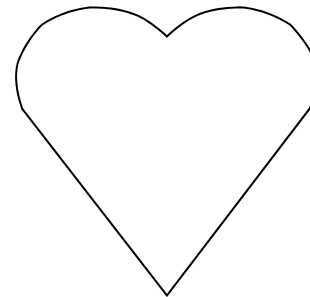
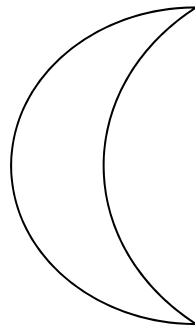
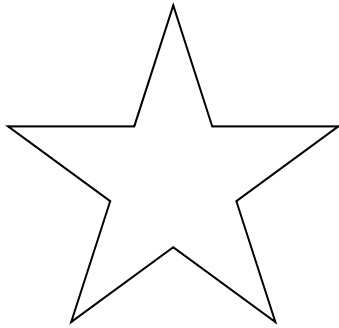


# Chamfer Distance for Handshape Detection and Recognition

CSE 6367 – Computer Vision  
Vassilis Athitsos  
University of Texas at Arlington

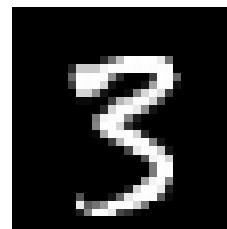
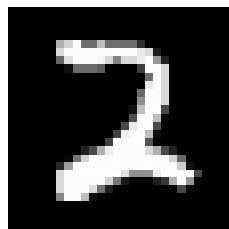
# Contours

- A contour is a curve/line (typically not straight) that delineates the boundary of a region, or between regions.

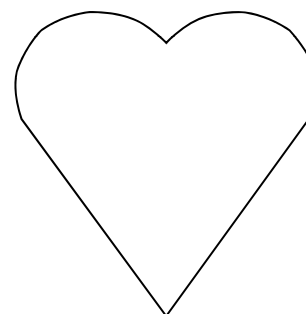
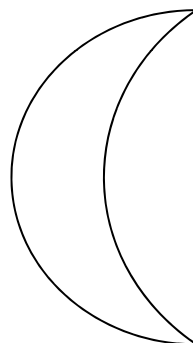
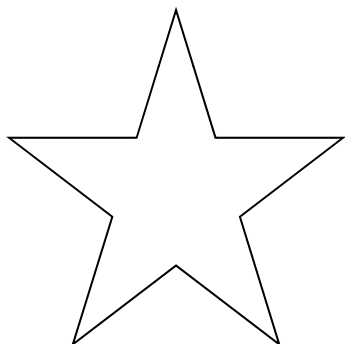


# Shapes Without Texture

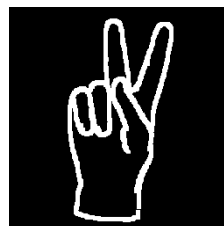
- Letters/numbers.



- Contours.

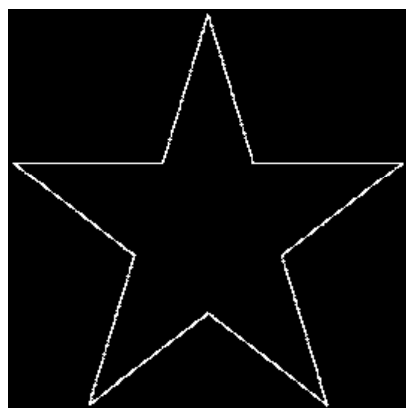


- Edge templates.

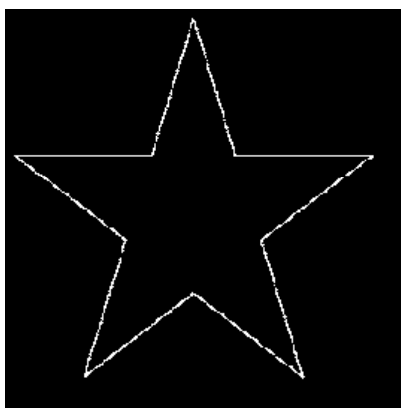


# Detecting Shapes Without Texture

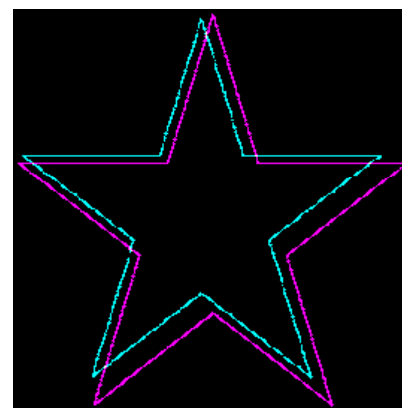
- Normalized correlation does not work well.
- Slight misalignments have a great impact on the correlation score.



star1

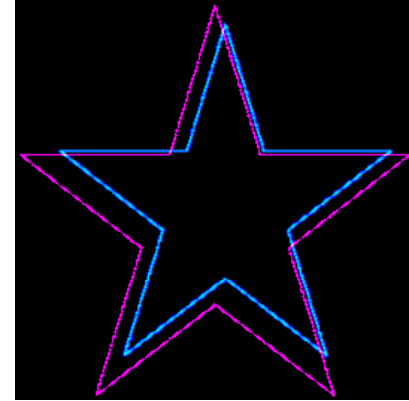
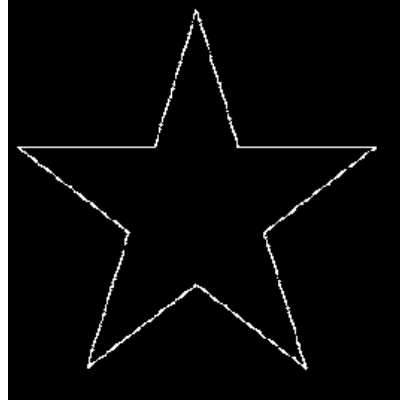
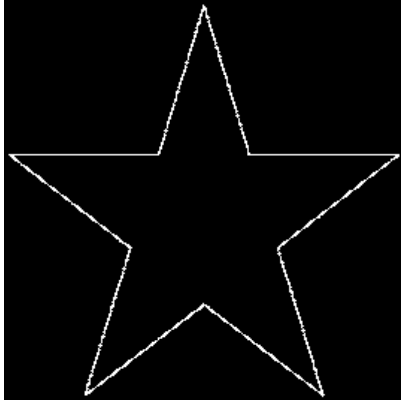


star3



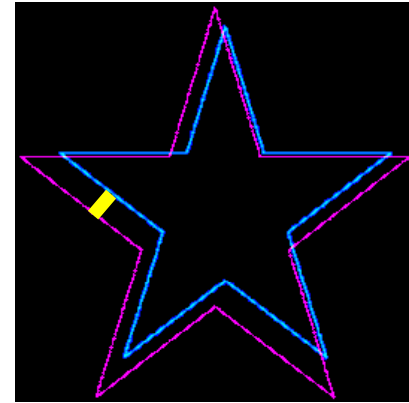
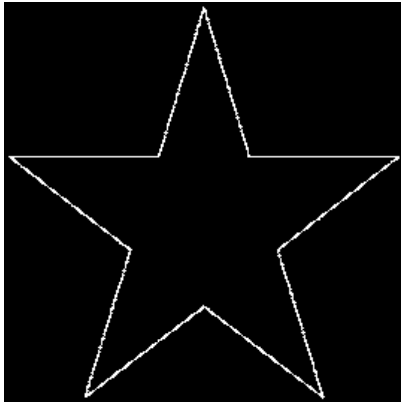
combined

# Chamfer Distance



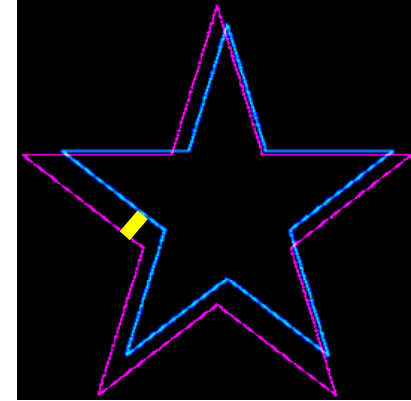
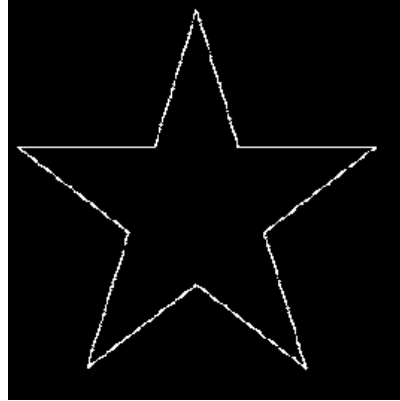
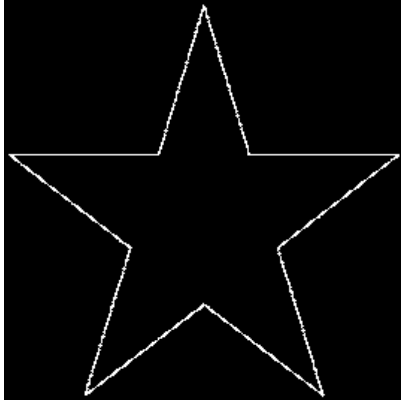
- For each edge pixel in star1:
  - How far is it from the nearest edge pixel in star3?
- The average of all those answers is the *directed chamfer distance from star1 to star3*.

# Chamfer Distance



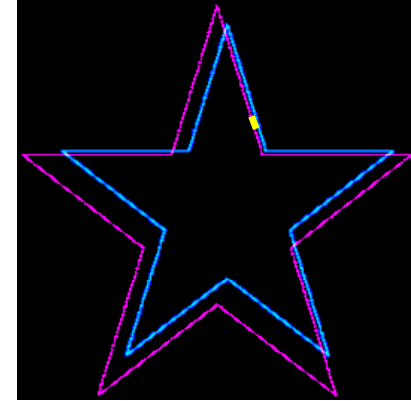
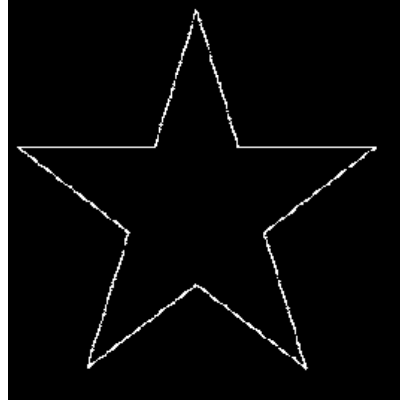
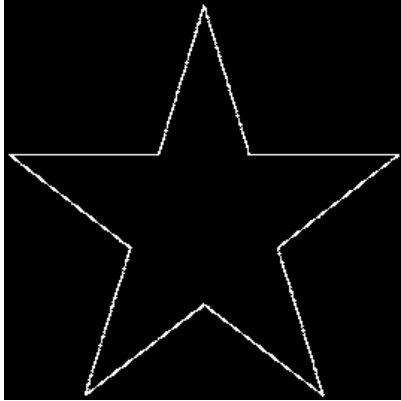
- For each edge pixel in star1:
  - How far is it from the nearest edge pixel in star3?
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# Chamfer Distance



- For each edge pixel in star1:
  - How far is it from the nearest edge pixel in star3?
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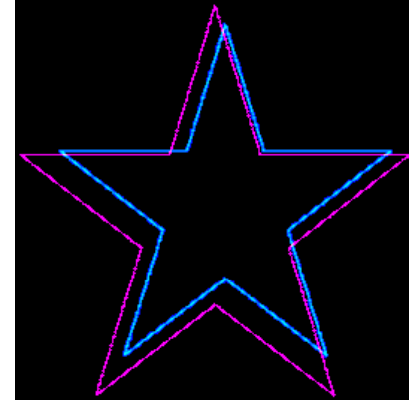
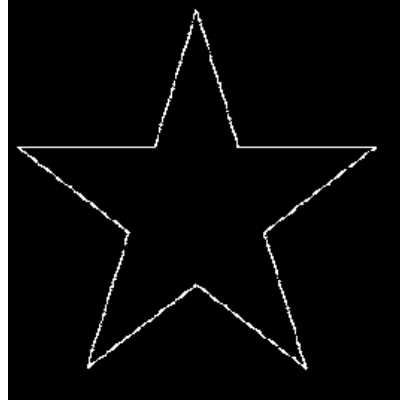
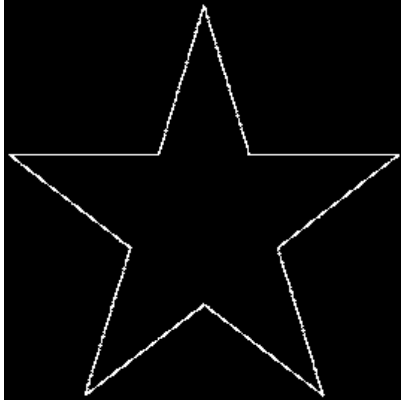
# Chamfer Distance



- For each edge pixel in star1:
  - How far is it from the nearest edge pixel in star3?
- The average of all those answers is the *directed chamfer distance from star1 to star3*.



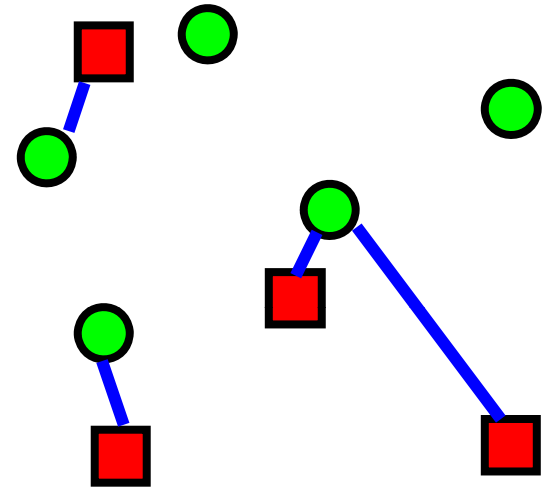
# Chamfer Distance



- For each edge pixel in star3:
  - How far is it from the nearest edge pixel in star1?
- The average of all those answers is the *directed chamfer distance from star3 to star1*.

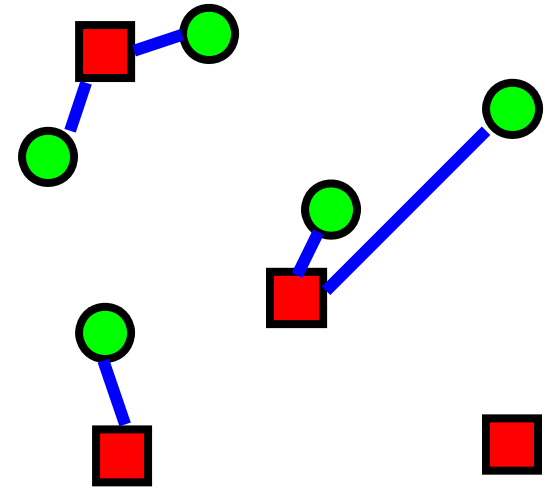
# Directed Chamfer Distance

- Input: two sets of points.
  - red, green.
- $c(\text{red}, \text{green})$ :
  - Average distance from each red point to nearest green point.



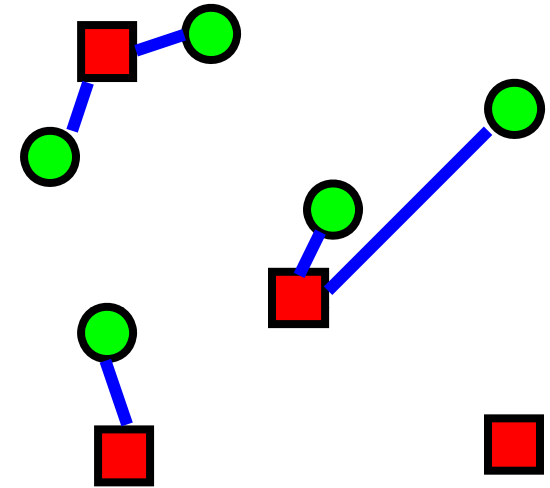
# Directed Chamfer Distance

- Input: two sets of points.
  - red, green.
- $c(\text{red}, \text{green})$ :
  - Average distance from each red point to nearest green point.
- $c(\text{green}, \text{red})$ :
  - Average distance from each green point to nearest red point.



# Chamfer Distance

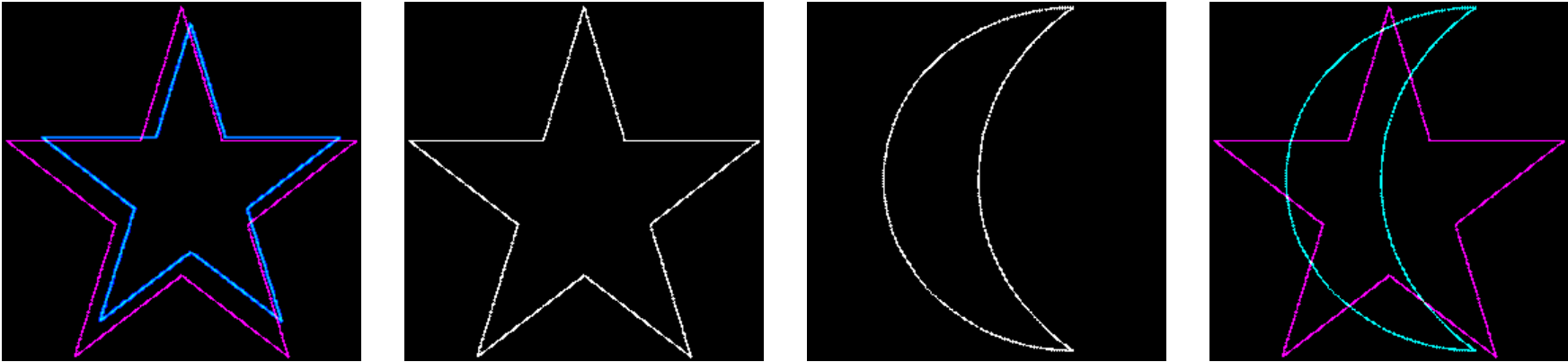
- Input: two sets of points.
  - red, green.
- $c(\text{red}, \text{green})$ :
  - Average distance from each red point to nearest green point.
- $c(\text{green}, \text{red})$ :
  - Average distance from each green point to nearest red point.



Chamfer distance:

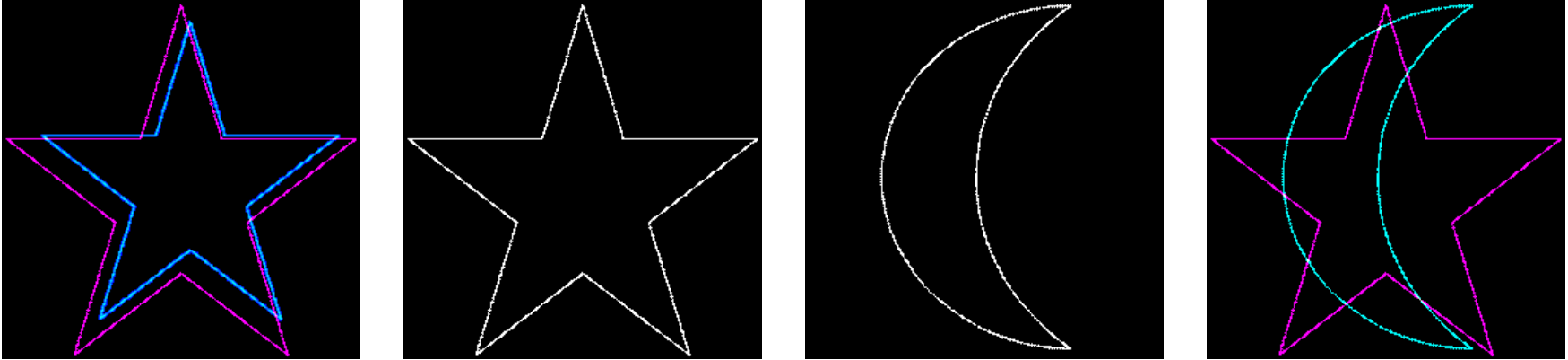
$$C(\text{red}, \text{green}) = c(\text{red}, \text{green}) + c(\text{green}, \text{red})$$

# Chamfer Distance



- On two stars:
  - 31 pixels are nonzero in both images.
- On star and crescent:
  - 33 pixels are nonzero in both images.
- Correlation scores can be misleading.

# Chamfer Distance

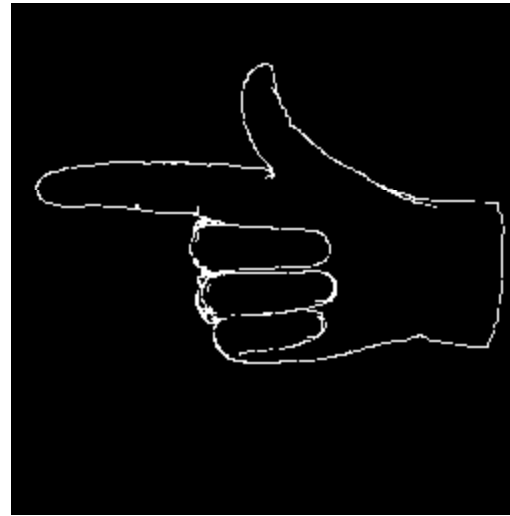


- Chamfer distance is much smaller between the two stars than between the star and the crescent.

# Detecting Hands



Input image



Template.

- Problem: hands are highly deformable.
- Normalized correlation does not work as well.
- Alternative: use edges.

# Detecting Hands



window

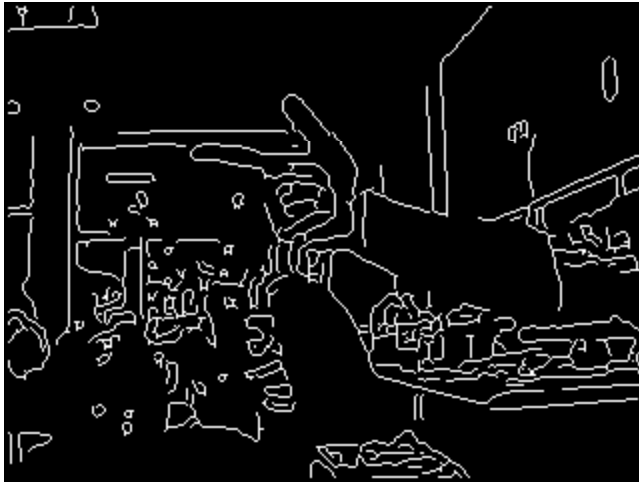


template

- Compute chamfer distance, at all windows, all scales, with template.
- Which version? Directed or undirected?
- We want small distance with correct window, large distance with incorrect windows.



# Direction Matters



window



template

- Chamfer distance from window to template: problems?

# Direction Matters



window



template

- Chamfer distance from window to template: problems?
- Clutter (edges not belonging to the hand) cause the distance to be high.

# Direction Matters



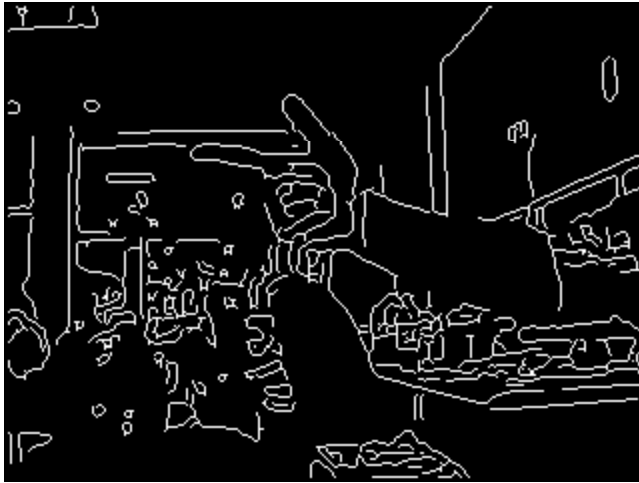
window



template

- Chamfer distance from template to window: problems?

# Direction Matters



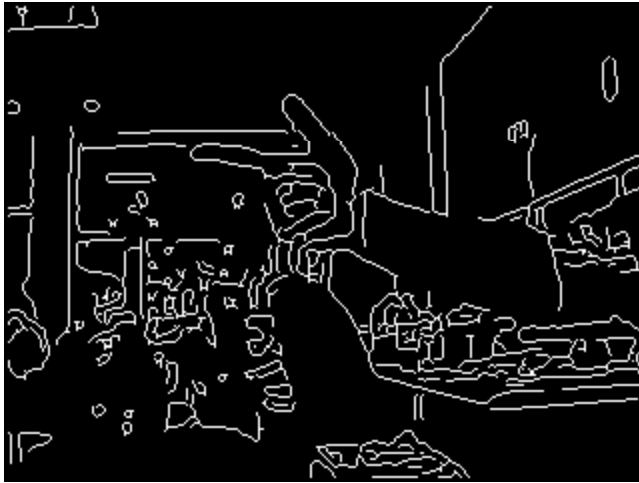
window



template

- Chamfer distance from template to window: problems?
- What happens when comparing to a window with lots of edges?

# Direction Matters



window



template

- Chamfer distance from template to window: problems?
- What happens when comparing to a window with lots of edges? Score is low.

# Choice of Direction



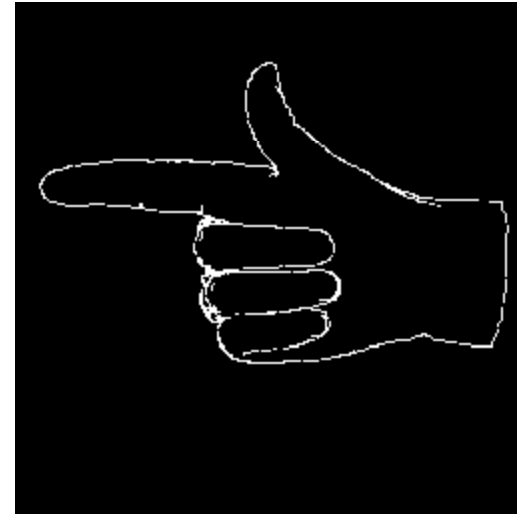
window



template

- For detection, we compute chamfer distance from template to window.
  - Being robust to clutter is a big plus, ensures the correct results will be included.
  - Incorrect detections can be discarded with additional checks.

# Computing the Chamfer Distance



- Compute chamfer distance, at all windows, all scales, with template.
- Can be very time consuming.

# Distance Transform



Edge image e1



Distance transform d1

- For every pixel, compute distance to *nearest edge pixel*.

```
d1 = bwdist(e1);
```



# Distance Transform



Edge image  $e1$



Distance transform  $d1$



$t1$

- If template  $t1$  is of size  $(r, c)$ :
  - Chamfer distance with a window  $(i:(i+r-1), (j:(j+c-1)))$  of  $e1$  can be written as:

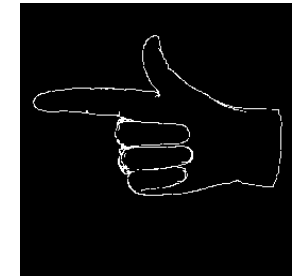
# Distance Transform



Edge image e1



Distance transform d1



t1

- If template t1 is of size (r, c):
  - Chamfer distance with a window (i:(i+r-1), (j:(j+c-1))) of e1 can be written as:

```
window = d1(i:(i+r-1), j:(j+c-1));  
sum(sum(t1 .* window))
```

- Computing image of chamfer scores for one scale:

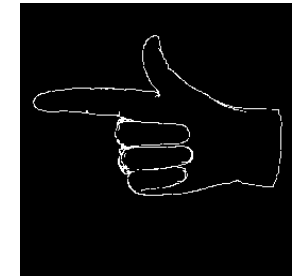
# Distance Transform



Edge image e1



Distance transform d1



t1

- Computing image of chamfer scores for one scale  $s$

```
resized = imresize(image, s, 'bilinear');  
resized_edges = canny(resized, 7);  
resized_dt = bwdist(resized_edges);  
chamfer_scores = imfilter(resized_dt, t1, 'symmetric');  
figure(3); imshow(chamfer_scores, []);
```

- How long does that take? Can it be more efficient?

# Improving Efficiency



Edge image e1



Distance transform d1



t1

- Which parts of the template contribute to the score of each window?

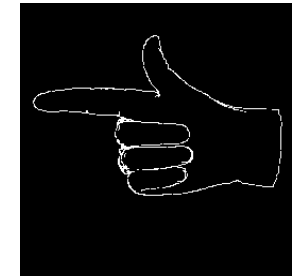
# Improving Efficiency



Edge image e1



Distance transform d1



t1

- Which parts of the template contribute to the score of each window?
- Just the nonzero parts.
- How can we use that?

# Improving Efficiency



Edge image e1



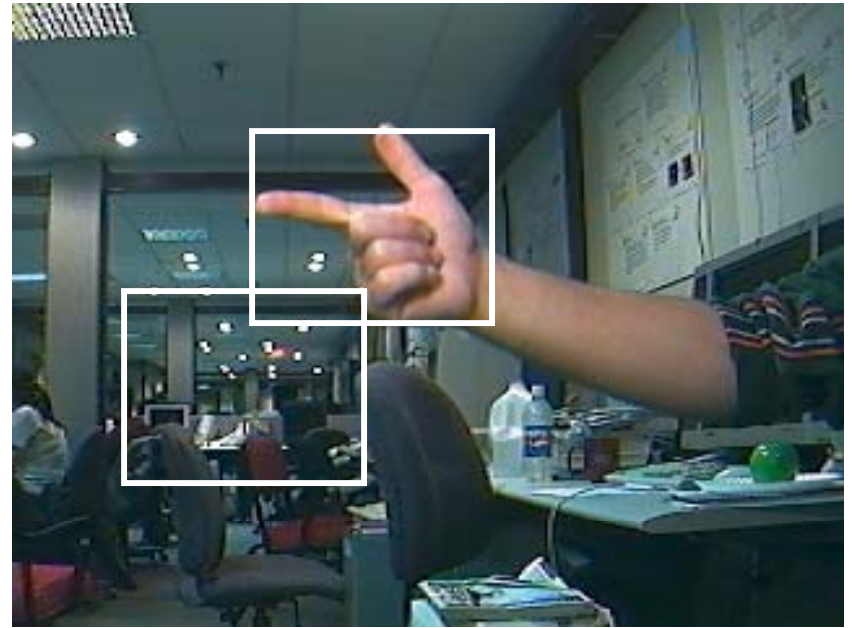
Distance transform d1



t1

- Which parts of the template contribute to the score of each window? Just the nonzero parts.
- How can we use that?
  - Compute a list of non-zero pixels in the template.
  - Consider only those pixels when computing the sum for each window.

# Results for Single Scale Search



- What is causing the false result?

# Results for Single Scale Search



- What is causing the false result?
  - Window with lots of edges.
- How can we refine these results?



# Results for Single Scale Search



- What is causing the false result?
  - Window with lots of edges.
- How can we refine these results?
  - Skin color, or background subtraction