Detecting Shapes in Raven’s Matrices

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Outline

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  - SIFT
  - Hough transform
  - Affine fitting
  - Clustering
- Adaptation to Rasmussen Model
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Motivation

- Learn to recognize objects
Motivation

- Computers are not THAT intelligent

\[ \square = \text{square} \]

\[ \nexists \square = \text{object2} \]
Problem

Given a test image, is it possible to determine whether or not a model exists in the test image? How many times?
Problem

What is the best \((x, y)\) location, scale and orientation from a model to a given test image?
Problem

- Used Raven's Matrices
Techniques used

- SIFT (Lowe, 2004)
- Hough Transform
- Affine fitting
- Clustering
SIFT

- Scale Invariant Feature Transform
- David Lowe, 2004
- Match keypoints between test and model
- Provides location, scale, orientation of keypoints
- Andrea Vedaldi, SIFT for Matlab
- `sift()`
  - Frames: 4xM matrix
  - Descriptors: 128-D vector
- `siftmatch()`, `plotsiftmatches()`
[frames_test, test_desc] = sift(test, 'Threshold', THRESHOLD, ...
  'EdgeThreshold', EDGE_THRESHOLD, 'BoundaryPoint', 0);
matches = siftmatch(test_desc, model_desc, SIFTMATCH_THRES);
plotmatches(test, model, frames_test, frames_model, matches);
SIFT

Siftmatch()
Hough Transform

- Feature extraction technique
- Image analysis, computer vision, digital image processing
- Voting procedure
Hough Transform

- Scene A: knife, blood, person on floor
  - Knife: kitchen, crime, camping
  - Blood: hospital, nose bleed, crime
  - Person on floor: sleeping, star gazing, crime

- Winner: Crime
Hough Transform

- Input: keypoint matches
- Create bins in Hough space
  - (x,y) location, scale, orientation
- Output:
  - ‘winning’ bin (most votes)
  - No winner (model DNE)
- Multiple winners
Hough Transform

\[ \Delta scale = \frac{\text{test}_\text{scale}}{\text{model}_\text{scale}} \]

\[ \Delta \theta = \text{test}_\text{orientation} - \text{model}_\text{orientation} \]

\[
\begin{bmatrix}
 x \\
 y \\
 1 \\
\end{bmatrix} = \begin{bmatrix}
 \Delta scale \times \cos(\Delta \theta) & -\sin(\Delta \theta) & x_t \\
 \sin(\Delta \theta) & \Delta scale \times \cos(\Delta \theta) & y_t \\
 0 & 0 & 1 \\
\end{bmatrix} \times \begin{bmatrix}
 -x_m + \frac{\text{model}_\text{width}}{2} \\
 -y_m + \frac{\text{model}_\text{height}}{2} \\
 1 \\
\end{bmatrix}
\]
Hough Transform

- Vote 2 closest bins in each dimension
- Total 16 bins
- Hash table, serialize indices
- Track winning bin
Affine Fitting

At least 3 distinct model points mapped to test image

(Lowe, 2004)
Affine Fitting

dashed_line2.jpg located at approximately (156.8097, 156.8097)
scale: 1.0062 times the model
orientation: 3.1173 radians
Clustering

- Unsupervised classification of patterns (observations, data, feature vectors) into groups (clusters) (Jain et al., 1999)
Clustering

- Track 30 bins with most votes
- If first bin has match between test and model, proceed with clustering
- Matlab’s subclust()

[C S] = subclust(X, [xy_radii xy_radii 0.4 0.3 0.3], Xbounds);
Plot of x and y radii versus number of clusters
Clustering

(a) Plot of all model points from (b) Sample showing 2 clusters
a dashed line to the image found in the image (green points dots in the center)
Clustering

(a) Three clusters found in (b) Top left cluster (c) siftmatch() results between Fig.
the left square the left square the left square

8b and the model
There are clusters located at (format: [a b c d e]):

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>156.8772</td>
<td>166.8502</td>
<td>1.0053</td>
<td>-0.9998</td>
<td>0.0211</td>
<td></td>
</tr>
<tr>
<td>196.0512</td>
<td>149.6497</td>
<td>1.0226</td>
<td>0.0021</td>
<td>-1.0000</td>
<td></td>
</tr>
<tr>
<td>240.3024</td>
<td>252.6831</td>
<td>0.8730</td>
<td>0.9999</td>
<td>-0.0109</td>
<td></td>
</tr>
</tbody>
</table>

where a and b represent the x-y location, c represents the relative scale from the model to the test image, and d and e represent the angle on a unit circle.

\[(\cos(\theta), \sin(\theta)) = (d,e)\]
Adaptation to Rasmussen Model

- Basic Idea
  - Apply SIFT/Hough transform on the 8 cells
  - map Rasmussen input with above output
  - If match
    - apply SIFT/Hough transform on answer cells

- theoretical
Adaptation to Rasmussen Model

Example 1

(a) Raven Matrix 1

(b) Databank of figures
Adaptation to Rasmussen Model

- **Cell 1’s output from Hough**

```
HOUGH IMPLEMENTATION
===============
dashed_line_horizontal.jpg located at approximately (173.7823,173.7823)
scale: 0.99973 times the model
orientation: 5.4982 radians

There are clusters located at (format: [a b c d e]):
   173.6544  157.8504  1.0045  0.7079  -0.7063

where a and b represent the x-y location, c represents the relative scale from the model to the test image, and d and e represent the angle on a unit circle.
(cos(theta), sin(theta)) = (d,e)
```
Adaptation to Rasmussen Model

- Cell 1’s output from Hough

```
Hough implementation
=====================
Circle.jpg located at approximately (179.9844, 179.9844)
scale: 1.0154 times the model
orientation: 6.2147 radians

There are clusters located at (format: [a b c d e]):
  180.5672  155.7880   1.0035   0.5597  -0.8287
where a and b ...
```

```
Hough implementation
=====================
No match for square.jpg
```
Adaptation to Rasmussen Model

- Modified version of Dan’s input

```
#matrix
circle; 1; 45deg
diamond; 1; 135deg
square; 1; 90deg
diamond; 2; 90deg
square; 2; 45deg
circle; 2; 135deg
square; 3; 135deg
circle; 3; 90deg
```

```
#answers
square; 3; 90deg
diamond; 2; 135deg
circle; 1; 45deg
circle; 3; 90deg
diamond; 3; 45deg
circle; 2; 135deg
square; 3; 45deg
diamond; 1; 90deg
```
Adaptation to Rasmussen Model

- logic

```
if cell 1 contains a circle and 1 dashed line at 45deg &&
cell 2 contains a diamond and 1 dashed line at 135deg &&
cell 3 contains a square and 1 dashed line at 90deg &&
...
&&
cell 8 contains a square and 3 dashed line at 90deg

then
apply the Hough transform on the answer cells
if Answer 1 contains a diamond and 3 dashed lines at 45deg
    then output Answer 1
else if Answer 2 contains a diamond and 3 dashed lines at 45deg
    then output Answer 2
...
else if Answer 8 contains a diamond and 3 dashed lines at 45deg
    then output Answer 8

end
```
Conclusions

- Is it possible to determine the existence of a model in a given test image?
  - YES!!!
    - SIFT, Hough transform
    - Clustering
- Theoretically adapt above methods to Rasmussen Model
Future Problems

- SIFT has limitations
  - Occlusion
  - Noise
- Non-detectable features (pixel-based)
Future Problems

- Clustering solutions
  - Similarity transform
  - Prior knowledge
  - First bin approach
  - Adjust more parameters

- Training images
References


Acknowledgements: Charlie Tang
The End