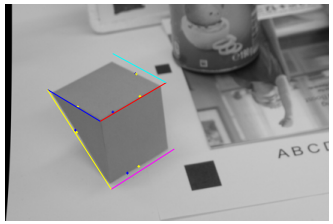
Matching only 15 block line pairs with L=5:
- 108924 interpretation tree successes
- 243680 verification attempts
- 111 solutions found (note rotation mirror)

Matching only 15 block line pairs with L=8:
- 60096 interpretation tree successes
- 120191 verification attempts
- 2 solutions found (note rotation mirror)

Matching all 25 line pairs with L=5:
- 1751792 interpretation tree successes
- 3732933 verification attempts
- 7 solutions found (good lines removed as duplicates)

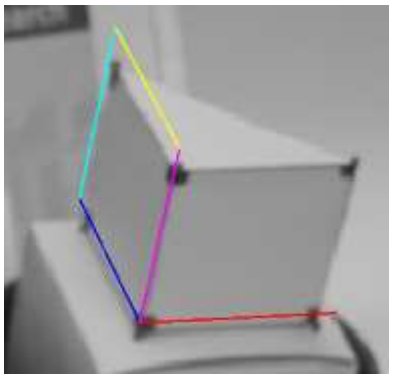
5 Segment Matching ?

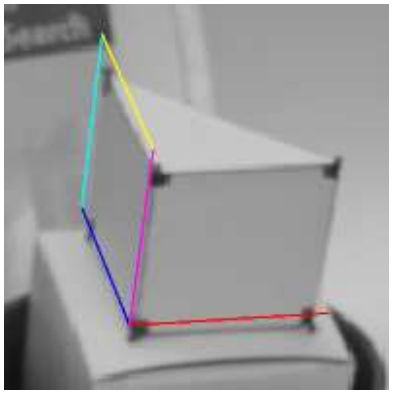




Calibration a bit off

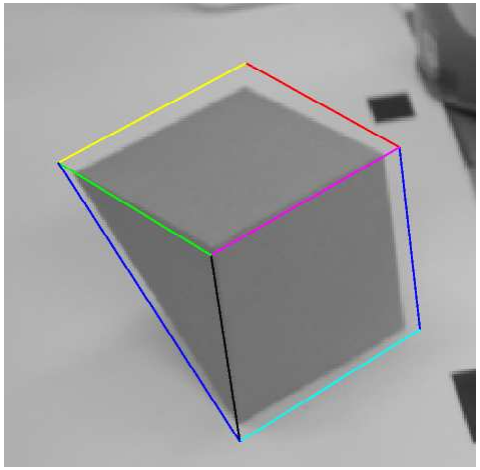
5 Segment Matching Overlay





? estimations not as good as for other block

8 Segment Matching Overlay



? a bit off

Discussion

- Hard to find reliable edges/lines, but Canny finds most reasonable edges and RANSAC can put them together for lines
- Given enough stereo correspondence constraints, can get reasonably correct correspondences
- Large features help stereo matching but require more preprocessing
- Stereo geometry easy but needs ? calibration not always easy
- Binocular feature matching stereo gives good 3D at corresponding features, but nothing in between
- Interpretation tree complexity large if weak tree pruning constraints

What We Have ?

- A full line-based stereo scene analysis and shape matching algorithm
- Simple modeling and matching algorithms
- 3D least-square position estimation algorithms