Indexing with Unknown Illumination and Pose

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The task – Shape Indexing

1. Recognize
2. Recover pose+lighting

Camel
Hippo
Dino
Camel
Why is it hard?

- Unknown pose
- Unknown lighting
- Clutter
- Occlusion
Assumptions

- Weak perspective projection
- 3D rigid transformation
- Lambertian model
• Identification using alignment
  Fischler and Bolles, Huttenlocher and Ullman

• “3D to 2D invariants do not exist”
  Burns et al., Moses et al., Clemens et al.

• Indexing faster than alignment
  Jacobs, Wolfson et al.
Previous Indexing Methods

- Ignored intensity information
- Need many point or line features
- Restricted to polyhedral objects
Our algorithm...

• Handles both *pose* and *lighting*
• Uses *intensities* to filter out incorrect matches
• Still relies on point features but only *very few* are needed
• *General* objects
Indexing with pose - Affine model
(Jacobs ’96)

\[ p_i = A P_i + t \quad \rightarrow \quad 8 \text{ DOF} \rightarrow 5 \text{ points} \]
Representation in two 2D tables

Offline – preprocessing

Online – matching

\[ \alpha_4 = \alpha_3 m + n_1 \]

\[ \beta_4 = \beta_3 m + n_2 \]
Modifications – still two 2D spaces

Offline – preprocessing

Online – matching

\[ r_1 = \alpha_3 \cos \theta + \alpha_4 \sin \theta \]

\[ r_2 = \beta_3 \cos \theta + \beta_4 \sin \theta \]
One 3D space

Offline – preprocessing

Online – matching

(θ, r₁, r₂)

(n₁, n₂, m)

Offline – preprocessing

Online – matching

(α₃, β₃)

(α₄, β₄)
False Matches

True match
How to eliminate the false matches

• Enforce rigidity using inverse Gramian Test - Weinshall, ‘93

\[
\frac{|x^T By| + |x^T Bx - y^T By|}{|x^T B y|} < \varepsilon
\]

• Consistency with lighting → NEXT
Harmonic Images – Linear Basis for Lighting
(Basri and Jacobs ’01, Ramamoorthi and Hanrahan ’01)
Representation by harmonics

\[ I = b \ast H \]

Unknown light

Intensities of image point set

Harmonics of model point set
The consistency measure

\[ I = b \ast H \]

For corresponding image and model sets this is minimal

Should we apply it on feature points?
“Smooth points”
Voting

- Sets of points that pass the lighting test vote for their respective model
- All models receive scores:
  - Score = fraction of image sets for which the model appears min
- Once model is selected its corresponding subsets used to determine its pose and lighting
Experiments

- Real 3d objects acquired using laser scanner

- Feature points collected automatically using Harris corner detector
Results
Results

dino
shark
bear
hippo
pinokio
elephant
camel
face
Results
Results – Indoor scene

dino
shark
bear
hippo
pinokio
elephant
camel
face
Results – Outdoor scene

dino
shark
bear
hippo

pinokio
elephant
camel
face
Results – Night Scene

dino, camel, shark, pinokio, bear, elephant, camel, face, hippo.
Results – Night Scene 2

dino
shark
bear
hippo
pinokio
elephant
camel
face
Filtering out matches

- Total: 5,940,480
- 2D table: 48,815
- 3D table: 1,916
- Rigidity: 331
- Lighting: 18
How much does lighting help?

Voting based on *Affine model*

- Dino
- Hippo
- Camel
- Pinokio
- Bear
- Elephant
- Shark
- Face
How much does lighting help?

Affine + **Rigidity** test

- Dino: 0.3
- Hippo: 0.2
- Camel: 0.3
- Pinokio: 0.1
- Bear: 0.01
- Elephant: 0.01
- Shark: 0.01
- Face: 0.01

Inset: Dinosaur model.
How much does lighting help?

Affine + Rigidity + \textit{Lighting}
Conclusion

• Identify 3d objects in 2d scenes
  • Unknown *pose, light*
  • *Clutter, occlusions*
  • *General, real objects*
  • *Fast, efficient*

• Combination of *intensity* cues and geometry
Thank you!