CS4495/6495
Introduction to Computer Vision

2B-L3 *Generalized Hough transform: Then and now*

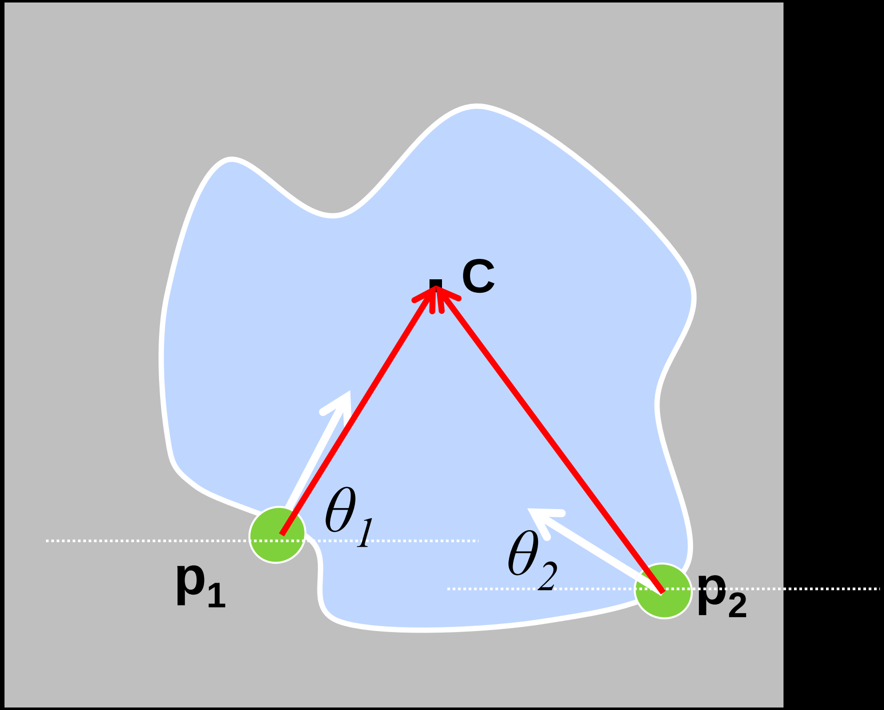
Generalized Hough transform

- **Non-analytic** models
  - *Parameters express variation in pose or scale of fixed but arbitrary shape (that was then)*
- **Visual code-word** based features
  - *Not edges but detected templates learned from models (this is "now")*

Generalized Hough transform

Training: build a Hough table

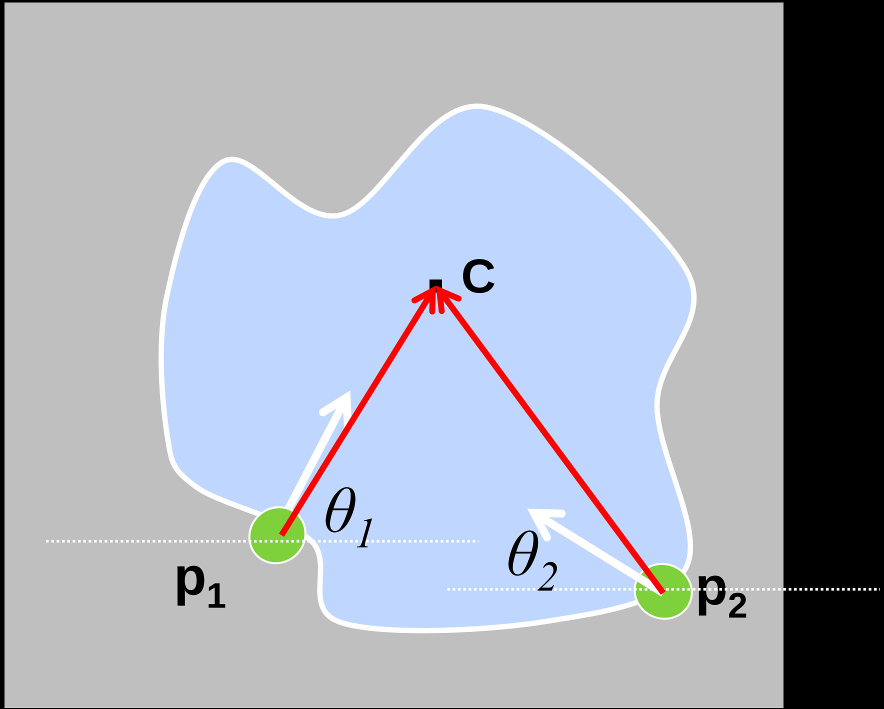
1. At each boundary point, compute displacement vector: $\mathbf{r} = \mathbf{c} - \mathbf{p}_i$
2. Measure the gradient angle θ at the boundary point.
3. Store that displacement in a table indexed by θ.



Generalized Hough transform

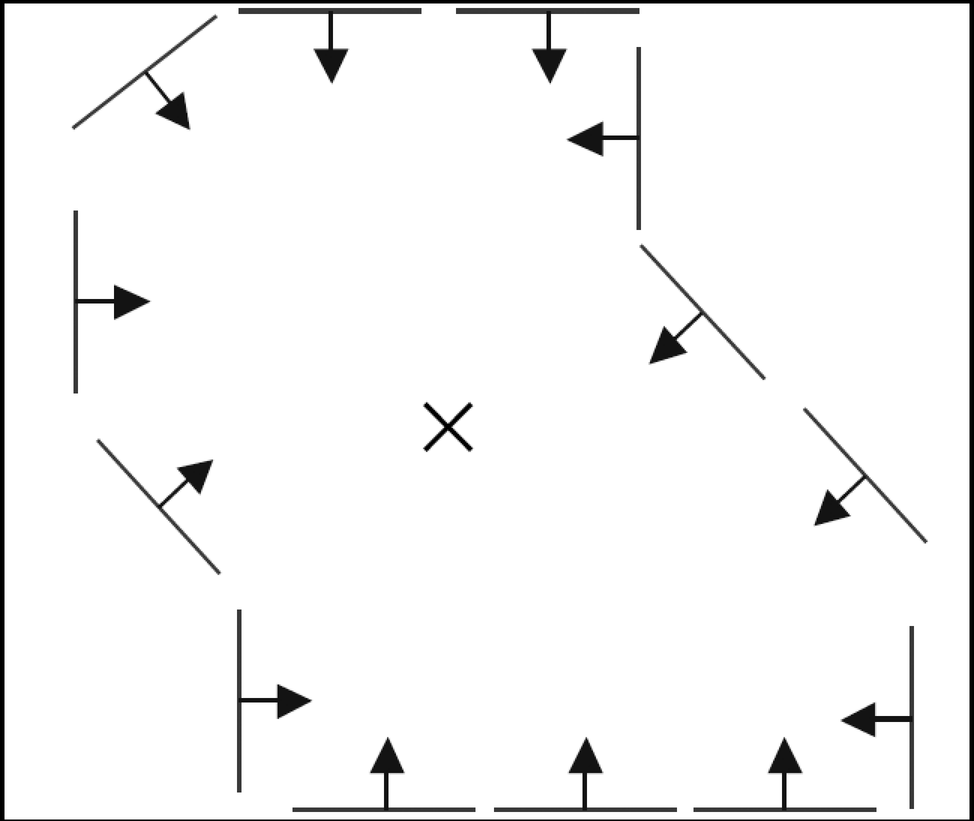
Recognition:

1. At each boundary point, measure the gradient angle θ
2. Look up all displacements in θ displacement table.
3. Vote for a center at each displacement.



[Dana H. Ballard, Generalizing the Hough Transform to Detect Arbitrary Shapes, 1980]

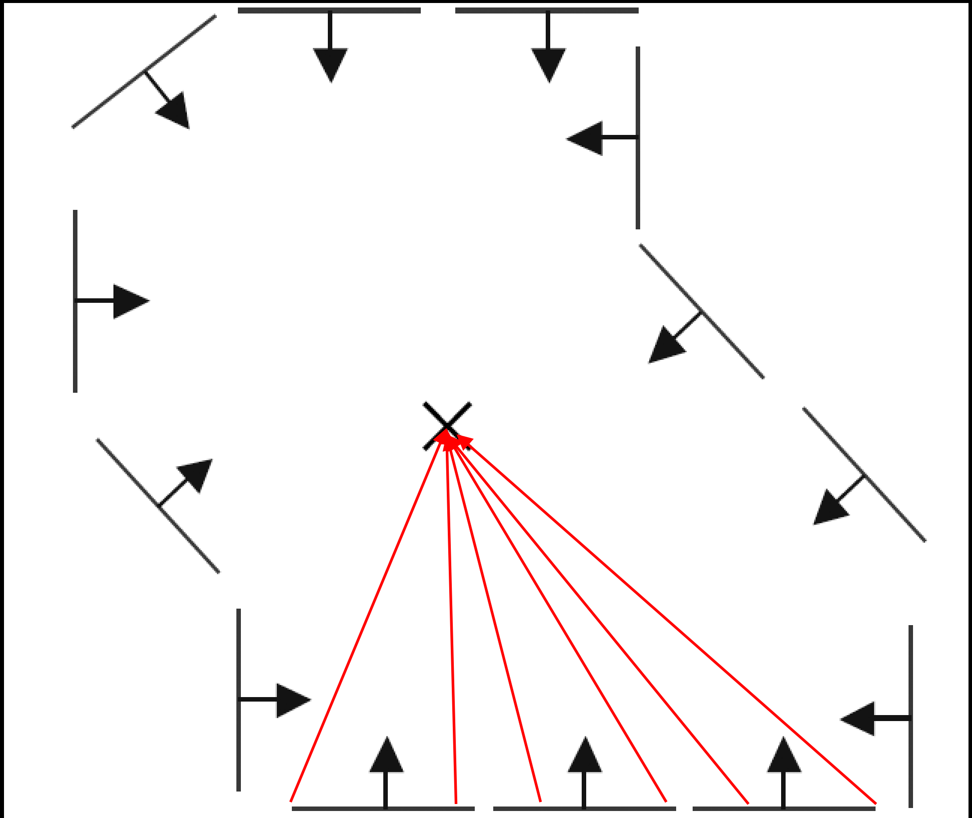
Example



Source: L. Lazebnik

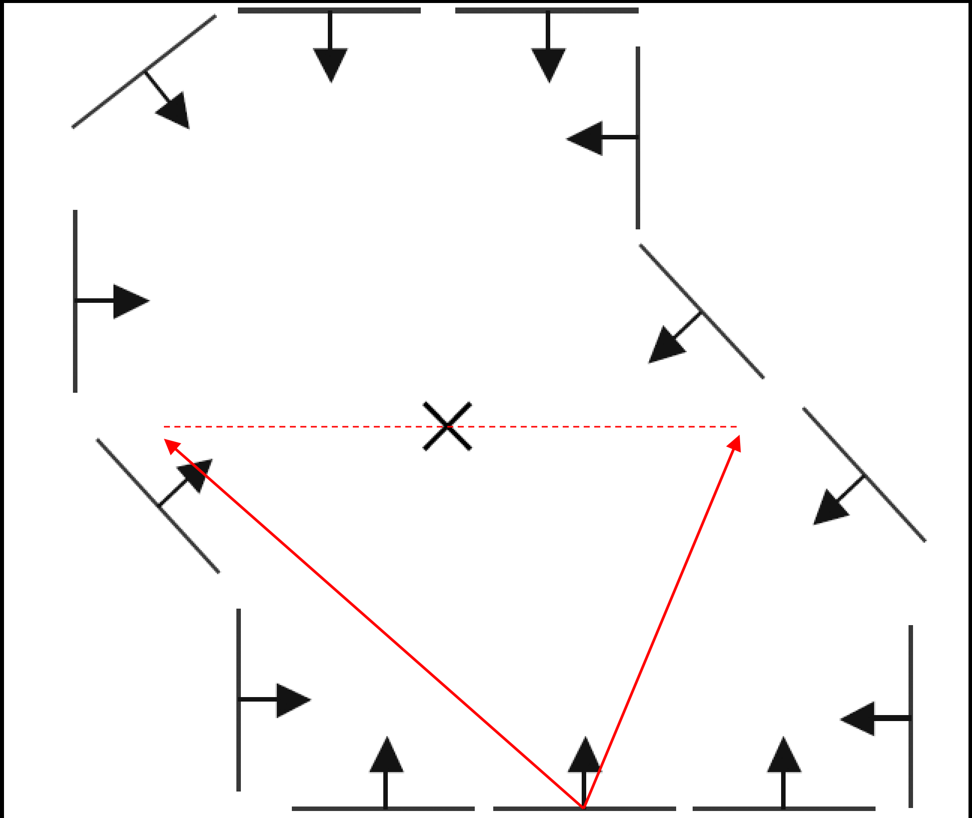
Example

Looking at the bottom horizontal boundary points (all the same θ), the set of displacements ranges over all the red vectors.



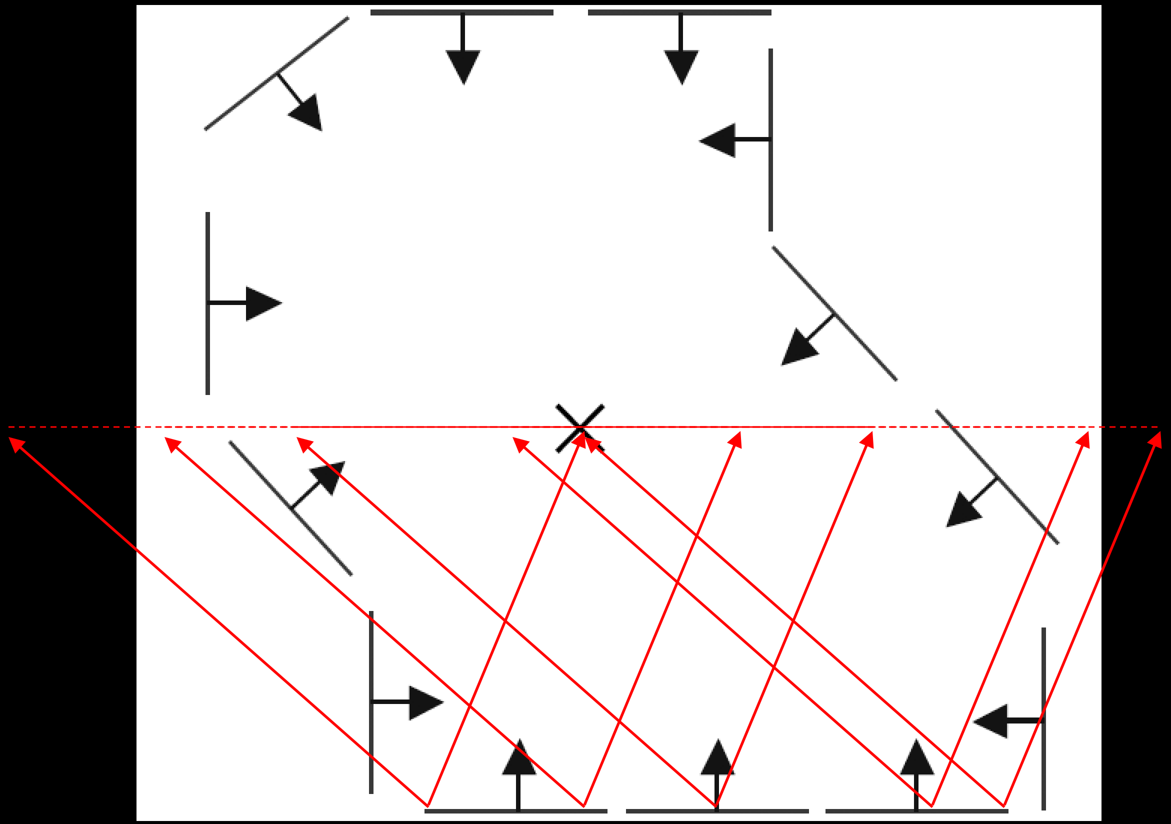
Example

At recognition, each bottom horizontal element votes for all those displacements.



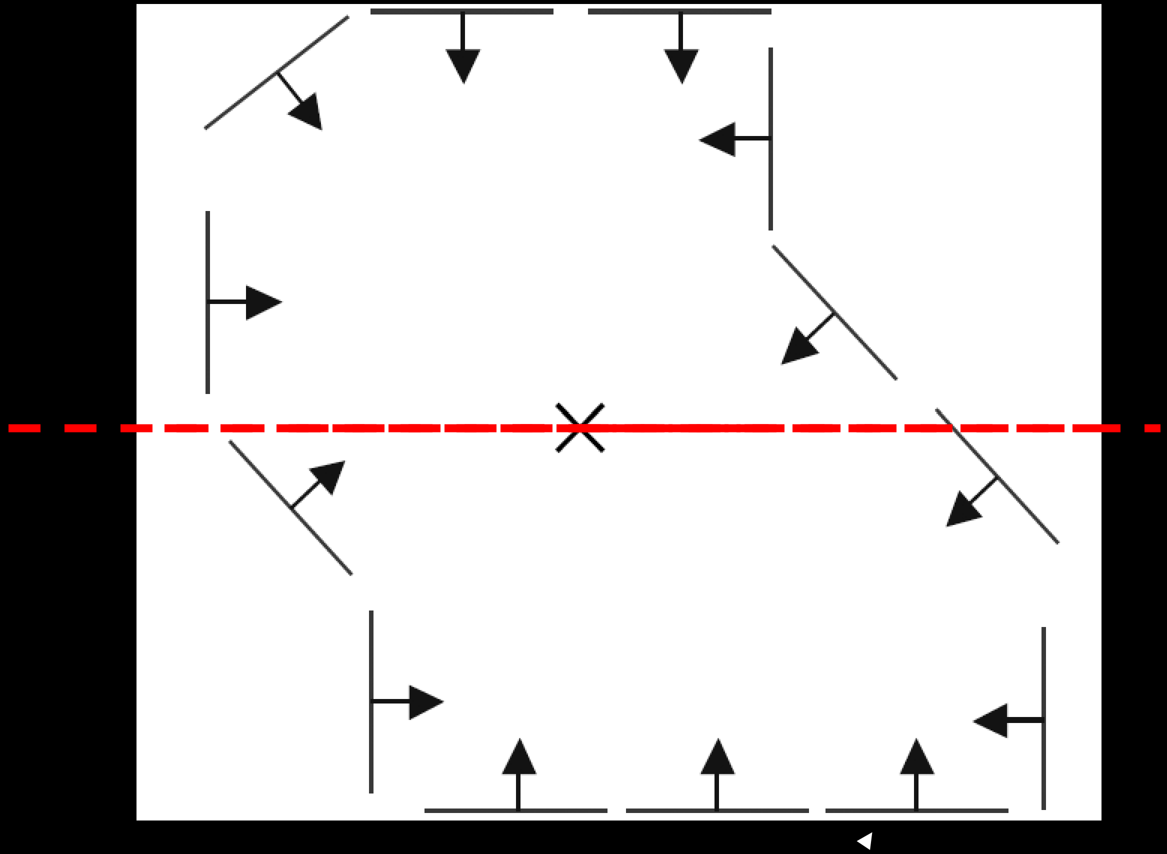
Example

At recognition, each bottom horizontal element votes for all those displacements.



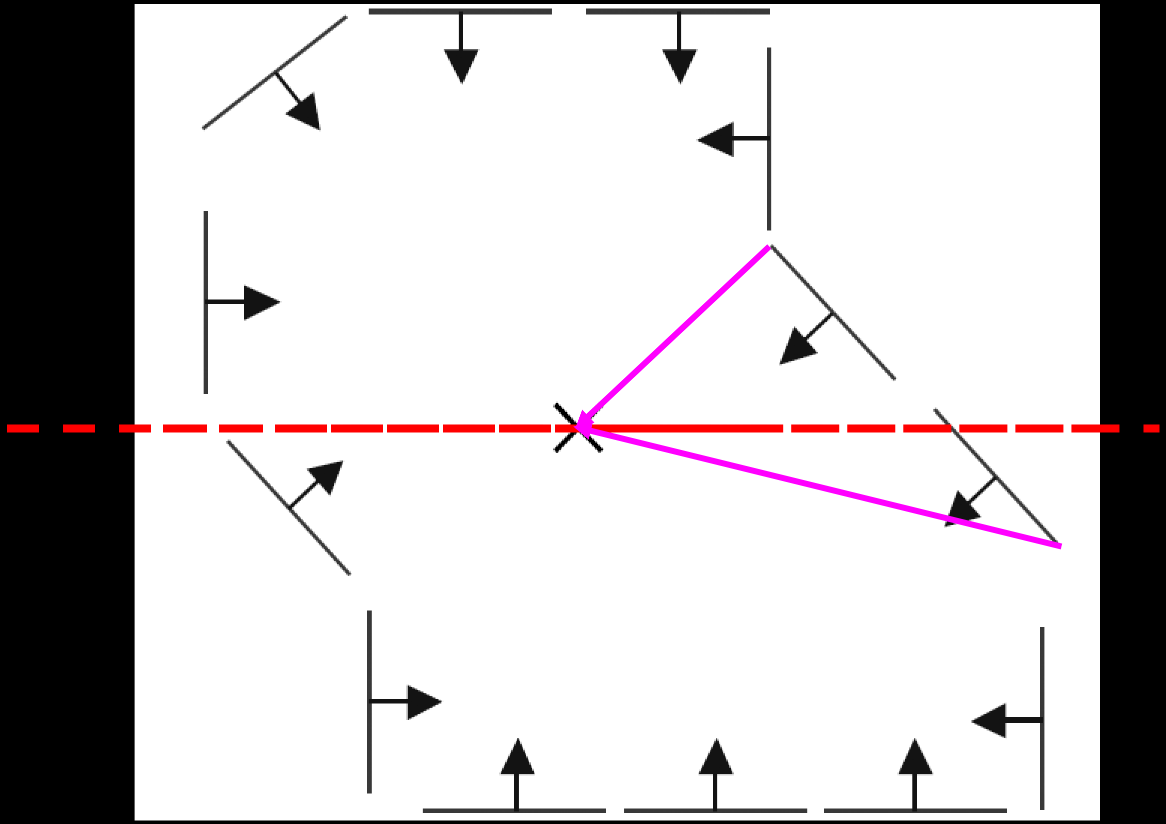
Example

At recognition, each bottom horizontal element votes for all those displacements.



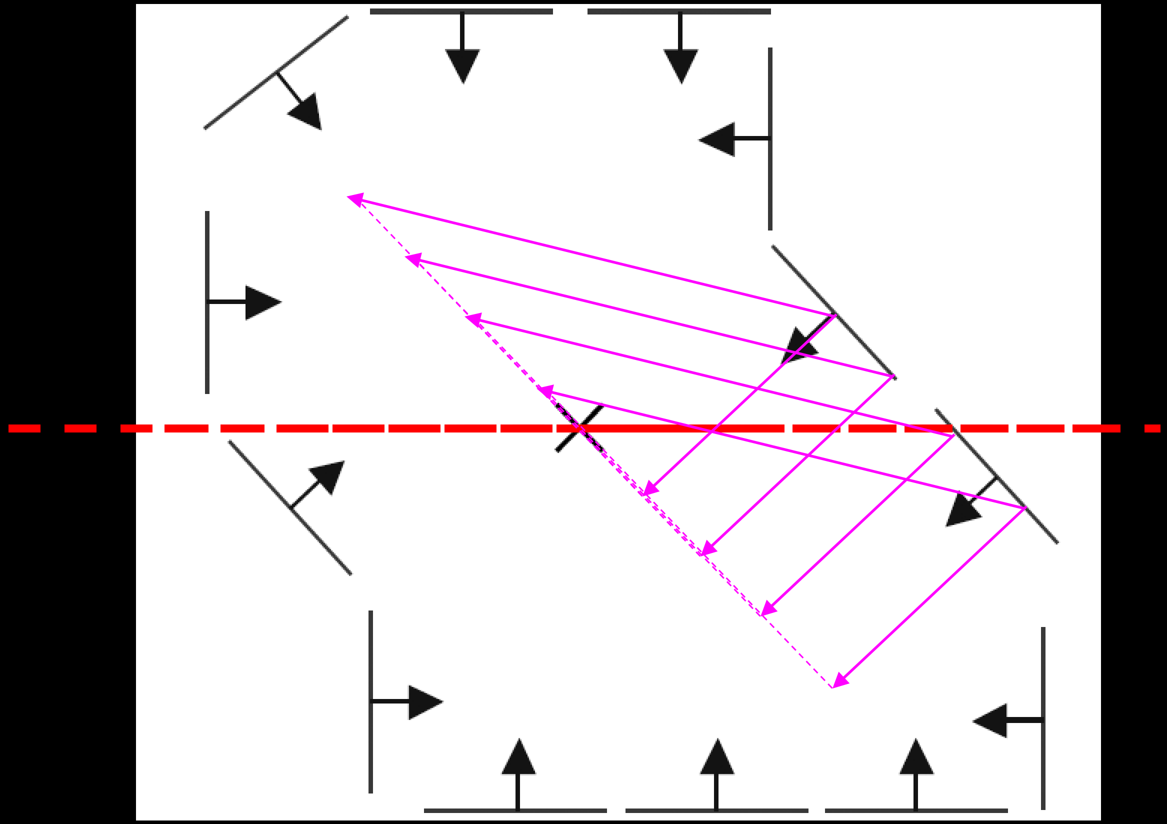
Example

Now do for the leftward pointing diagonals.



Example

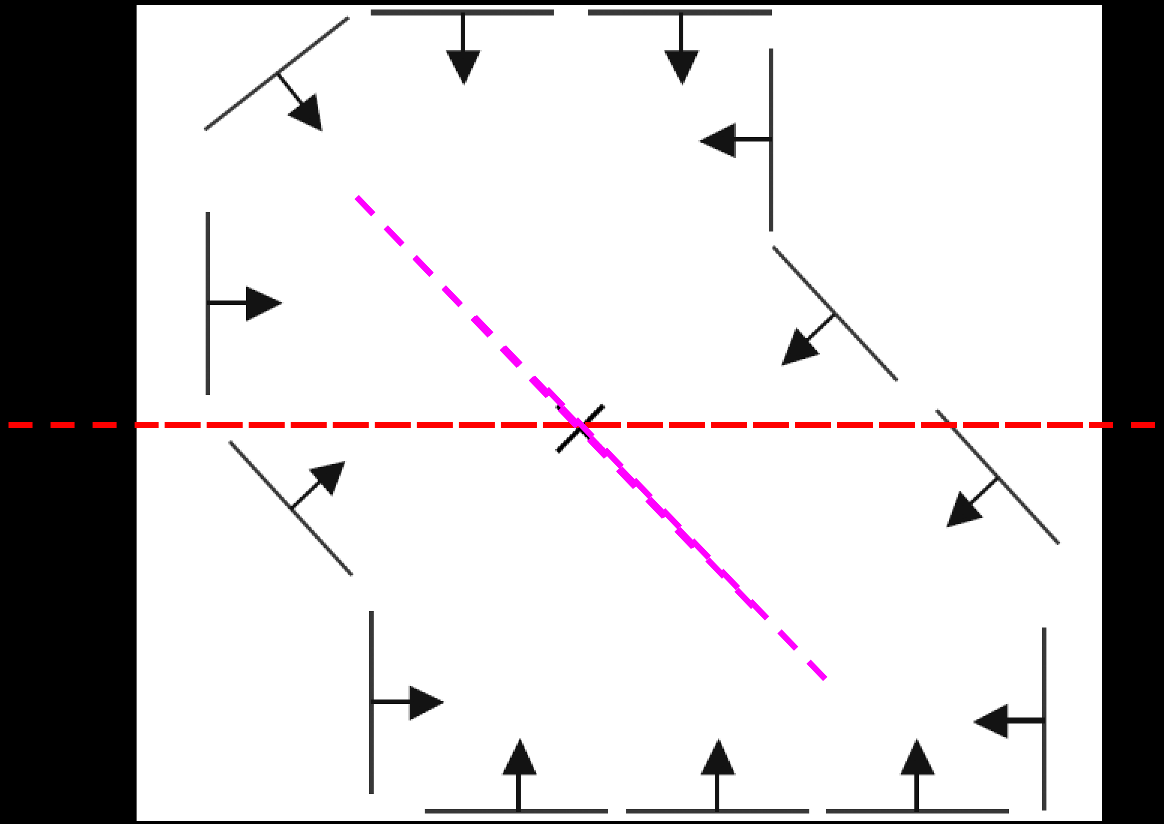
Now do for the leftward pointing diagonals.



Example

Now do for the leftward pointing diagonals.

And the center is found.



Generalized Hough transform

If orientation is known:

1. For each edge point

    Compute gradient direction θ

    Retrieve displacement vectors r to vote for reference point.

2. Peak in this Hough space (X,Y) is reference point with most supporting edges

Generalized Hough transform

If orientation is unknown:

For each edge point

For each possible master θ^*

Compute gradient direction θ

New $\theta' = \theta - \theta^*$

For θ' retrieve displacement vectors r to vote for reference point.

Peak in this Hough space (now X,Y, θ^*) is reference point with most supporting edges

[Dana H. Ballard, Generalizing the Hough Transform to Detect Arbitrary Shapes, 1980]

Generalized Hough transform

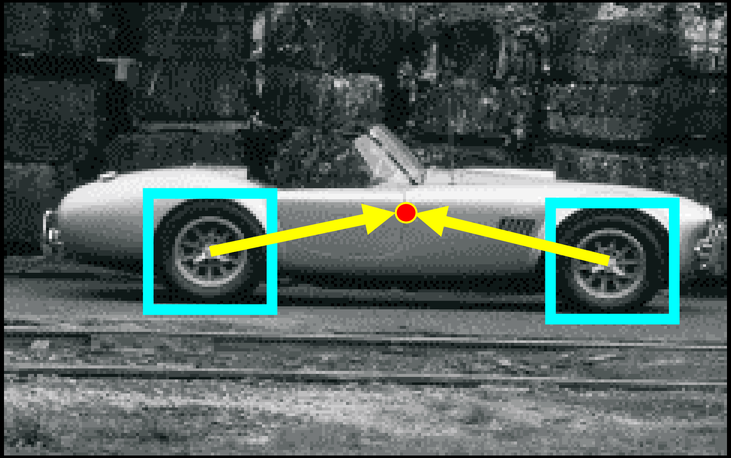
If scale S is unknown:

- For each edge point
  - For each possible master scale S:
    - Compute gradient direction θ
    - For θ' retrieve displacement vectors r
    - Vote r scaled by S for reference point.

Peak in this Hough space (now X,Y, S) is reference point with most supporting edges

Application in recognition

- Instead of indexing displacements by gradient orientation, index by "visual codeword"



training image

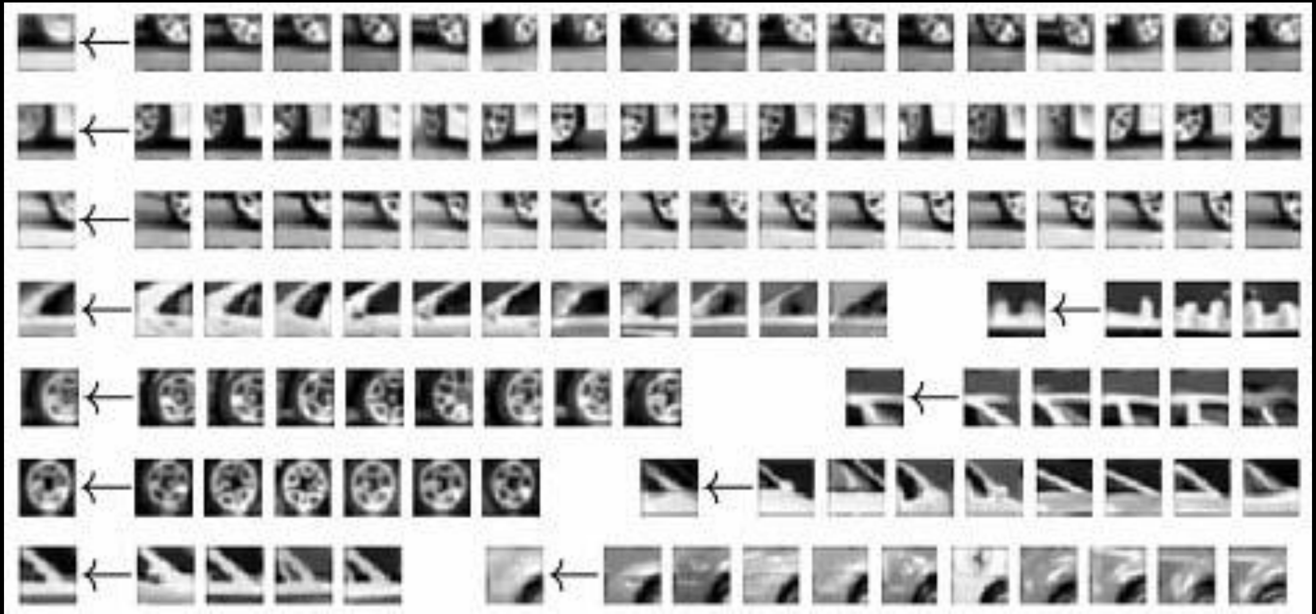
visual codeword with displacement vectors

B. Leibe, A. Leonardis, and B. Schiele, Combined Object Categorization and Segmentation with an Implicit Shape Model, ECCV Workshop 2004

Source: S. Lazebnik

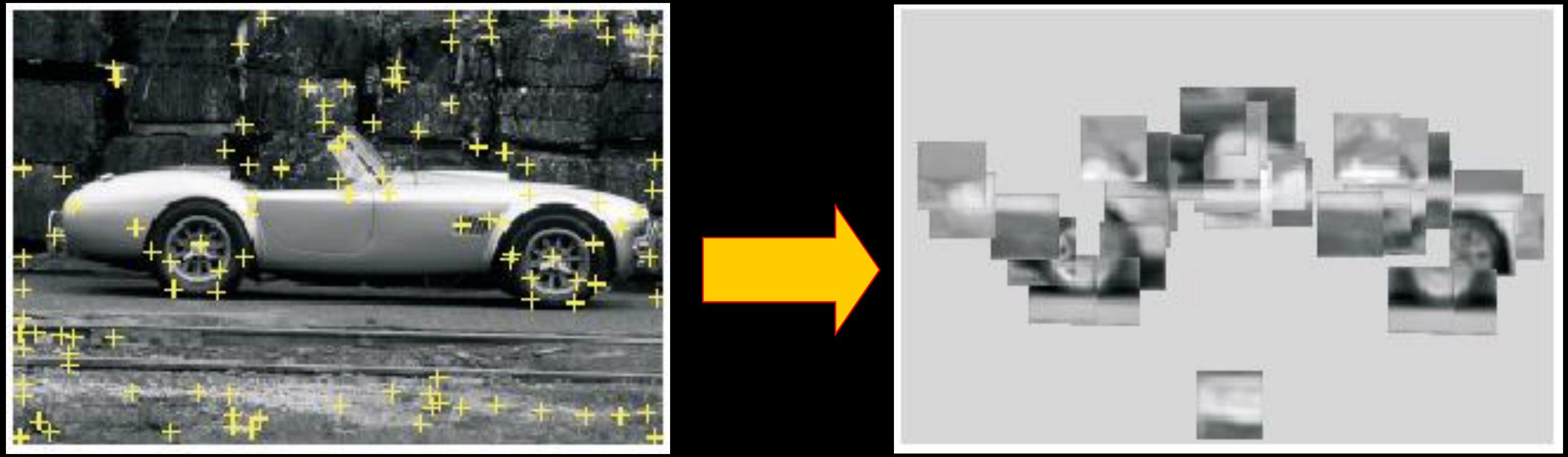
Training: Visual code-words

1. Build codebook of patches around extracted interest points using clustering (more on this later in the course)



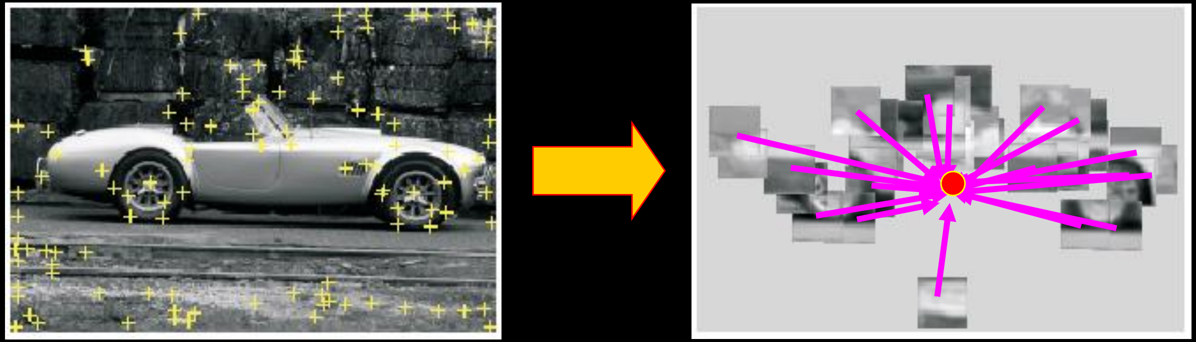
Training: Interest points

1. Build codebook of patches around extracted interest points using clustering
2. Map the patch around each ***interest point*** to closest codebook entry



Training: Displacements

1. Build codebook of patches around extracted interest points using clustering
2. Map the patch around each interest point to closest codebook entry
3. For each codebook entry, store all displacements relative to object center



Application in recognition

test image