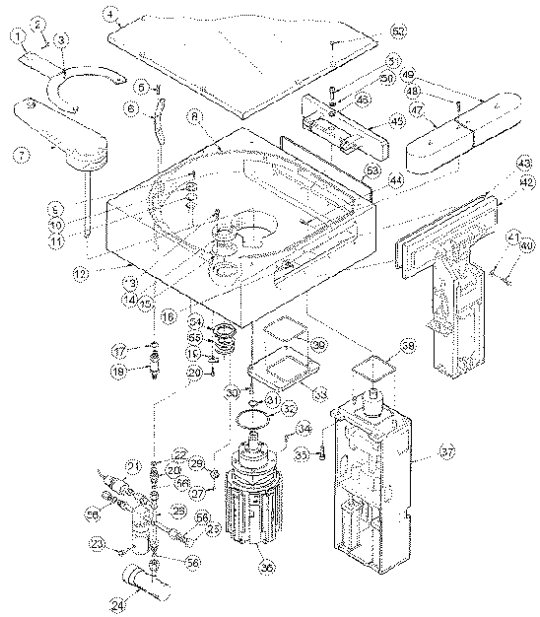
Lines and Arcs Segmentation

In some image sets, lines, curves, and circular arcs are more useful than regions or helpful in addition to regions.

Lines and arcs are often used in

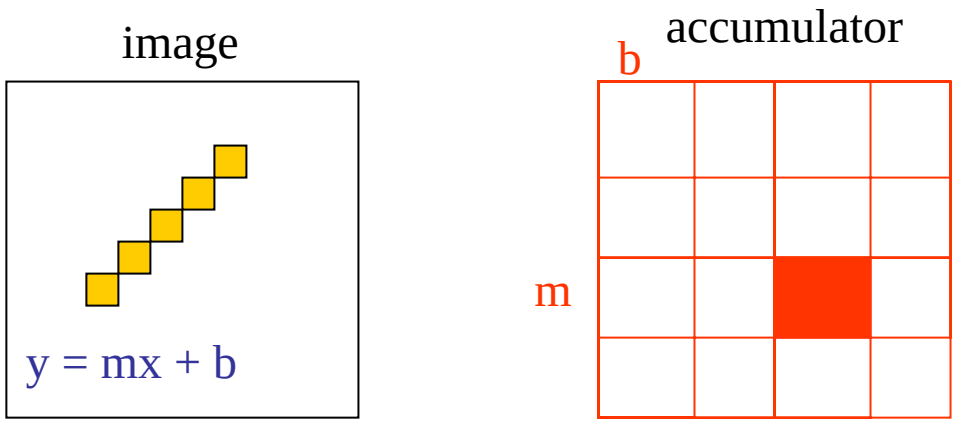
- object recognition
- stereo matching
- document analysis



1. Parameter Estimation Methods
Hough Transform

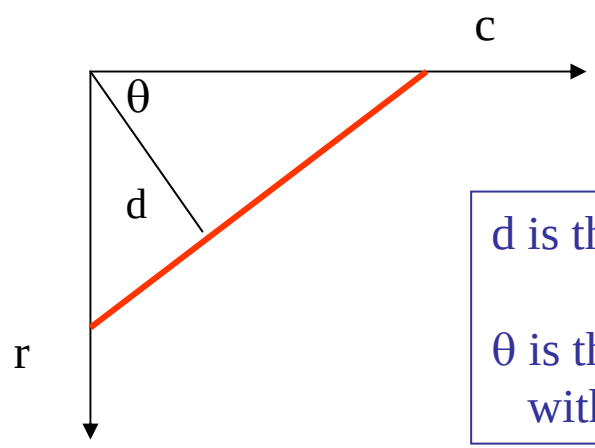
- The Hough transform is a method for detecting lines or curves specified by a parametric function.

- If the parameters are p1, p2, … pn, then the Hough procedure uses an n-dimensional accumulator array in which it accumulates votes for the correct parameters of the lines or curves found on the image.



Finding Straight Line Segments

- $y = mx + b$ is not suitable (why?)
- The equation generally used is: $d = r \sin \theta + c \cos \theta$



d is the distance from the line to origin

θ is the angle the perpendicular makes with the column axis

Procedure to Accumulate Lines

- Set accumulator array A to all zero.
  Set point list array PTLIST to all NIL.

- For each pixel (R,C) in the image {

    - compute gradient magnitude GMAG
    - if GMAG > gradient_threshold {

        - compute quantized tangent angle THETAQ
        - compute quantized distance to origin DQ
        - increment A(DQ,THETAQ)
        - update PTLIST(DQ,THETAQ) } }

Example

gray-tone image

0	0	0	100	100
0	0	0	100	100
0	0	0	100	100
100	100	100	100	100
100	100	100	100	100

DQ

-	-	3	3	-
-	-	3	3	-
3	3	3	3	-
3	3	3	3	-
-	-	-	-	-

THETAQ

-	-	0	0	-
-	-	0	0	-
90	90	40	20	-
90	90	90	40	-
-	-	-	-	-

Accumulator A

distance	angle 0	10	20	30	40	…90
360	-	-	-	-	-	-	-
.	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
3	4	-	1	-	2	-	5
0	-	-	-	-	-	-	-

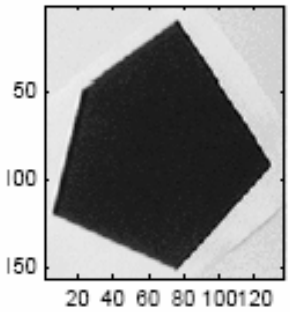
PTLIST

360	-	-	-	-	-	-	-
.	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
3	*	-	*	-	*	-	*
0	-	-	-	-	-	-	-

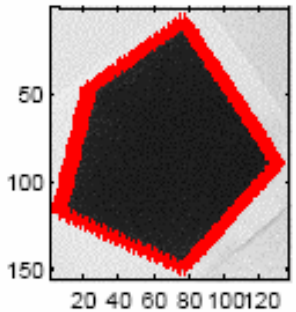
(3,1)
(3,2)
(4,1)
(4,2)
(4,3)

(1,3)(1,4)(2,3)(2,4)

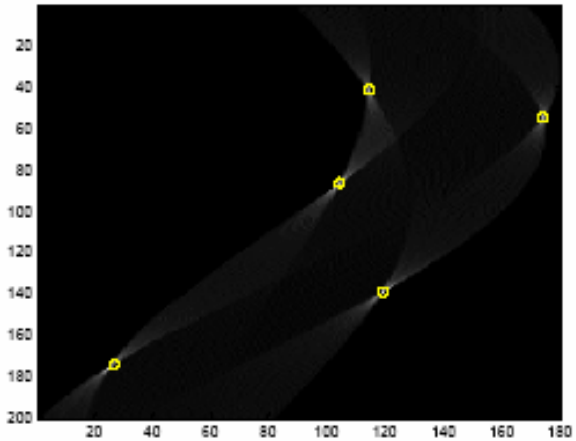
Examples



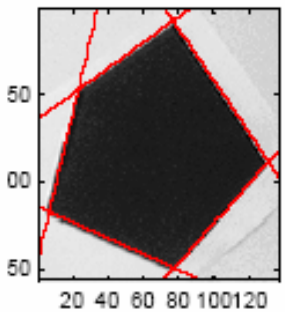
Original Image



Detected Edges



The vote histogram with the detected lines marked with 'o'



Detected lines

Examples cont

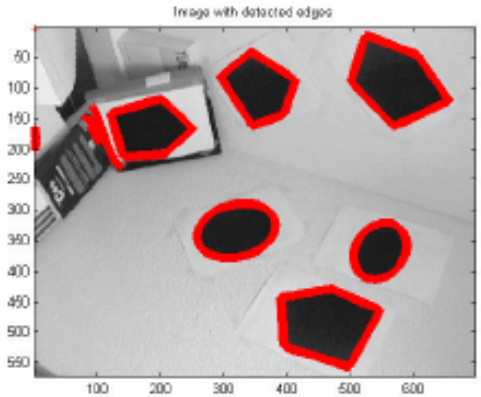
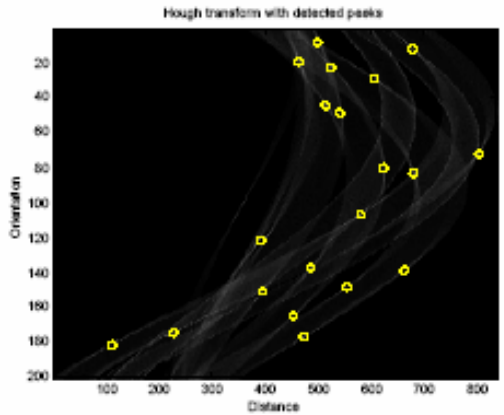


Image with detected edges



The vote histogram with the selected lines

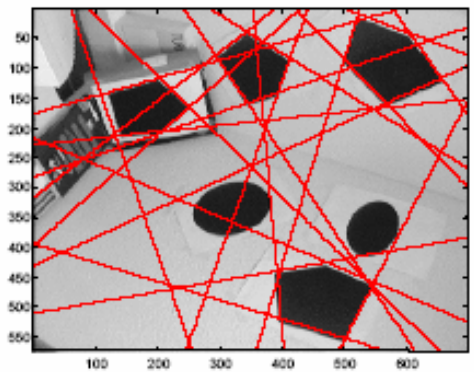


Image with the detected lines

How do you extract the line segments from the accumulators?

pick the bin of A with highest value V
while V > value_threshold {

- order the corresponding pointlist from PTLIST
- merge in high gradient neighbors within 10 degrees
- create line segment from final point list
- zero out that bin of A
- pick the bin of A with highest value V }

Line segments from Hough Transform

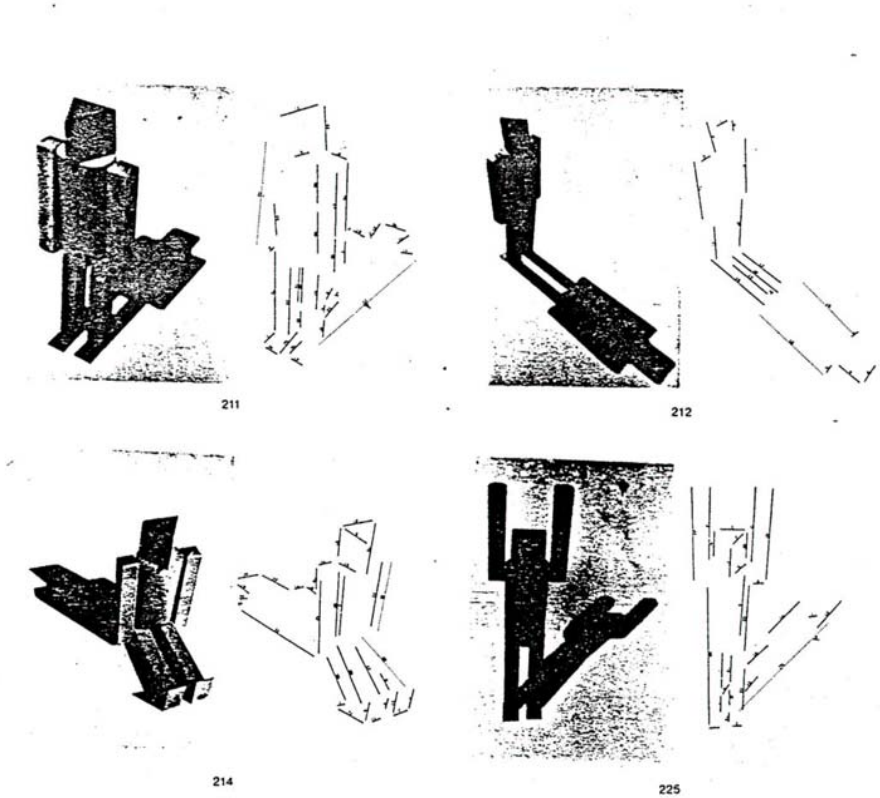
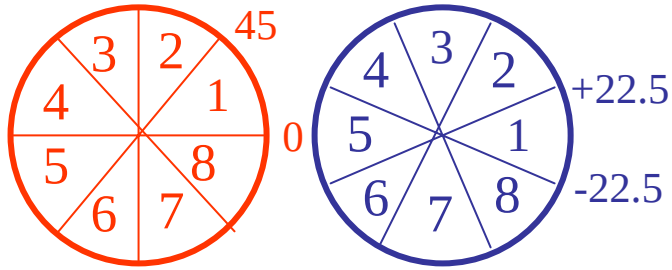


Fig.7. Puppet scenes 211, 212, 214, 225 and the edges recovered by the algorithm.

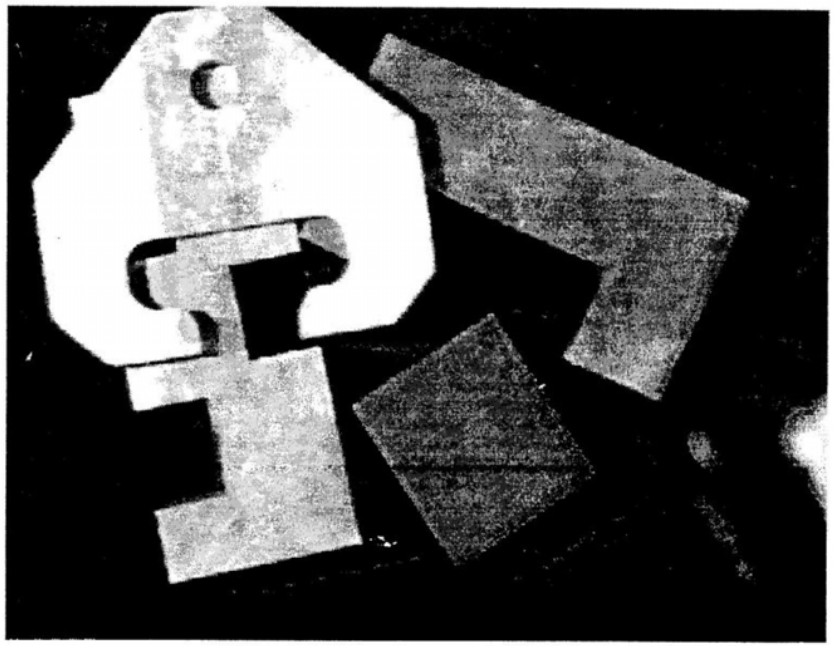
A Nice Hough Variant
The Burns Line Finder

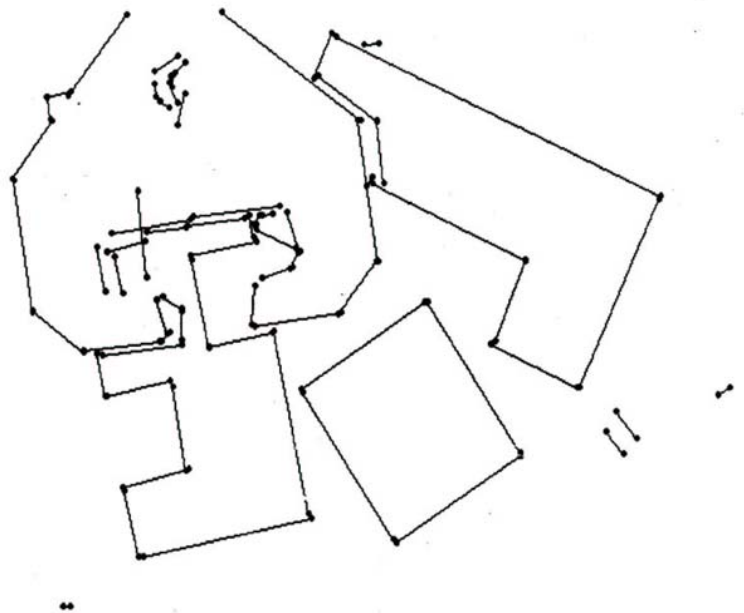


1. Compute gradient magnitude and direction at each pixel.
2. For high gradient magnitude points, assign direction labels to two symbolic images for two different quantizations.
3. Find connected components of each symbolic image.

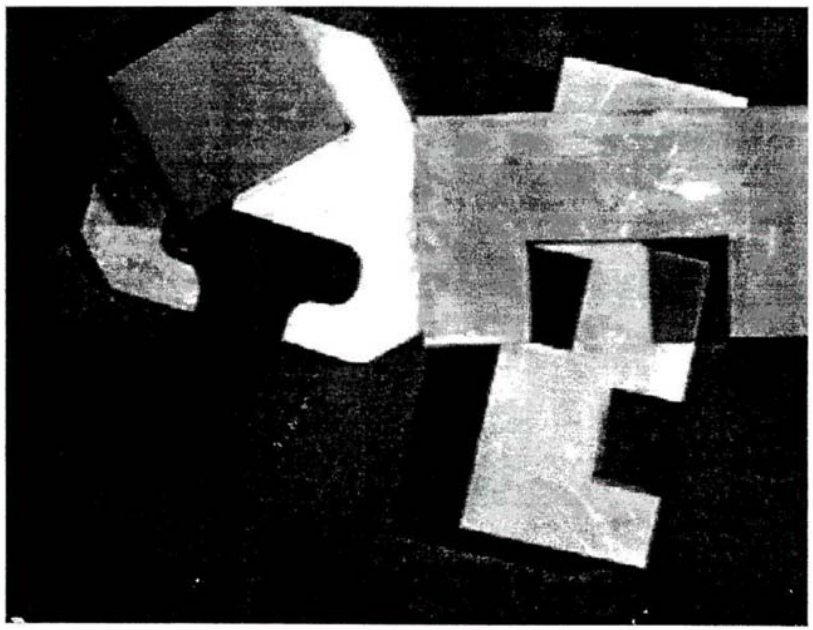
- Each pixel belongs to 2 components, one for each symbolic image.
- Each pixel votes for its longer component.
- Each component receives a count of pixels who voted for it.
- The components that receive majority support are selected.

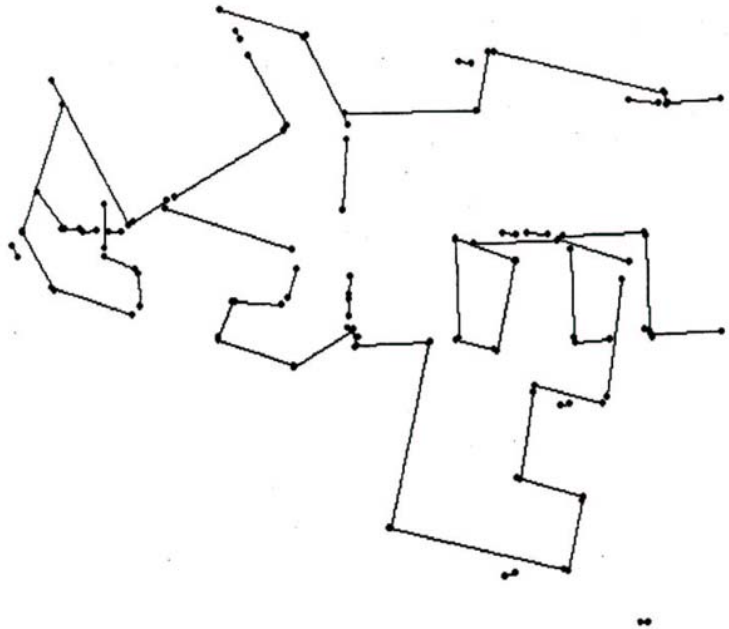
Burns Example 1





Burns Example 2





2. Tracking Methods

Mask-based Approach

Use masks to identify the following events:

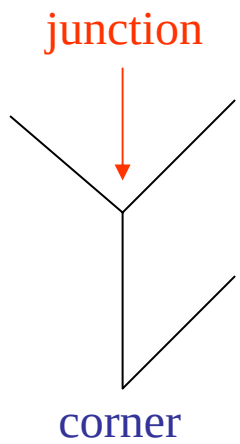
1. start of a new segment

2. interior point continuing a segment

3. end of a segment

4. junction between multiple segments

5. corner that breaks a segment into two



Edge Tracking Procedure

```
for each edge pixel P {
  classify its pixel type using masks
  case
    1. isolated point :          ignore it

    2. start point :             make a new segment

    3. interior point :          add to current segment

    4. end point :               add to current segment and finish it

    5. junction or corner :      add to incoming segment
                                 finish incoming segment
                                 make new outgoing segment(s)
```

A Good Tracking Package: the ORT toolkit

- Part of the C software available on the class web page
- Updated versions are available
- How does it work?

How ORT finds segments

(Communicated by Ata Etemadi who designed it; this is really what he said.)

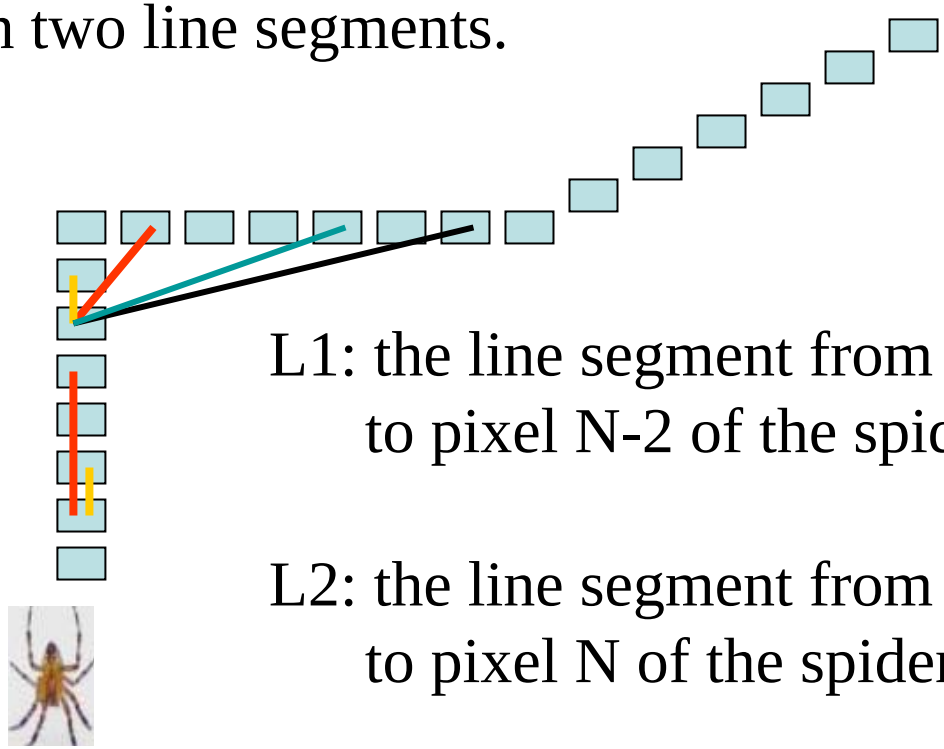
- The algorithm is called Strider and is like a spider striding along pixel chains of an image.
- The spider is looking for local symmetries.
- When it is moving along a straight or curved segment with no interruptions, its legs are symmetric about its body.
- When it encounters an obstacle (ie. a corner or junction) its legs are no longer symmetric.
- If the obstacle is small (compared to the spider), it soon becomes symmetrical.
- If the obstacle is large, it will take longer.

Strider

- Strider tracks along a pixel chain, looking for junctions and corners.
- It identifies them by a measure of assymmetry.
- The accuracy depends on the length of the spider and the size of its stride.
- The larger they are, the less sensitive it becomes.

Strider

The measure of asymmetry is the angle between two line segments.



angle 0 here

L1: the line segment from pixel 1 of the spider to pixel N-2 of the spider

L2: the line segment from pixel 1 of the spider to pixel N of the spider

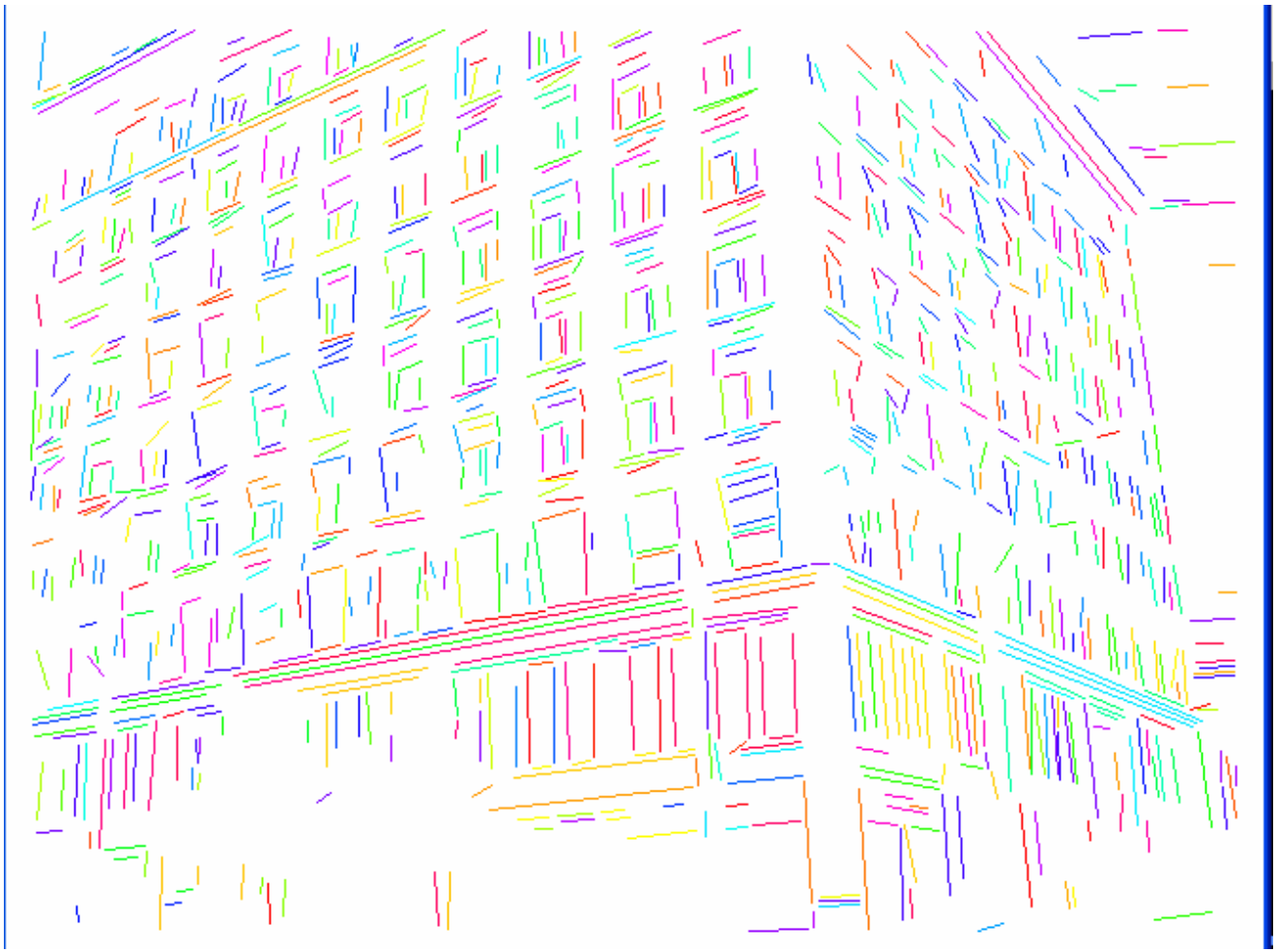
The angle must be <= arctan(2/length(L2))

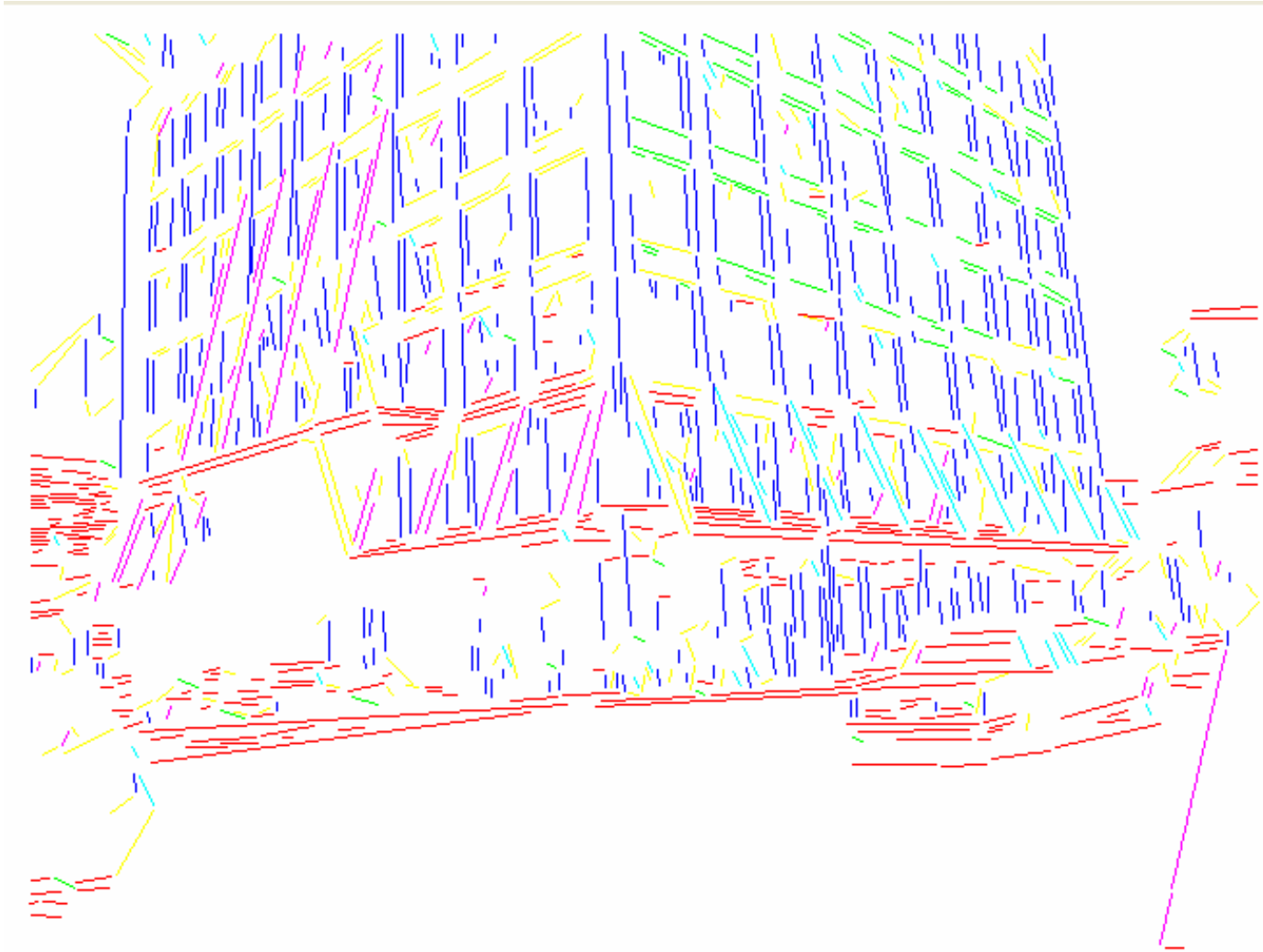
Longer spiders allow less of an angle.

Strider

- The parameters are the length of the spider and the number of pixels per step.
- These parameters can be changed to allow for less sensitivity, so that we get longer line segments.
- The algorithm has a final phase in which adjacent segments whose angle differs by less than a given angle are joined.

Ort finds line segments for building detection





(410,1): 0-RGB(255,255,255)

Advantages of Strider

- works on pixel chains of arbitrary complexity
- can be implemented in parallel
- no assumptions and the effects of the parameters are well understood

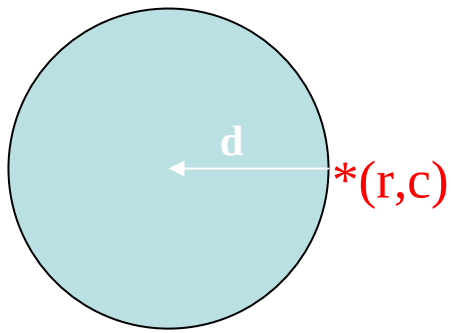
Hough Transform for Finding Circles

Equations:

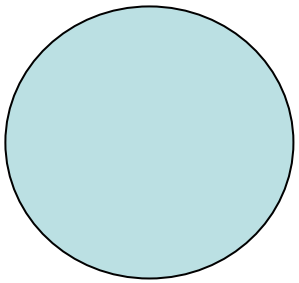
$$r = r0 + d \sin \theta$$
$$c = c0 + d \cos \theta$$

r, c, d are parameters

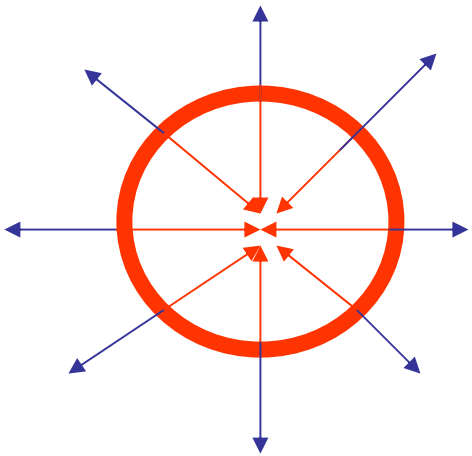
Main idea: The gradient vector at an edge pixel points to the center of the circle.



Why it works



Filled Circle:
Outer points of circle have gradient direction pointing to center.



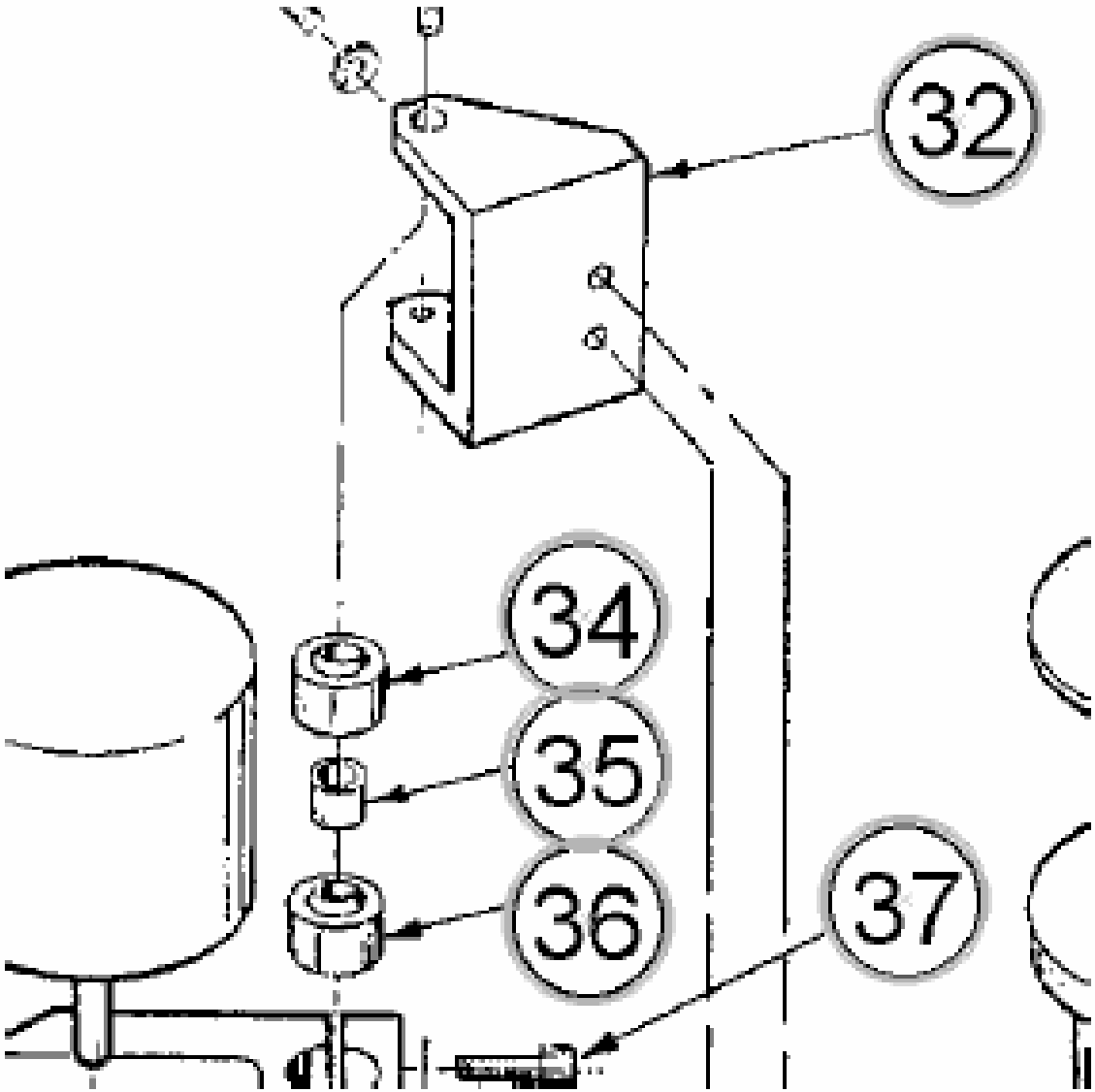
Circular Ring:
Outer points gradient towards center.
Inner points gradient away from center.

The points in the away direction don’t accumulate in one bin!

Procedure to Accumulate Circles

- Set accumulator array A to all zero.
  Set point list array PTLIST to all NIL.

- For each pixel (R,C) in the image {
  For each possible value of D {
  - compute gradient magnitude GMAG
  - if GMAG > gradient_threshold {
  . Compute THETA(R,C,D)
  . R0 := R - D*cos(THETA)
  . C0 := C - D* sin(THETA)
  . increment A(R0,C0,D)
  . update PTLIST(R0,C0,D) }}


32
34
35
36
37

Finding lung nodules (Kimme & Ballard)

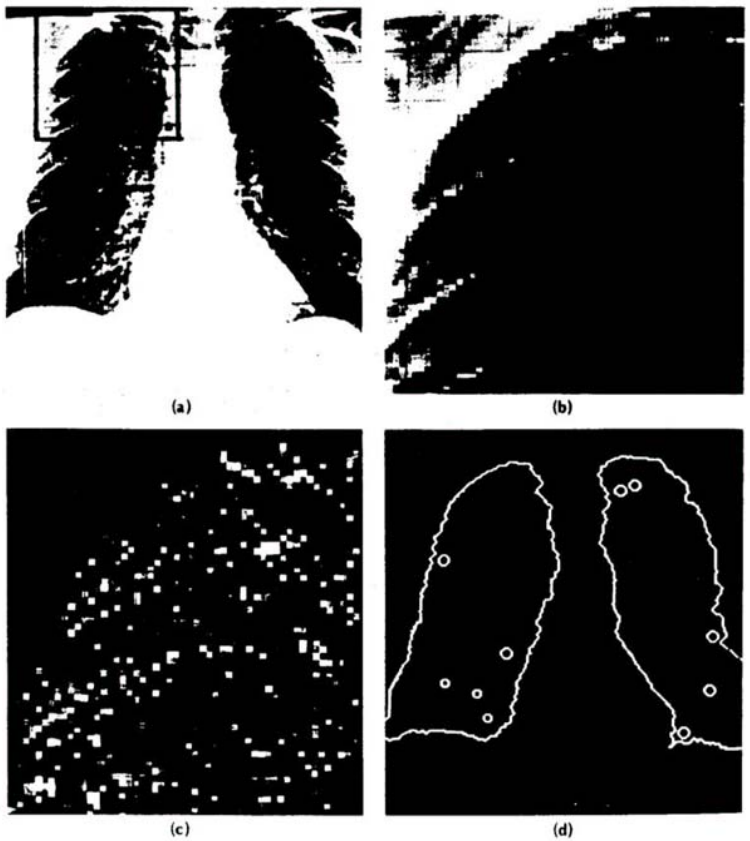


Fig. 4.7 Using the Hough technique for circular shapes. (a) Radiograph. (b) Window. (c) Accumulator array for $r = 3$. (d) Results of maxima detection.

Summary

- The Hough transform and its variants can be used to find line segments or circles.
- It has also been generalized to find other shapes
- The original Hough method does not work well for line segments, but works very well for circles.
- The Burns method improves the Hough for line segments and is easy to code.
- The Srider algorithm in the ORT package gives excellent line and curve segments by tracking.