

Image
Derivative
Convolution

Leonhard
Applis

What
makes
an Edge?
Problems
Definition

Gradient
based
approach
Local
maxima
method

1D
approach
2D
Approach
Simple
Example
Filters

Advanced
gradient
based
edge de-
tection

3x3 Filters
3x3
Examples
Evaluations

Comments

Edge Detection

Leonhard Applis

TH Nürnberg

05.11.2018

Table of Contents

1 What makes an Edge?

- Problems
- Definition

2 Basics of gradient-based edgedetection

- 1D approach
- 2D Approach
- Simple Example
- Filters

3 Advanced gradient-based edgedetection

- 3x3 Filters
- 3x3 Examples
- Evaluations

4 Compass Operators

5 Edge Sharpening

What makes an edge?

Image
Detection
101

Leonhard
Applis

What
makes
an Edge?

Problems
Definition

Convolution
Kernel
Based
Approach
Gradient
Magnitude

1D
approach

2D
Approach

Simple
Example

Filters

Advanced
gradient
based
edge de-
tection

3x3 Filters

3x3
Examples

Evaluations

Comments



Figure: Felix

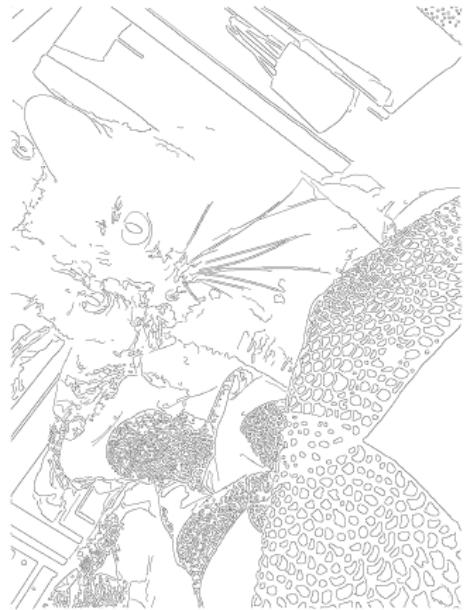


Figure: Felix's Edges

Problem I: Contrast



Figure: High Contrast Felix



Figure: Low Contrast Felix

Home
Contact
About

Leonhard
Applis

CV
Publications
Teaching

Problems

Definition

Gradients and
convolution
Forward
Backward
Derivatives
Optimization

1D
approach

2D
Approach

Simple
Example

Filters

Advanced
gradients
based
on
edges
detection

3x3 Filters

3x3
Examples

Evaluations

Comments

Problem II: Smoothness



Figure: Smooth Felix

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Applis

Convolution
and backprop
gradient

Problems
Definition

Convolution
and backprop
gradient
filter
blurring
edge detec

1D
approach

2D
Approach

Simple
Example

Filters

Advanced
gradient
based
edge de-
tection

3x3 Filters
3x3
Examples
Evaluations

Comments

Problem III: Noise



Figure: Salted Felix

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Applis

Convolution
Cross-correlation
Gradients
Sobel
Gaussian
Median

Problems
Definition

Convolution
Cross-correlation
Gradients
Sobel
Gaussian
Median

1D
approach

2D
Approach

Simple
Example

Filters

Advanced
gradients
based
edge detec-
tion

3x3 Filters
3x3
Examples
Evaluations

Comments

Definition

In Image Processing, an edge can be defined as a set of contiguous pixel positions where an abrupt change of intensity, gray- or color-values occur. Edges represent boundaries between objects and background. Sometimes, the edge-pixel-sequence may be broken due to insufficient intensity difference.(Malay K. Pakhira)

Table of Contents

Image
Detection
Definition
**Leonhard
Applis**

What makes
an Edge
Problems
Definition

Basics of
gradient-
based
edgedetec-
tion

1D
approach
2D
Approach
Simple
Example
Filters

Advanced
gradient-
based
edgedetec-
tion

3x3
Examples
Evaluations

Compass

1 What makes an Edge?

- Problems
- Definition

2 Basics of gradient-based edgedetection

- 1D approach
- 2D Approach
- Simple Example
- Filters

3 Advanced gradient-based edgedetection

- 3x3 Filters
- 3x3 Examples
- Evaluations

4 Compass Operators

5 Edge Sharpening

Requirements

- ① color values known (for example only grayscale)
- ② picture scale known
- ③ loaded as pixelmatrix

One dimensional approach

Image
Derivatives
Convolution

Leonhard
Applis

What
makes
an edge
Problems

Definition

Convolution
Kernel
Filter
Blur
Gaussian

1D
approach

2D
Approach

Simple
Example

Filters

Advanced
gradients
based
edge de-
tection

3x3 Filters

3x3
Examples

Evaluations

Comments

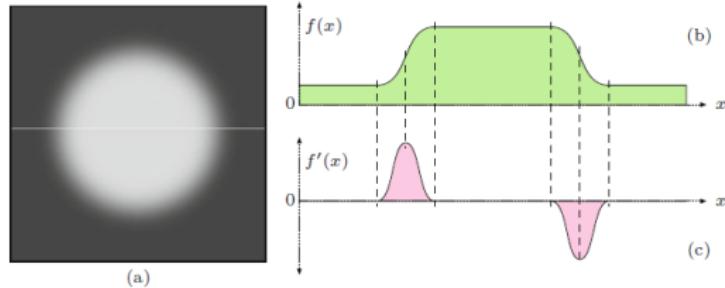


Figure: One dimensional image function and derivation

Only applicable with known, steady functions

Approximating discrete derivation

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What
makes
an image
Problems
Definition

Convolution
Kernel
Filter
Blur
Sharpen

1D
approach

2D
Approach

Simple
Example

Filters

Advanced
gradient
based
edge de-
tection

3x3 Filters
3x3
Examples
Evaluations

Problem: the image function is discrete, therefore we need to approximate the derivation

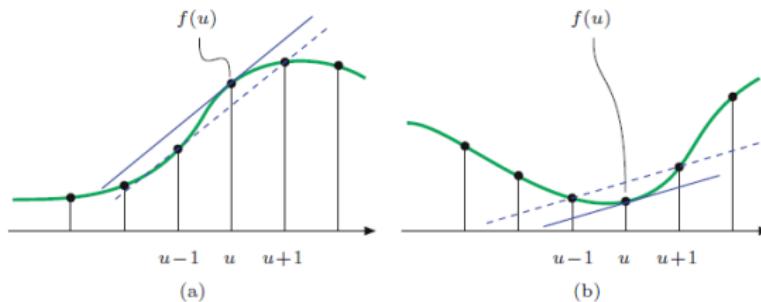


Figure: Approximation of the derivation for discrete imagefunctions

$$\frac{df}{dx}(u) \approx \frac{f(u+1) - f(u-1)}{(u+1) - (u-1)} = \frac{f(u+1) - f(u-1)}{2}$$

Two dimensional approach

If working with full images, we got two dimensions and therefore two partial derivations:

$$I_x = \frac{\partial I}{\partial x}(u, v), I_y = \frac{\partial I}{\partial y}(u, v)$$

the **gradient** at the point (u, v) is

$$\nabla I(u, v) = \begin{pmatrix} I_x(u, v) \\ I_y(u, v) \end{pmatrix}$$

And the **magnitude** is

$$|\nabla I| = \sqrt{I_x^2 + I_y^2}$$

Example

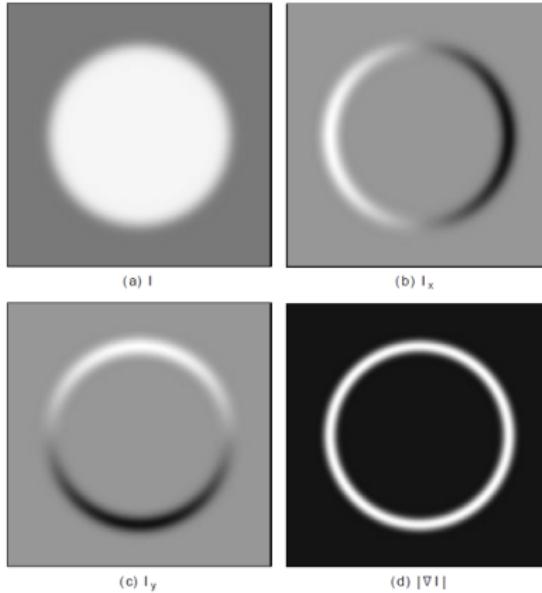


Figure: Visualisation of simple gradient-based edgedetection

Example with Felix



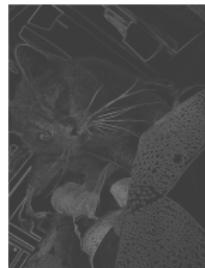
(a) I



(b) I_x



(c) I_y



(d) $|\nabla I|$

Figure: Simple Filters applied to Felix¹

¹ All images have a 50% increased brightness

Implementation with filters

Expressing the gradient as a *linear filter* is simple:

$$I_x = [-0.5 \quad 0 \quad 0.5]$$

$$I_y = \begin{bmatrix} -0.5 \\ 0 \\ 0.5 \end{bmatrix}$$

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Applis

What
makes
an edge
Problem
Definition

Convolution
Kernel
Based
Approach

1D
approach
2D
Approach

Simple
Example

Filters

Advanced
gradient
based
edge de-
tection

3x3 Filters
3x3
Examples
Evaluations

Comments

Table of Contents

Leonhard
Applis

What
makes
an Edge?

Problems

Definition

Convolution
Kernel
Based
Edge
Detection

1D
approach

2D
Approach

Simple
Example

Filters

Advanced
gradient-
based
edgede-
tection

3x3 Filters

3x3
Examples

Evaluations

1 What makes an Edge?

- Problems
- Definition

2 Basics of gradient-based edgedetection

- 1D approach
- 2D Approach
- Simple Example
- Filters

3 Advanced gradient-based edgedetection

- 3x3 Filters
- 3x3 Examples
- Evaluations

4 Compass Operators

5 Edge Sharpening

Prewitt Operator

Idea: Include neighborhood

$$H_x^P = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \quad H_y^P = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

$$\nabla I^P(u, v) \approx \frac{1}{6} \cdot \begin{pmatrix} (I * H_x^P)(u, v) \\ (I * H_y^P)(u, v) \end{pmatrix}$$

Sobel

Idea: Include neighbourhood but weight center more

$$H_x^S = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad H_y^S = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

$$\nabla I^S(u, v) \approx \frac{1}{8} \cdot \begin{pmatrix} (I * H_x^S)(u, v) \\ (I * H_y^S)(u, v) \end{pmatrix}$$

Comparison with Felix

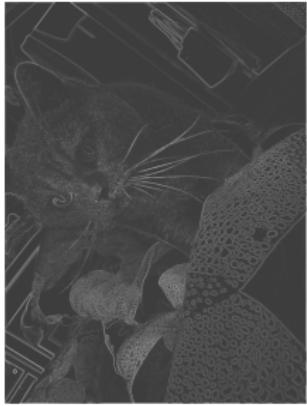


Figure: Simple edge filter

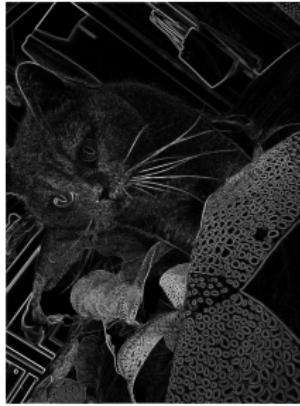


Figure: Prewitt Operator



Figure: Sobel Operator

Evaluations

general magnitude: $E(u, v) = \sqrt{I_x^2(u, v) + I_y^2(u, v)}$
holds for every Operator

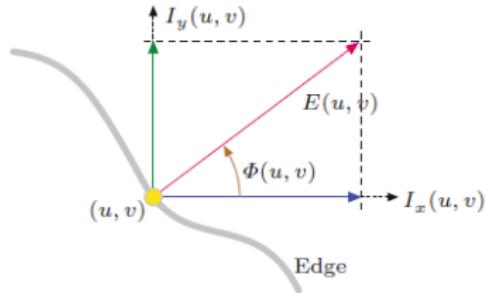


Figure: Visualisation of edge direction

$$\Phi(u, v) = \tan^{-1} \left(\frac{I_y(u, v)}{I_x(u, v)} \right) = \arctan(I_x(u, v), I_y(u, v))$$

Table of Contents

Leonhard
Applis

What
makes
an Edge?

Problems

Definition

Convolution
Kernel
Based
Edge
Detection

1D
approach

2D
Approach

Simple
Example

Filters

Advanced
gradient
based
edge de-
tection

3x3 Filters

3x3
Examples

Evaluations

Compass

1 What makes an Edge?

- Problems
- Definition

2 Basics of gradient-based edgedetection

- 1D approach
- 2D Approach
- Simple Example
- Filters

3 Advanced gradient-based edgedetection

- 3x3 Filters
- 3x3 Examples
- Evaluations

4 Compass Operators

5 Edge Sharpening

Table of Contents

Leonhard
Applis

What
makes
an Edge?

Problems

Definition

Convolution
Kernel
Based
Edge
Detection

1D
approach

2D
Approach

Simple
Example

Filters

Advanced
gradient
based
edge de-
tection

3x3 Filters

3x3
Examples

Evaluations

1 What makes an Edge?

- Problems
- Definition

2 Basics of gradient-based edgedetection

- 1D approach
- 2D Approach
- Simple Example
- Filters

3 Advanced gradient-based edgedetection

- 3x3 Filters
- 3x3 Examples
- Evaluations

4 Compass Operators

5 Edge Sharpening