IMAGE PROCESSING (EDGE DETECTION)

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Introduction

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Introduction

- Edges occur at boundaries between regions of different color, intensity, or texture.
- An edge is a location of rapid intensity variation.
- Detecting edges can be helpful for segmenting an image into coherent regions.
- Reduce the amount of data to be processed, disposing less relevant information.
- Important to feature detection and feature extraction.

Edge Detection and Segmentation using graph searches

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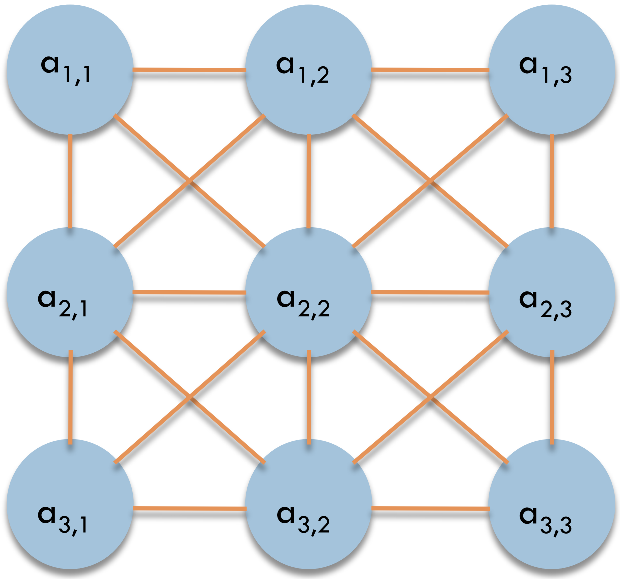
Visualization

- If we see an image as a graph, with te pixels as vertices, we can do a search in the image in the same way that we do in a graph.

$a_{1,1}$	$a_{1,2}$	$a_{1,3}$
$a_{2,1}$	$a_{2,2}$	$a_{2,3}$
$a_{3,1}$	$a_{3,2}$	$a_{3,3}$



Edge Detection

- Visit each vertex and edge of the graph asking if there is a significant change in the intensity in at least one of its neighbors.
- If a certain pixel has at least one neighbor with a significant change in the intensity level, then consider that pixel as an edge.
- Noise can be interpreted as an edge with this approach.

Edge Detection

Segmentation

- Define an initial node and mark it with a color.
- Start a Depth First Search (DFS) starting in that node.
- If the intensity of current node does not present a significant change with the intensity of the initial node, then mark it with the same color.
- The algorithm depends in the selection of the initial vertex.

Segmentation

Sobel Operator

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Sobel Operator

- Commonly used in edge detection algorithms.
- Computes an approximation of the gradient of the image intensity.
- At each point od the image, the magnitude of the gradient is calculated by:

$$|G| = \sqrt{G_x^{\ 2} + G_y^{\ 2}}$$

- Where G_x and G_y are the first derivates in x-direction and y-direction respectively.

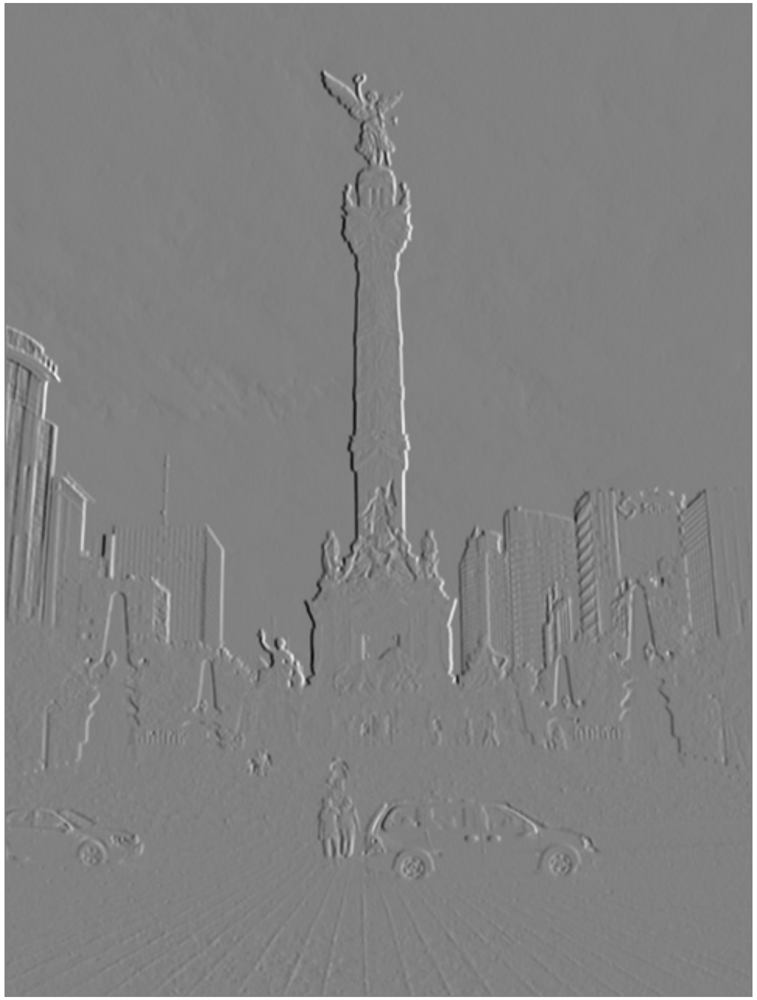
Sobel Operator

- To obtain the first derivates in both directions, the Sobel operator use the following kernels

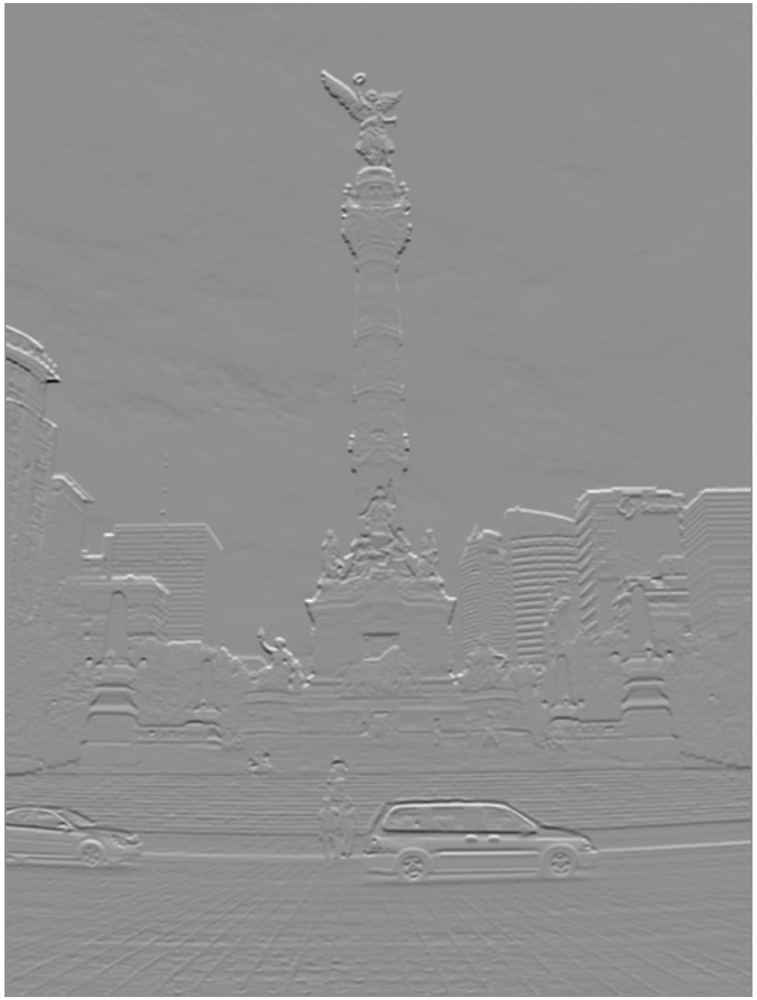
$$K_{Gx} = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad K_{Gy} = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

- The sobel operator convolve an image with the kernels to find the points where the intensity change abruptly.

Sobel Operator



X Derivate



Y Derivate

Sobel Operator (Final Result)

Canny Edge Detector

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Canny Edge Detector

- Developed by John F. Canny (JFC) in 1986.
- One of the most used algorithms in image processing for detecting edges.
- The goal of JFC was to implement the optimal edge detection algorithm, based on the following points:

Canny Edge Detector

- **Good Detection:** The algorithm must be able to detect as many real edges as possible in the image.

- **Good Localization:** The detected edges should be marked as close as possible to the real edges.

- **Minimal Response:** A real edge must not result in more than one detected edge, and image noise must not affect in the detection of new edges.

Canny Edge Detector

- Canny Edge Detector functionality is based in these five steps:
  1. Smoothing
  2. Gradient Detection
  3. Non-maximum supression
  4. Double Thresholding
  5. Edge Tracking

Test Image

Smoothing

- Gaussian Filter is used to reduce the amount of noise in the image.
  - Noise can be detected as edges by the algorithm.
- The image is then convolved with the Gaussian Filter.
- One commonly used kernel with standard deviation of $\sigma = 1.4$ is the following:

$$\frac{1}{159}\begin{bmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{bmatrix}$$

Smoothing

Original Image

Smoothed Image

Gradient Detection

- Sobel operator is applied to the image.
  - Calculates the gradient of the image intensity.
  - The gradient points in the direction of the largest possible intensity increase.
  - Areas where intensity changes are notorious, like edges, are detected.
- Each point in the image is replaced by the magnitude of the gradient in the given point.
- The gradient is composed by the first derivates in the x-direction (Gx) and y-direction (Gy).

Gradient Detection

- The Sobel Filter uses these two kernels to convolve the image and calculate the first derivates of the image:

$$K_{Gx} = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad K_{Gy} = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

- The magnitude of the gradient (G) is given by

$$|G| = \sqrt{{G_x}^2 + {G_y}^2}$$

Gradient Detection

Before Sobel Operator

After Sobel Operator

Non-maximum Supression

- Each point is compared with it's neighbors, depending on the direction of the gradient in the given point.

- For each point in the image, the direction of the gradient is calculated using the following expression:

$$\theta = \tan^{-1}\left(\frac{|G_x|}{|G_y|}\right)$$

Non-maximum Supression

- Round the gradient direction θ to the nearest 45°.
- Compare its value with the neighbor located in that direction and also in the opposite direction .
- If the intensity of the image in the given point is not greater than the intensity of its two neighbors, the value is supressed.

Non-maximum Supression

- The objective of doing this is to convert “blurred” edges into “sharp” edges.

- Edge pixels are preserved where the gradient has local maxima.

Non-maximum Supression

Before Non-maximum Supression

After Non-maximum Supression

Double Thresholding

- A high threshold value H_{th} is defined.
- A low threshold value L_{th} ($L_{th} < H_{th}$) is defined.
- Values bigger or equal to H_{th} are painted in white (strong edge).
- Values between L_{th} and H_{th} are painted in gray (weak edge).
- Values smaller or equal to L_{th} are supressed.

Double Thresholding

Before Double Threshoding

After Double Thresholding

Edge Tracking

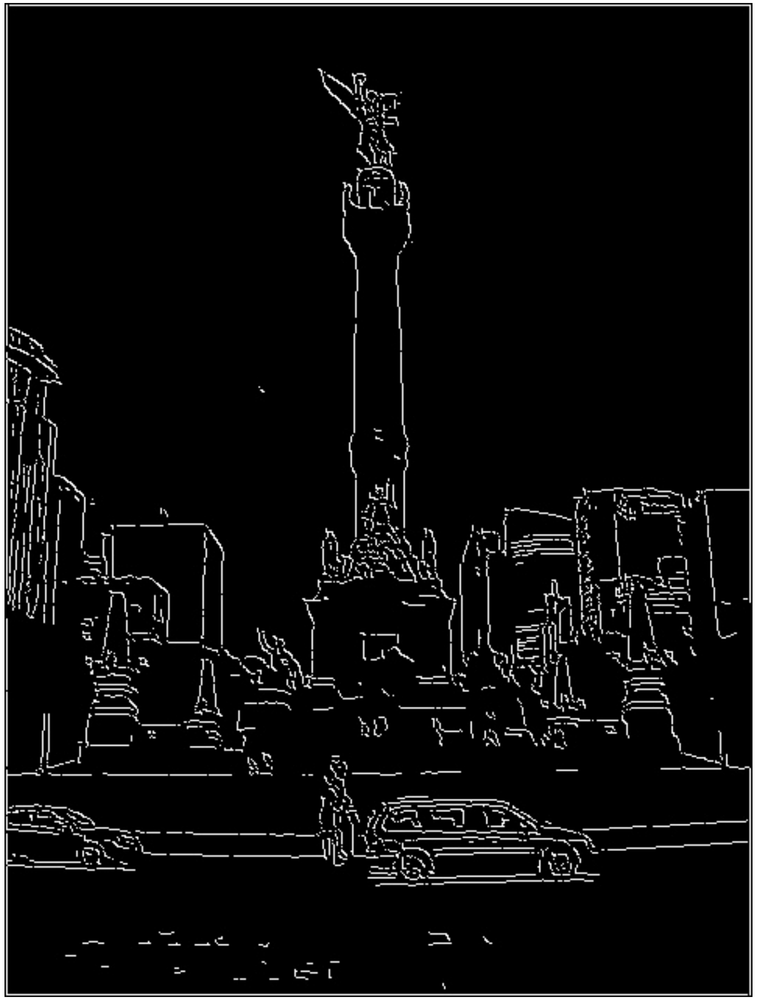
- If a certain pixel of weak edge is not connected directly or indirecty to a strong edge, is supressed. Otherwise is marked as a strong edge.

- The image can be seen as a graph, with each pixel representing a vertex connected to its neighbors.

- A depth first search (DFS) can be used to track the edges

Edge Tracking

Before Edge Tracking



After Edge Tracking

Result

Original Image

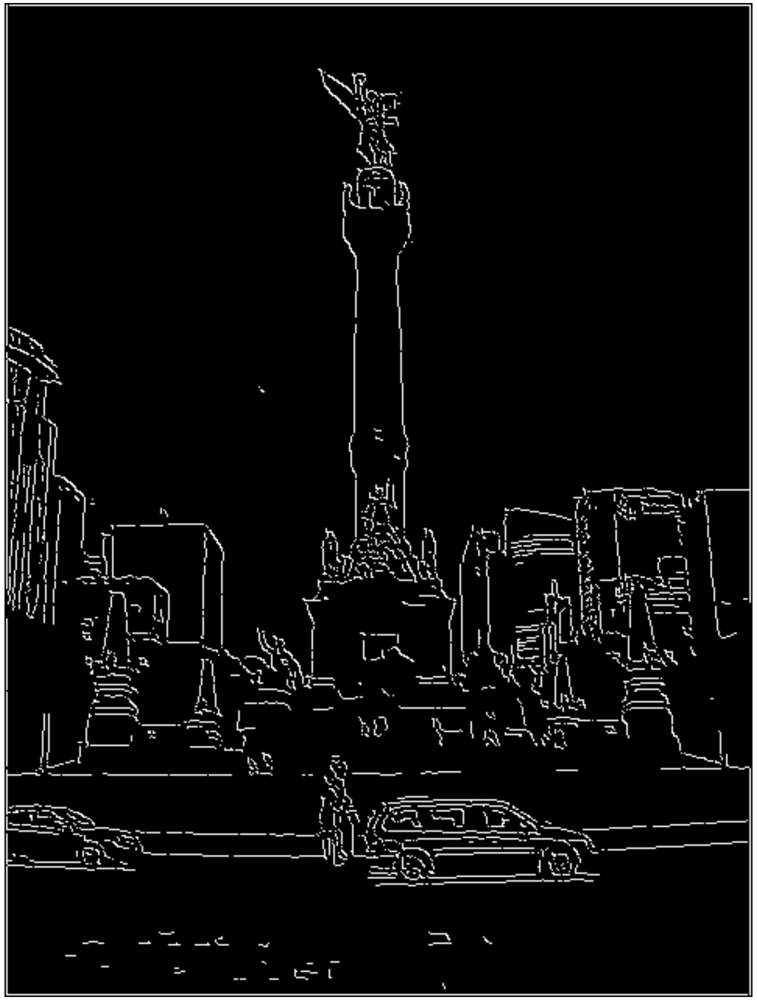


Image after applying Canny
Edge Detector

Future Work

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Future Work

- Study and implement the most common methods for image processing
  - Edge Detection
  - Corner Detection
  - Segmentation
  - Filters
  - Etc.
- Continue studying about the Dirichlet Process and machine learning techniques to apply them in image segmentation algorithms.