Programming Assignment 1 Part 1

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I. Canny Edge Detection Implementation

A. Introduction

The purpose of this part of the assignment is to implement the *Canny Edge Detector* algorithm in Python without using any of the built function in Python libraries (i.e. convolution, Gaussian filter, non-maximum suppression, etc). Furthermore, the algorithm is tested with three different standard deviation (σ) values to observe the impact on the output.

B. Canny Edge Detection Algorithm

Fig. 1 shows a high level diagram of the Canny edge detection algorithm implementation. The input image is convolved with a 1D Gaussian mask along the rows to obtain Ix and along the columns to obtain Iy. Next, Ix and Iy are convolved with the 1D Gaussian derivative along the rows and columns, respectively to obtain $Ix\ '$ and $Iy\ '$. The two outputs are then combined by computing the magnitude (M). Non-maximum suppression (NMS) is applied to thin out the edges. Finally, hysteresis tresholding (HT) is used to suppressing all the other edges that are weak and not connected to strong edges.

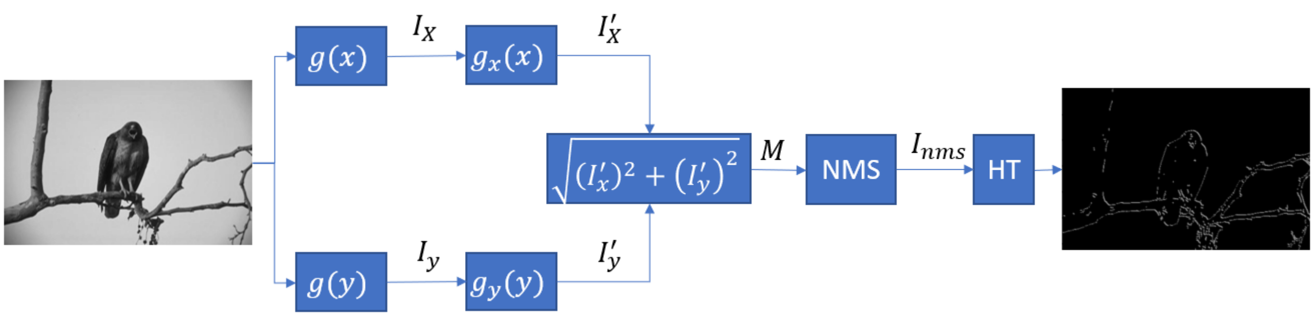


Fig. 1: High Level Diagram of the Canny Edge Detection Implementation

C. Results and Discussion

To evaluate the results, a grayscale image from Berkeley Segmentation Dataset [1] were used. The images were tested using three different Gaussian masks with three standard deviation values $\sigma \in \{1, 5, 10\}$ and zero mean $\mu = 0$.

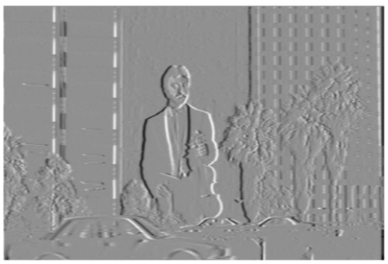
Fig. 2 shows the results for $\sigma = 1$. Starting from top left, I is the input image to the algorithm. Ix and Iy are images blurred by 1D Gaussian filter in x and y directions, respectively. $Ix\ '$ and $Iy\ '$ are the results of applying the 1D Gaussian derivative on the the blurred images. The size of the Gaussian mask and Gaussian derivative is set to 4. $Ix\ '$ and $Iy\ '$ show the vertical and horizontal edges in the image, respectively. The magnitude M combines the horizontal and vertical edges into one result. To thin out the edges on the output, NMS is applied as shown in Fig. 2g. Finally, HT is applied to reduce some of the weak edges. The HT, requires weak and strong threshold values which can be tuned to produce the based result based on the image and the application. For the results in Fig.2-4, the thresholds are set to 0.1 and 0.3. Since, the image in Fig. 2g had pixels that are already black or white, which means that they are either less than weak or greater than strong, the HT does not have much impact on the image.

Fig. 3-4 show the results for σ equal to 5 and 10. By comparing the final results for the three sigma's, it may be observed that the lower values of sigma result in more edges and detect finer features, while higher values detect larger scale edges and provide a coarse result.

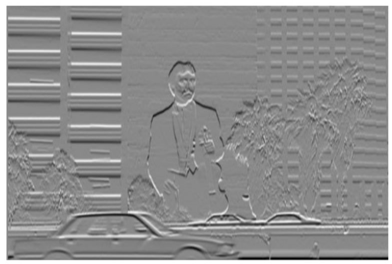
(a) I

(b) Ix

(c) Iy



(d) $Ix\,'$



(e) $Iy\,'$

(f) M

(g) After NMS

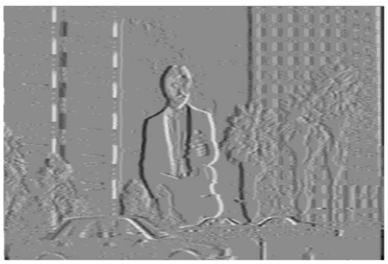
(h) After NMS and HT

Fig. 2: a) Original input image that we want to apply Canny Edge Detection on, b) Original image convolved with 1D Gaussian with ($\sigma = 1$) in x-direction, b) Original image convolved with 1D Gaussian in y-direction, c) Ix with 1D Gaussian derivative (vertical edges), d) Iy convolved with 1D Gaussian (horizontal edges, f) Magnitude of $Ix\,'$ and $Iy\,'$, g) Image after applying non-max suppression (NMS) to image in f), and h) Image after applying hysteresis thresholding (HT) to image in g).

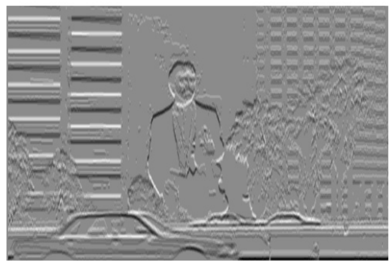
(a) I

(b) Ix

(c) Iy



(d) $Ix\,'$



(e) $Iy\,'$

(f) Magnitude

(g) After NMS

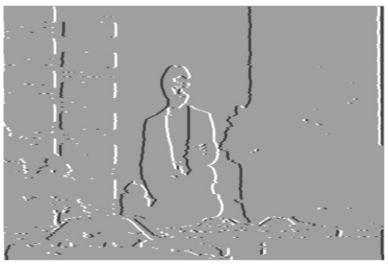
(h) After NMS and HT

Fig. 3: a) Original input image that we want to apply Canny Edge Detection on, b) Original image convolved with 1D Gaussian with ($\sigma = 5$) in x-direction, b) Original image convolved with 1D Gaussian in y-direction, c) Ix with 1D Gaussian derivative (vertical edges), d) Iy convolved with 1D Gaussian (horizontal edges, f) Magnitude of $Ix\,'$ and $Iy\,'$, g) Image after applying non-max suppression (NMS) to image in f), and h) Image after applying hysteresis thresholding (HT) to image in g).

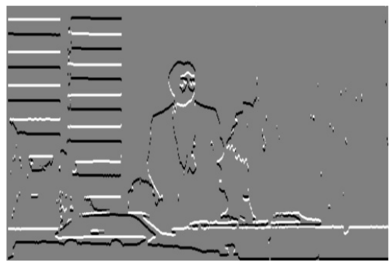
(a) I

(b) Ix

(c) Iy



(d) $Ix\,'$



(e) $Iy\,'$

(f) Magnitude

(g) After NMS

(h) After NMS and HT

Fig. 4: a) Original input image that we want to apply Canny Edge Detection on, b) Original image convolved with 1D Gaussian with ($\sigma = 10$) in x-direction, b) Original image convolved with 1D Gaussian in y-direction, c) Ix with 1D Gaussian derivative (vertical edges), d) Iy convolved with 1D Gaussian (horizontal edges, f) Magnitude of $Ix\,'$ and $Iy\,'$, g) Image after applying non-max suppression (NMS) to image in f), and h) Image after applying hysteresis thresholding (HT) to image in g).

References

[1] "Berkeley Segmentation Dataset: Images," https://www2.eecs.berkeley.edu/Research/Projects/CS/vision/bsds/BSDS300/html/dataset/images.html, 2003, [Online; accessed 06-Oct-2021].