Edge Detection

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What makes an edge?

Figure: Felix

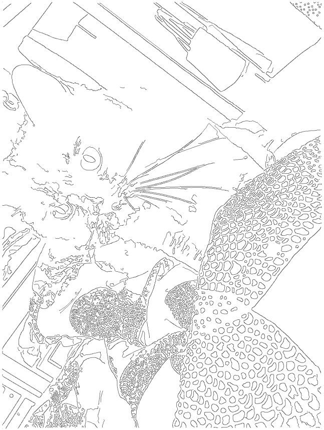

Figure: Felix's Edges

Problem I: Contrast

Figure: High Contrast Felix

Figure: Low Contrast Felix

Problem II: Smoothness

Figure: Smooth Felix

Problem III: Noise

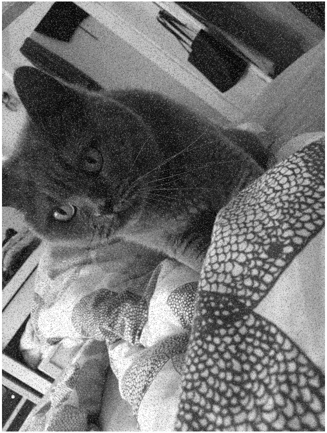

Figure: Salted Felix

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)

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Requirements

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

One dimensional approach

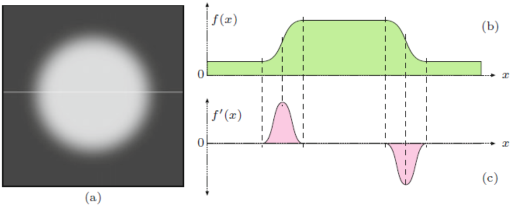


Figure: One dimensional image function and derivation

Only applyable with known, steady functions

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

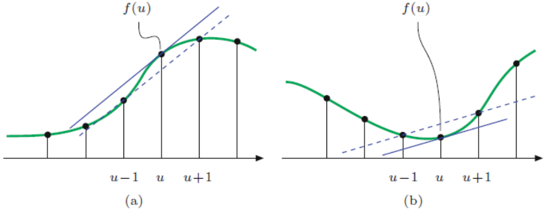


Figure: Approximation of the derivation for discrete imagefunctions

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

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

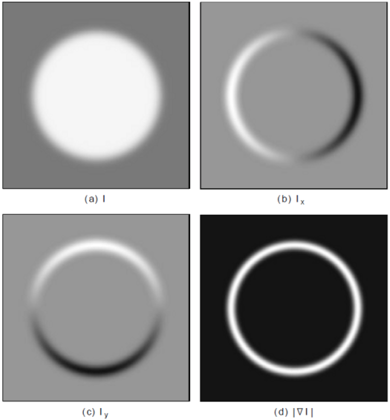
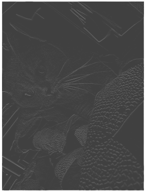


Figure: Visualisation of simple gradient-based edgedetection

Example with Felix

(a) I

(b) I_x



(c) I_y

(d) $|\nabla I|$

Figure: Simple Filters applied to Felix[1]

[1] All images have a 50% increased brightness

Implementation with filters

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

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

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Prewitt Operator

Idea: Include neighboorhood

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

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

Sobel

Idea: Include neighboorhood but weight center more

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

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

Comparison with Felix

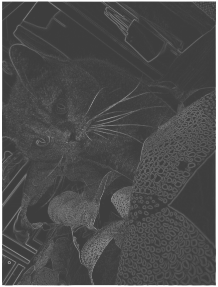

Figure: Simple edge filter

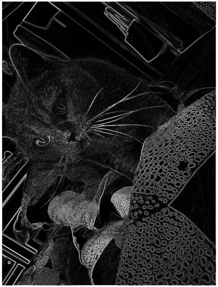

Figure: Prewitt Operator

Figure: Sobel Operator

Evaluations

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

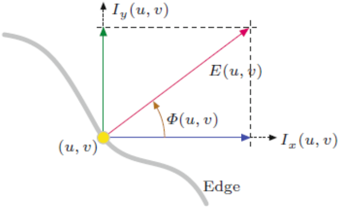

Figure: Visualisation of edge direction

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

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