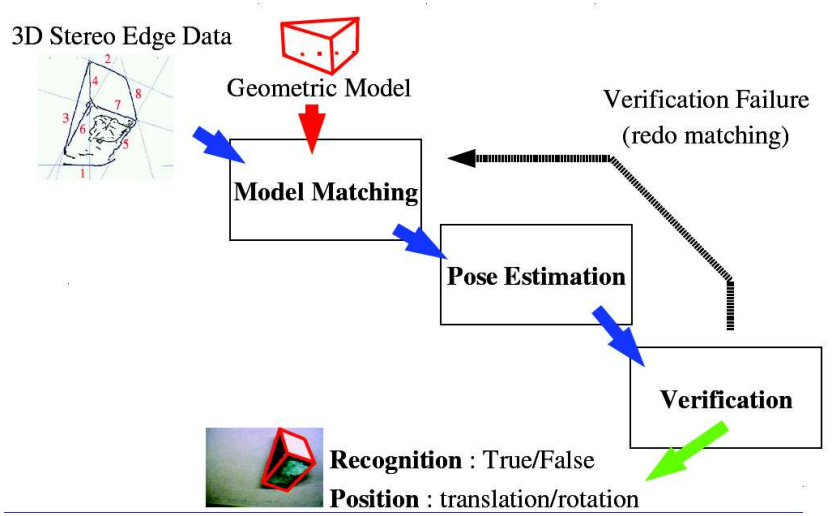
3D Model Matching and Verification

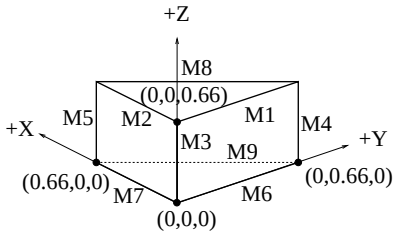
Robert B. Fisher
School of Informatics
University of Edinburgh

3D Edge Based Recognition Pipeline



3D Wireframe Part Model

Match 3D data edges to 3D wireframe 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 Interpretation Tree 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 vectors except:

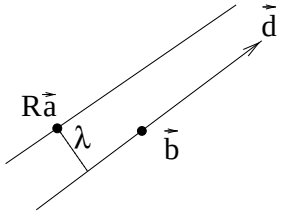
1) Use line directions instead of surface normals
2) Don't know which $\pm$ direction for edge correspondence: try both for each matched segment
3) If $det(\mathrm{R}) = -1$ then need to flip symmetry

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



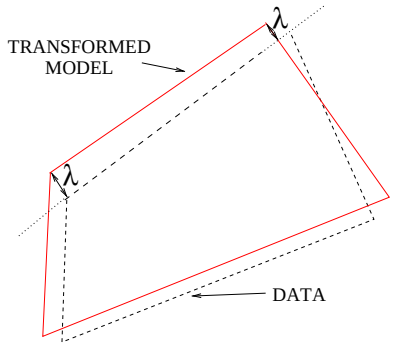
$\vec{\lambda}_i = \mathrm{R}\vec{a}_i + \vec{t} - \vec{b} - \vec{d}_i(\vec{d}_i'(\mathrm{R}\vec{a}_i + \vec{t} - \vec{b}))$ is translation error to minimize

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 verification 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 Performance

Matching only 15 block line pairs with L=5:

- 108924 interpretation tree successes
- 243680 verification attempts
- 111 solutions found (note rotation mirror)

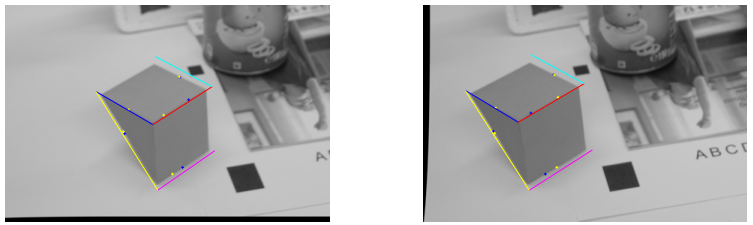
Matching only 15 block line pairs with L=8:

- 60096 interpretation tree successes
- 120191 verification attempts
- 2 solutions found (note rotation mirror)

Matching all 25 line pairs with L=5:

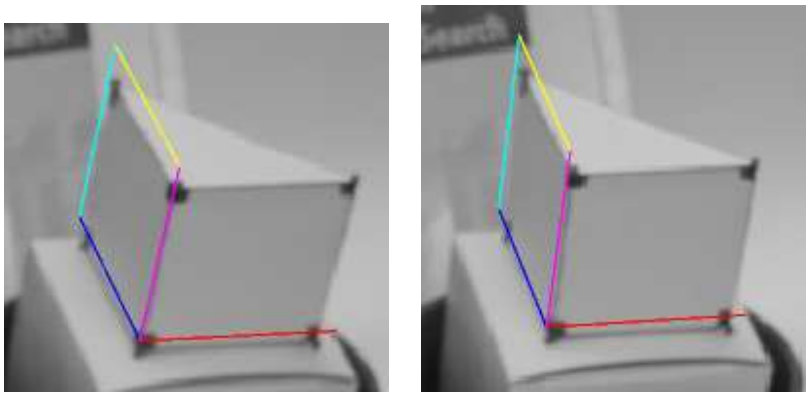
- 1751792 interpretation tree successes
- 3732933 verification attempts
- 7 solutions found (good lines removed as duplicates)

5 Segment Matching Overlay



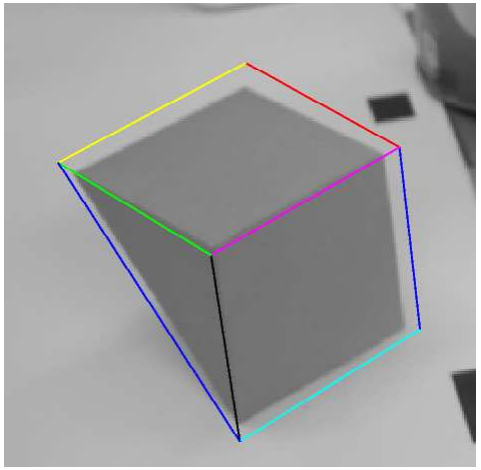
Calibration a bit off

5 Segment Matching Overlay



3D line estimations not as good as for other block

8 Segment Matching Overlay



Calibration 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 accurate 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 Learned

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