



Edge-based
Segmenta-
tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

Hough
Transform

Edge-based Segmentation

基于边缘的图像分割

ZhaoHaiwei DaiJialun WangRuchen

CVBIOUC

<http://vision.ouc.edu.cn/~zhenghaiyong>

April 28, 2015



Contents

Edge-based
Segmenta-
tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

Hough
Transform

1 Introduction

- Edge & Boundary
- Problems
- Steps in Edge Detection
- Steps in Image Segmentation

2 Edge Detection

- Edge Detection Techniques
- Marr-Hildreth
- Canny Edge Detection

3 Edge Linking

- Edge Tracking
- Hough Transform



What?

Edge-based Segmenta- tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge Linking

Edge Tracking

Hough
Transform





Edge & Boundary

Edge-based Segmentation

Introduction

Edge & Boundary

Problems

Steps in Edge Detection

Steps in Image Segmentation

Edge Detection

Edge Detection Techniques

Marr-Hildreth

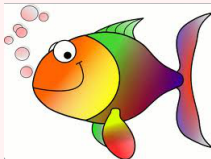
Canny Edge Detection

Edge Linking

Edge Tracking

Hough Transform

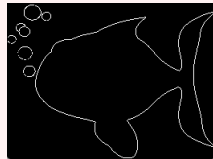
original image



edge



boundary



The edge of object may be not a boundary, the boundary may also be not edge.



Problems

Edge-based Segmentation

Introduction

Edge & Boundary

Problems

Steps in Edge Detection

Steps in Image Segmentation

Edge Detection

Edge Detection Techniques

Marr-Hildreth

Canny Edge Detection

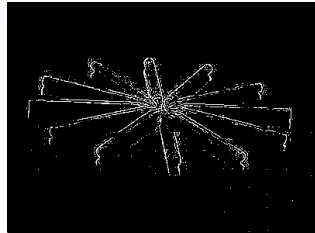
Edge Linking

Edge Tracking

Hough Transform

Edge detection is a simple and fast technique used in segmentation methods. However, there also are some problems:

- **Noise and background** affect the accurate of edge detection.
- Edges are the sign of lack of continuity, and ending.





Steps in Edge Detection

Edge-based Segmenta- tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge Linking

Edge Tracking

Hough
Transform

- 1 **Filtering:** Filtering to reduce noise results in a loss of edge strength.
- 2 **Enhancement:** In order to facilitate the detection of edges, it is essential to determine changes in intensity in the neighborhood of a point.
- 3 **Detection:** Find the zero crossing and peak value to detect edge.



Problems

Edge-based
Segmentation

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

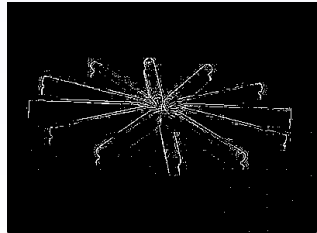
Edge
Linking

Edge Tracking

Hough
Transform

Edge detection is a simple and fast technique used in segmentation methods. However, there also are some problems:

- Noise and background affect the accurate of edge detection.
- Edges are the sign of **lack of continuity**, and ending.





Step in Image Segmentation

Edge-based Segmentation

Introduction

Edge & Boundary

Problems

Steps in Edge Detection

Steps in Image Segmentation

Edge Detection

Edge Detection Techniques

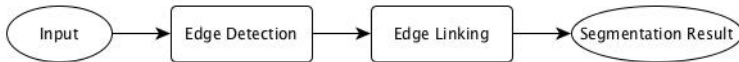
Marr-Hildreth

Canny Edge Detection

Edge Linking

Edge Tracking

Hough Transform





Edge Detection

Edge-based
Segmentation

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

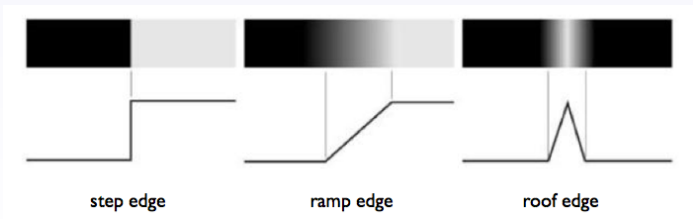
Edge
Linking

Edge Tracking

Hough
Transform

Three edge types and definitions:

- Step edge
- Ramp edge
- Roof edge





Edge Detection

Edge-based Segmentation

Introduction

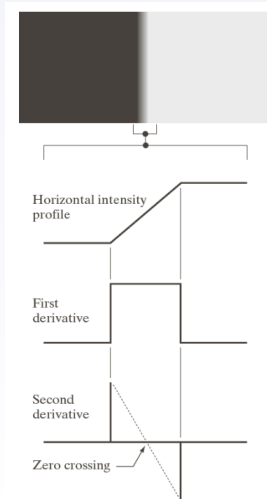
- Edge & Boundary
- Problems
- Steps in Edge Detection
- Steps in Image Segmentation

Edge Detection

- Edge Detection Techniques
- Marr-Hildreth
- Canny Edge Detection

Edge Linking

- Edge Tracking
- Hough Transform





Edge Detection Techniques¹

Edge-based
Segmenta-
tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

Hough
Transform

- Roberts Edge Detection
- Sobel Edge Detection
- Prewitt Edge Detection
- ...
- Marr-Hildreth Edge Detection (LoG)
- Canny Edge Detection

¹Rafael C. Gonzalez *et al.*, “Digital Image Processing”, Publishing House of Electronics Industry, 2011.



Gradient

Edge-based
Segmentation

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

Hough
Transform

The gradient ∇f of a function is:

$$\nabla f = \text{grad}(f) = \begin{bmatrix} g_x \\ g_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

The **magnitude** of the gradient is:

$$M(x, y) = \text{mag}(\nabla f) = \sqrt{g_x^2 + g_y^2}$$

The **direction** of the greatest rate of change is:

$$\alpha(x, y) = \arctan \left[\frac{g_x}{g_y} \right]$$



Edge Detection Techniques

Edge-based
Segmenta-
tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

Hough
Transform

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

■ Roberts Edge Detection

-1	0
0	+1

0	-1
+1	0

$$g_x = \frac{\partial f}{\partial x} = z_9 - z_5$$

$$g_y = \frac{\partial f}{\partial y} = z_8 - z_6$$



Edge Detection Techniques

Edge-based
Segmenta-
tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

Hough
Transform

■ Sobel Edge Detection

-1	-2	-1
0	0	0
+1	+2	+1

-1	0	-1
-2	0	+2
-1	0	+1

$$g_x = \frac{\partial f}{\partial x} = (z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)$$

$$g_y = \frac{\partial f}{\partial y} = (z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7)$$

■ Prewitt Edge Detection

-1	-1	-1
0	0	0
+1	+1	+1

-1	0	+1
-1	0	+1
-1	0	+1



Marr-Hildreth Edge Detection (LoG)²

Edge-based
Segmenta-
tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge
Linking

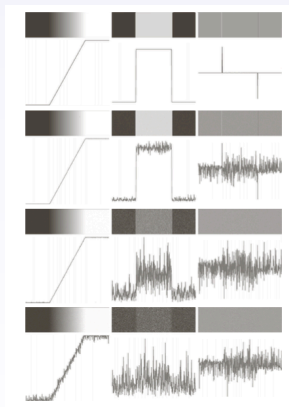
Edge Tracking

Hough
Transform

This method combines
Gaussian filtering with the
Laplacian for edge detection.

Idea:

- 1 **Gaussian filter** is used to
swipe away noise from the
image
- 2 **Laplace operator**
- 3 Locate **zero crossings**



²Marr D, Hildreth E, “Theory of Edge Detection”, Proc. of the Royal Society of London, 1980.



Canny Edge Detection³

Edge-based
Segmenta-
tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

Hough
Transform

Canny is the best edge detection detector.

Idea:

- 1 Low error rate
- 2 Edge points should be well localized

³Joun F. Canny, "A Computational Approach To Edge Detection", PAMI, 1986.



Canny Edge Detection

Edge-based
Segmenta-
tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

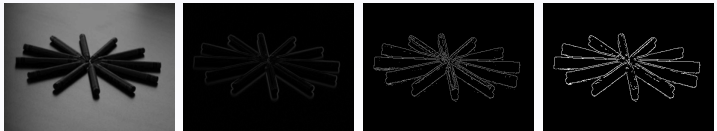
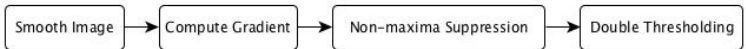
**Canny Edge
Detection**

Edge
Linking

Edge Tracking

Hough
Transform

Canny algorithm:





Canny Edge Detection

Edge-based
Segmentation

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

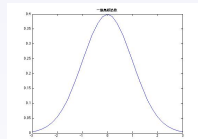
Hough
Transform

Gauss Filter:

1 Gaussian distribution

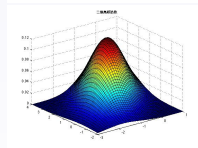
- one dimension:

$$G(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{x^2}{2\sigma^2}}$$



- two dimension:

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$



2 Gaussian kernel

$\frac{1}{273}$

1	4	7	4	1
4	16	26	16	4
7	26	41	26	7
4	16	26	16	4
1	4	7	4	1



Canny Edge Detection

Edge-based
Segmenta-
tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

**Canny Edge
Detection**

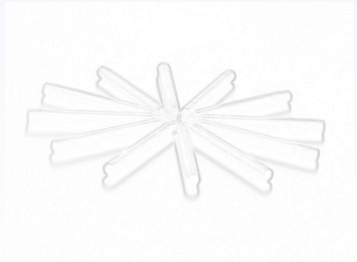
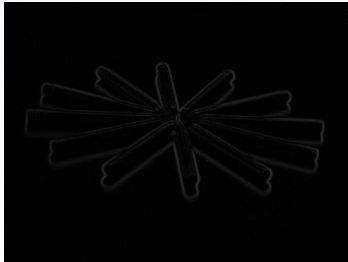
Edge
Linking

Edge Tracking

Hough
Transform

Compute Gradient:

$$S_x = \begin{bmatrix} -1 & 1 \\ -1 & 1 \end{bmatrix}, S_y = \begin{bmatrix} 1 & 1 \\ -1 & -1 \end{bmatrix}$$





Canny Edge Detection

Edge-based
Segmentation

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

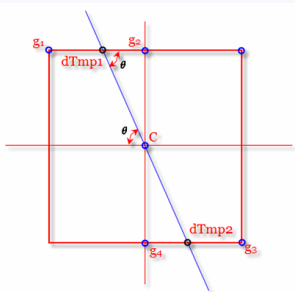
Edge
Linking

Edge Tracking

Hough
Transform

Non-maxima Suppression (NMS):

- Edges generated using gradient typically contain **wide ridges** around local maxima.
- Use non-maxima suppression to thin those ridges to find **thin edges** corresponding to local maxima.





Canny Edge Detection

Edge-based Segmentation

Introduction

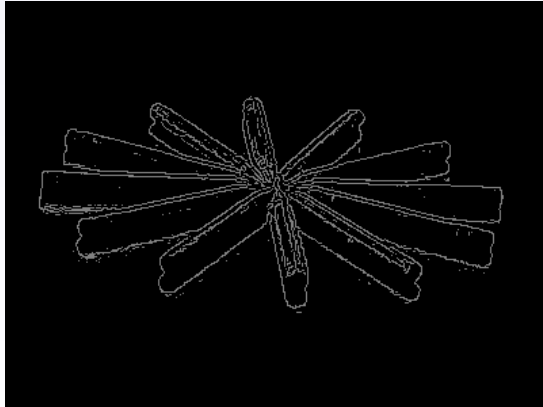
- Edge & Boundary
- Problems
- Steps in Edge Detection
- Steps in Image Segmentation

Edge Detection

- Edge Detection Techniques
- Marr-Hildreth
- Canny Edge Detection**

Edge Linking

- Edge Tracking
- Hough Transform

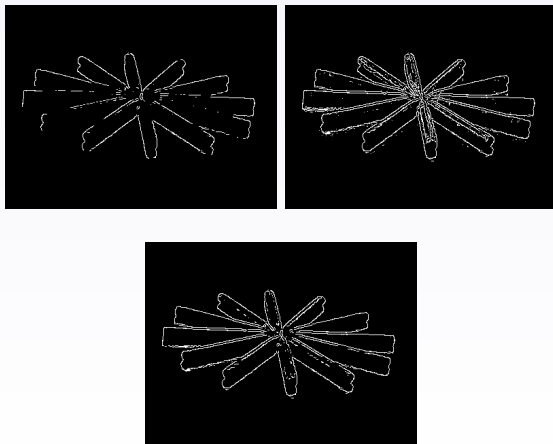




Canny Edge Detection

Double thresholding:

- **Problem:** The received image may still contain false edge points.



Edge-based
Segmenta-
tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

Hough
Transform



Edge Linking

Edge-based Segmenta- tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge Linking

Edge Tracking

Hough
Transform

- Edge Tracking
- Hough Transform
- Curve Fitting
- Dynamic Programming
- ...



Edge Tracking

Edge-based
Segmentation

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

Hough
Transform

Idea:

- Each point is linked to the adjacent if magnitude and direction of the gradient are **similar**.

$e(x, y)$ is magnitude of the gradient, $\theta(x, y)$ is the direction of the gradient, if two each points meet the following conditions:

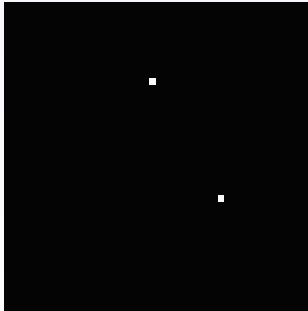
$$\begin{cases} |e(x_i, y_i) - e(x_j, y_j)| \leq E \\ |\theta(x_i, y_i) - \theta(x_j, y_j)| \leq A \\ |e(x_i, y_i)|, |e(x_j, y_j)| > E \end{cases}$$



Hough Transform

The Hough Transform can be used to detect **lines**, **circles** or other parametric curves.

Idea:



Edge-based
Segmenta-
tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

Hough
Transform



Hough Transform

Edge-based
Segmentation

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

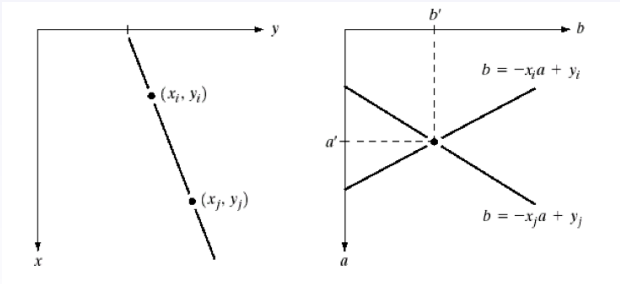
Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

Hough
Transform



$$y = a'x + b'$$
$$\begin{cases} b = -x_i a + y_i \\ b = -x_j a + y_j \end{cases}$$



Hough Transform

Edge-based
Segmentation

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

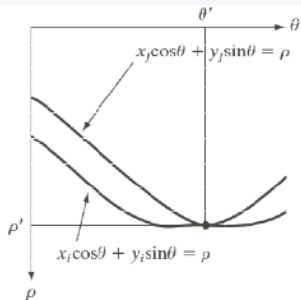
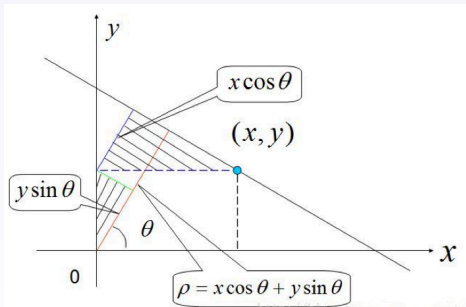
Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

Hough
Transform



$$\begin{cases} \rho' = x_i \cos \theta' + y_i \sin \theta' \\ \rho' = x_j \cos \theta' + y_j \sin \theta' \end{cases}$$

\Rightarrow

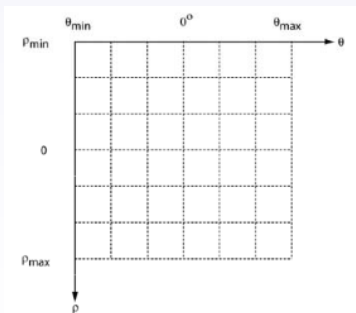
$$\begin{cases} x_i \cos \theta + y_i \sin \theta = \rho \\ x_j \cos \theta + y_j \sin \theta = \rho \end{cases}$$



Hough Transform

Hough algorithm:

- 1 Quantize the parameter space (ρ, θ) . This quantized space is referred to as the **accumulator cells**.
- 2 Count the number of times a line intersects a given cell.
- 3 Lines can be found as peaks in this accumulator space.



$$\rho = x \cos \theta + y \sin \theta$$

Edge-based
Segmenta-
tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

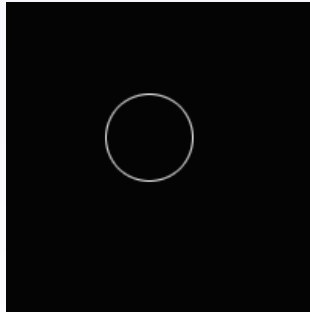
Hough
Transform



Hough Transform

Edge-based
Segmenta-
tion

Circle:



$$(x - a)^2 + (y - b)^2 = r$$

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge
Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge
Linking

Edge Tracking

Hough
Transform



Edge-based Segmentation

Introduction

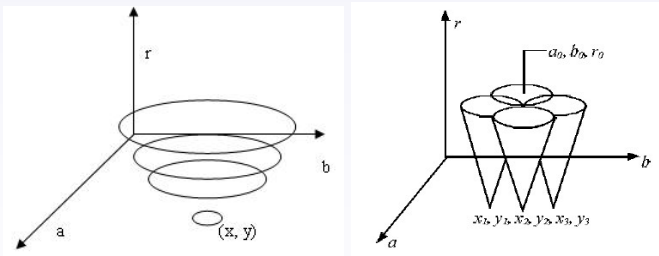
- Edge & Boundary
- Problems
- Steps in Edge Detection
- Steps in Image Segmentation

Edge Detection

- Edge Detection Techniques
- Marr-Hildreth
- Canny Edge Detection

Edge Linking

- Edge Tracking
- Hough Transform



$$(a - x_i)^2 + (b - y_i)^2 = r$$



Edge-based Segmenta- tion

Introduction

Edge &
Boundary

Problems

Steps in Edge
Detection

Steps in Image
Segmentation

Edge Detection

Edge Detection
Techniques

Marr-Hildreth

Canny Edge
Detection

Edge Linking

Edge Tracking

Hough
Transform

Thanks!