

# 3D Model Matching and Verification

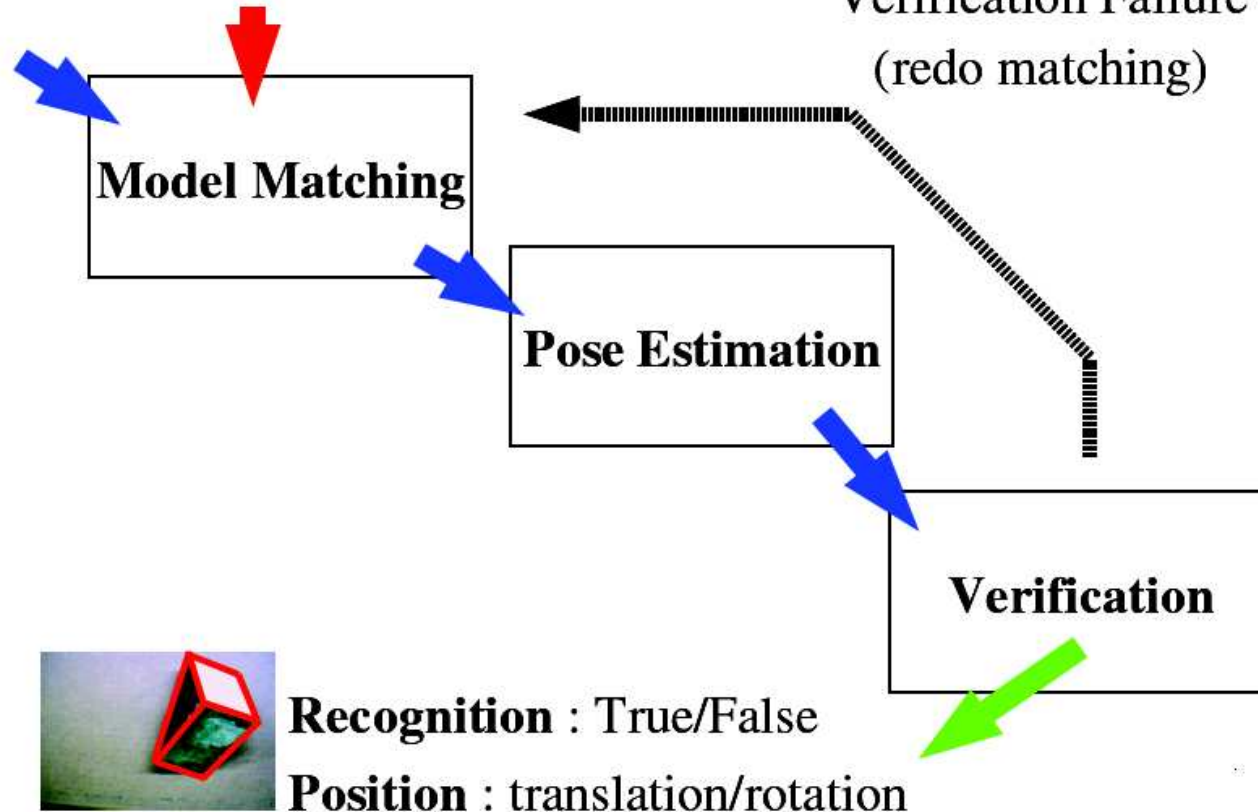
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# 3D Edge Based Recognition Pipeline

3D Stereo Edge Data

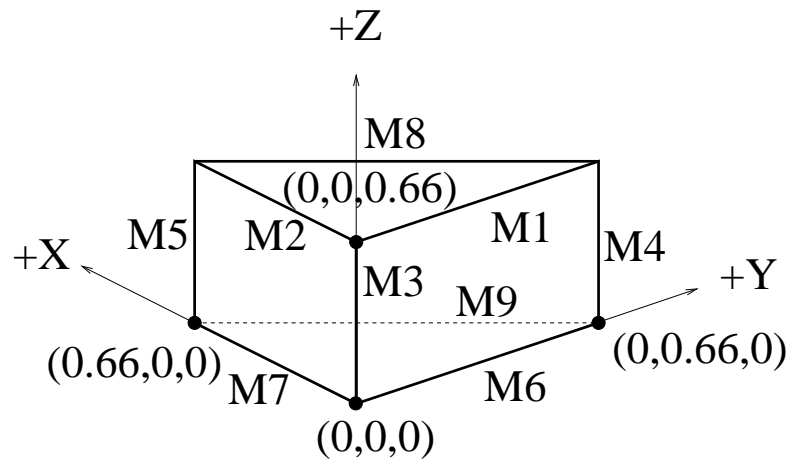


Geometric Model



## 3D Wireframe Part Model

Match 3D data edges to 3D wireframe model edges



Model =

$(0,0,0)-(0.66,0,0)$

$(0,0,0)-(0,0.66,0)$

$(0,0,0)-(0,0,0.66)$

$(0.66,0,0)-(0.66,0,0.66)$

$(0,0.66,0)-(0,0.66,0.66)$

$(0,0,0.66)-(0.66,0,0.66)$

$(0,0,0.66)-(0,0.66,0.66)$

$(0.66,0,0)-(0,0.66,0)$

$(0.66,0,0.66)-(0,0.66,0.66)$

## 3D Model Matching

Use Interpretation Tree algorithm: match edges, Limit = 5

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

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

## 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  $\mathbf{R}$ ): estimate rotation from matched vectors  
except:

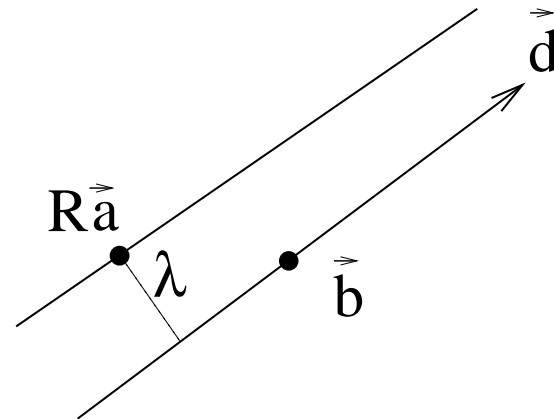
- 1) Use line directions instead of surface normals
- 2) Don't know which  $\pm$  direction for edge correspondence:  
try both for each matched segment
- 3) If  $\det(\mathbf{R}) = -1$  then need to flip symmetry

## 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  $i$

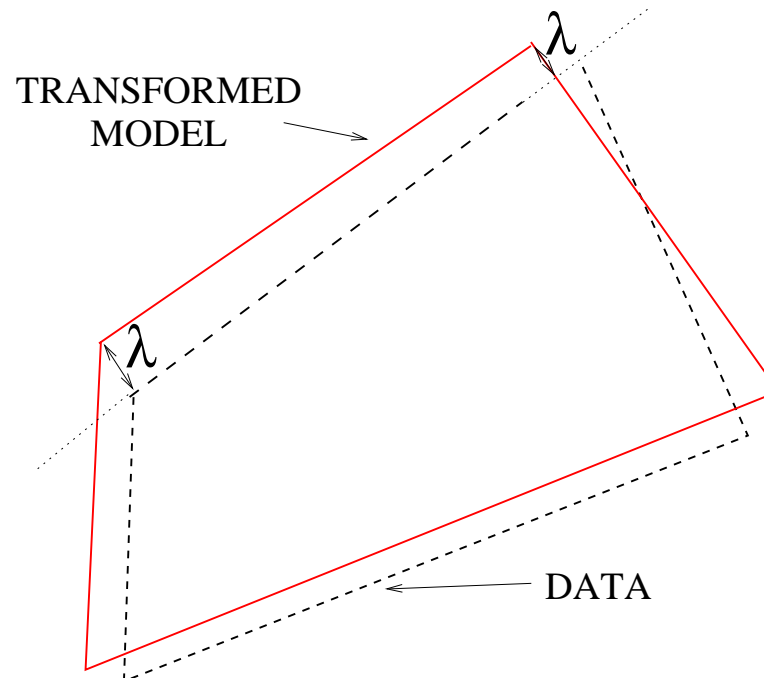
Previously estimated rotation  $R$



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

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

How:  $\mathbf{L} = \sum_i (I - \vec{d}_i \vec{d}_i') (I - \vec{d}_i \vec{d}_i')$   
 $\vec{n} = \sum_i (I - \vec{d}_i \vec{d}_i') (I - \vec{d}_i \vec{d}_i') (R\vec{a}_i - \vec{b}_i)$   
 $\vec{t} = \mathbf{L}^{-1} \vec{n}$



## 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)

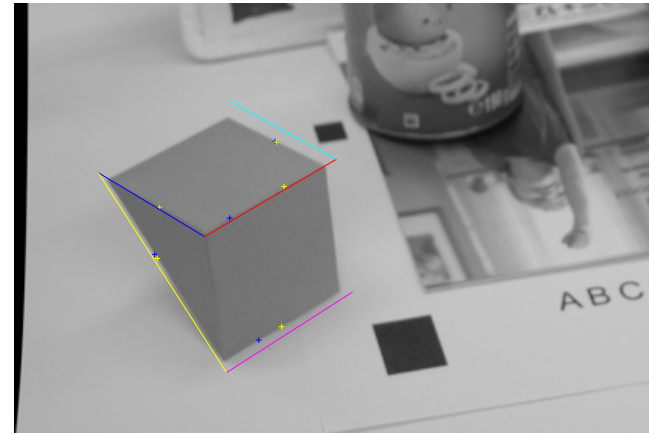
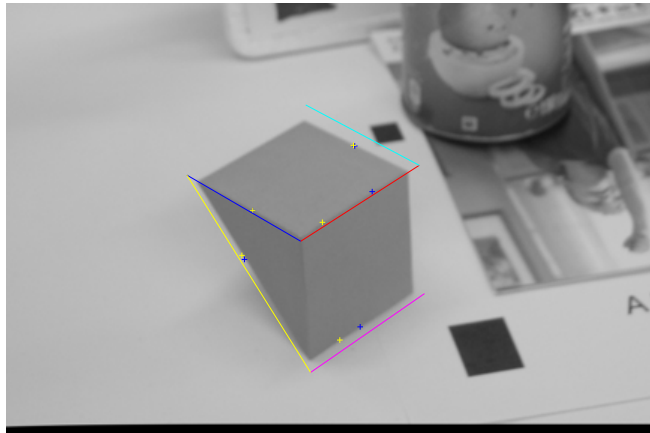
Matching all 25 line pairs with  $L=5$ :

1751792 interpretation tree successes

3732933 verification attempts

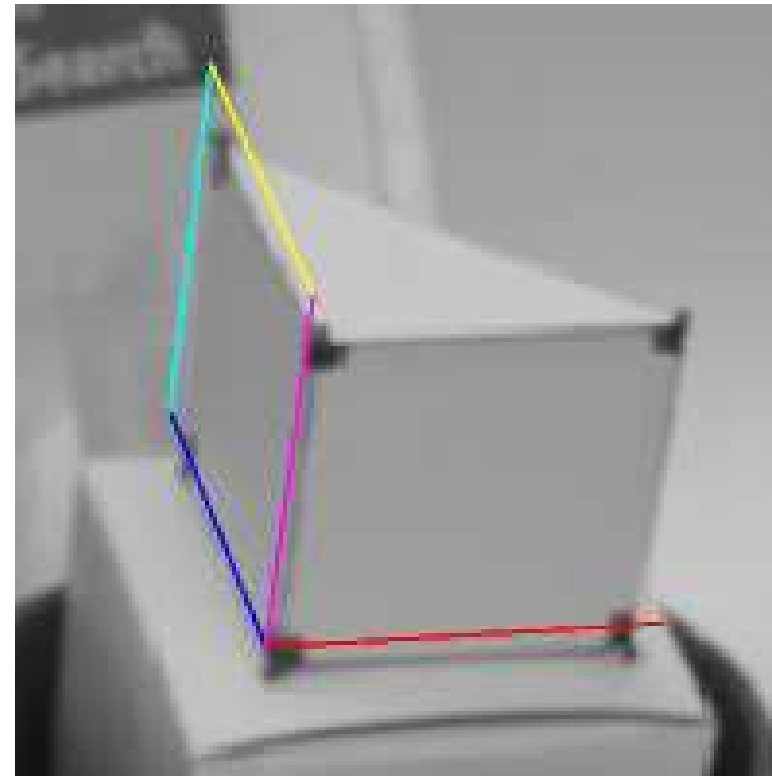
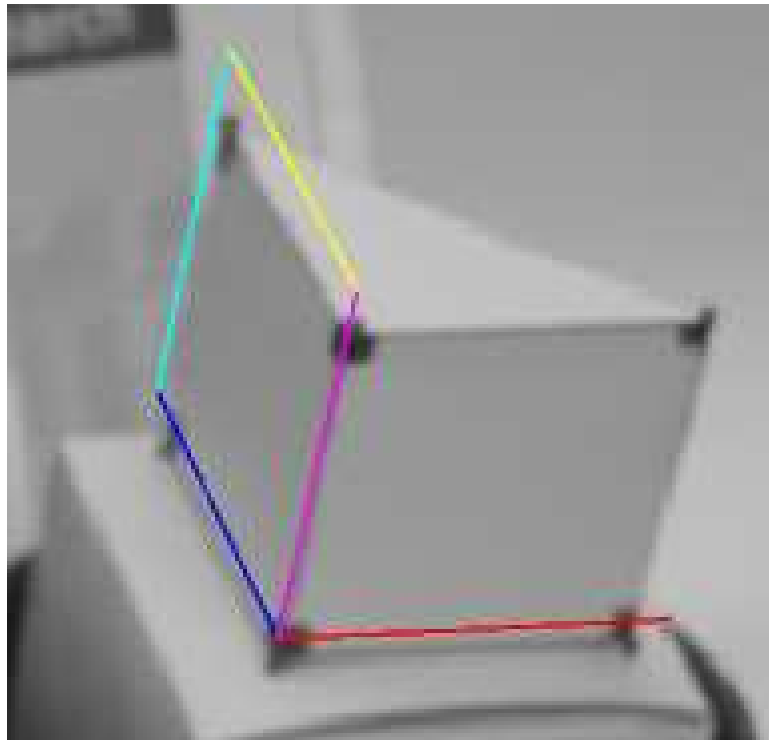
7 solutions found (good lines removed as duplicates)

## 5 Segment Matching Overlay



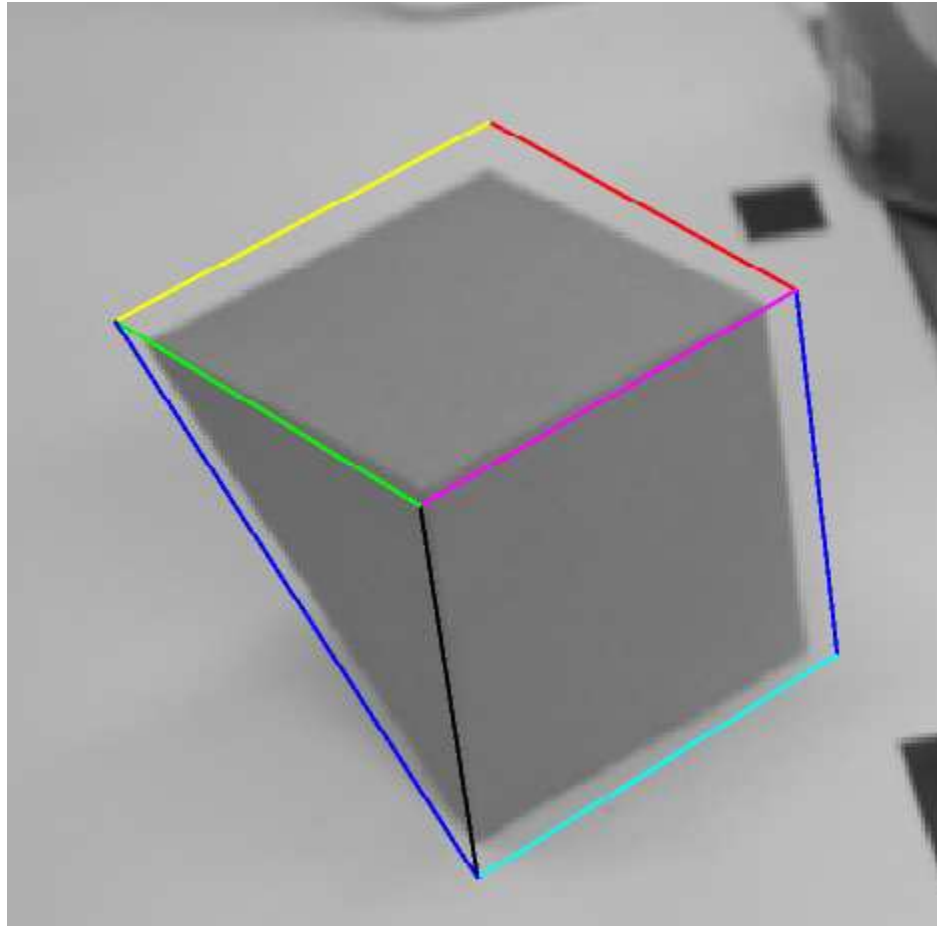
Calibration a bit off

## 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