
GNR602 Course Project

Wavelet Transform based edge enhancement through Daubechies wavelet as mother wavelet

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Introduction

- Edge enhancement is an image processing filter that enhances the edge contrast of an image or video in an attempt to improve its acutance.
- We are going to exploit the method of Edge Detection for the given image, and will use the detected edges for the edge enhancement implementation by superimposing it on the image.
- Some Famous Edge detection algorithms are Canny, Sobel, Prewitt, etc.

Literature Review

- The idea proposed in the paper by Zhang, Bao [1], is about a new edge detection by scale multiplication in wavelet domain. The idea is to multiply two adjacent scales of dyadic wavelet transforms as a product function to magnify the edge structures and suppress noise.
- Scale Multiplication is very effective when it comes to edge detection. This is carried out by taking two wavelets with different scales and multiplying them together. The wavelet transformed image then has two components, which are the horizontal and vertical components. These components are then multiplied with the corresponding vertical and horizontal components in the next scale.
- Thresholding is then used to remove small values from edge images. . More often than not, most edge detectors will generate non-zero values for all the image pixels in the edge image. Hence with thresholding, we achieve a better edge map.

Approach

- The process of edge detection involves selecting a suitable mother wavelet and scaling of it to produce the father wavelets. This will give us two wavelets with different scales. Then the given image is wavelet transformed using wavelets in two scales. The transformed image of one scale is multiplied with the other transformed image. Then we do some post processing to get the desired edge map.
- We will be using DB-4 wavelet as the mother wavelet in our project.

Approach - Scale Multiplication

- The Scale multiplication involves using Gaussian filter differentiated in X and Y direction to find the respective gradients.
- The Gaussian Filter is then scaled for a bigger scale and their respective gradients are found. This gives the edges in X and Y direction found using the Gaussian derivative filter.
- By using the formula given below, the two wavelet functions for the wavelet is found.

$$\psi^1(x, y) = \frac{\partial \theta(x, y)}{\partial x}, \quad \psi^2(x, y) = \frac{\partial \theta(x, y)}{\partial y}$$

$$W_j f(x) = f * \psi_j(x)$$

Approach – Scale Multiplication

- The given image is filtered using the 2 wavelets calculated. This gives the W_{11} and W_{21} for the scale J . Now the other wavelet is constructed using the same way but with a larger Gaussian filter scale. This will yield 2 wavelets which is applied to the image to get the wavelet transformed image W_{21} and W_{22} . Thus the edge in the X and Y direction of the image is found using the wavelets.

$$P_j^{f,1}(x,y) = W_j^1 f(x,y) \cdot W_{j+1}^1 f(x,y)$$

Approach – Scale Multiplication

- After finding the edges in X and Y direction using the 2 scales of the wavelet (i.e. Gaussian filter here) we multiply the edge image in X direction with the corresponding edge image in X direction found using the higher scale. The same is done for Y direction edge image.
- Using the below formula, the edge map of the image is found using the scale multiplication process.

$$M_{jf}(x, y) = \sqrt{P_j^{f,1}(x, y) + P_j^{f,2}(x, y)}$$

Approach - Thresholding

- Now the obtained edge map $M f(x, y)$ is thresholded and some post processing is performed.
- Some examples of post processing include non-maximal suppression, which is deleting the points in the edge image whose magnitude is less than the neighboring pixels which are in the direction of the pixel under consideration
- Then proper thresholding is done using the threshold value. We have taken various threshold values for our results.

Approach - Superimposing Edges

- After getting the Edge map from the Edge detector, we superimpose the edge map with the original image
- The contrast of the edges depends upon the weightage we will take of the edge map while superimposing
- More weightage will lead to color loss of the image, but increment in edge contrast and edge enhancement is done

RESULTS

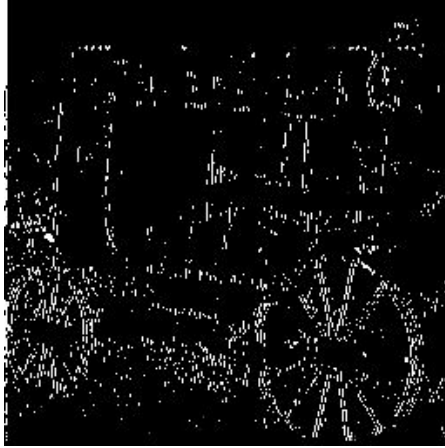
Parameters Used:

- Threshold = $1e5$
- db4 threshold = 15
- weight factor of edges = 0.2

Results (Carriage)



Original



Vertical Edge



Horizontal Edges



Diagonal edges

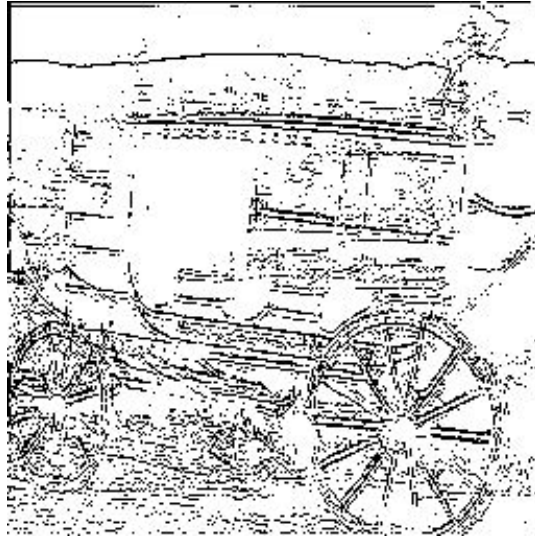
Parameters: Threshold = $1e5$, db4 threshold = 15, weight factor of edges = 0.2

Results (Carriage)



Original

+



Combined edges

=



Enhanced Edge image

Results



Original



Vertical Edge



Horizontal Edges



Diagonal edges

Results



Original

+



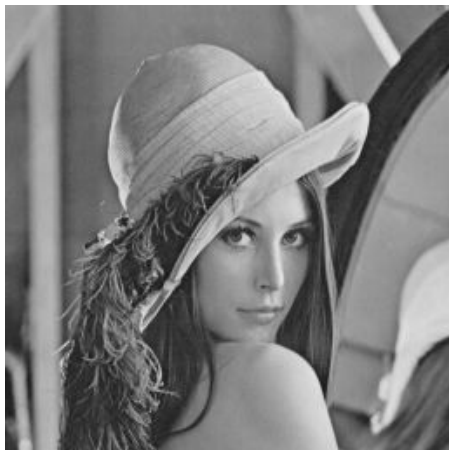
Combined edges

=

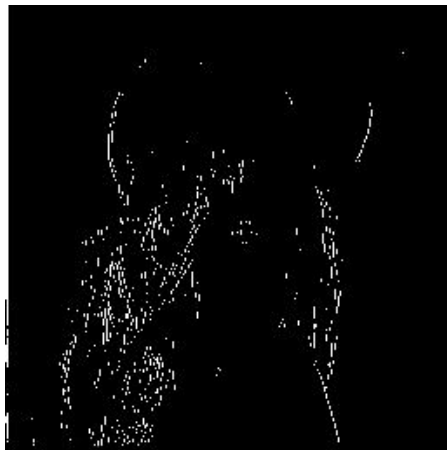


Enhanced Edge image

Results



Original



Vertical Edge



Horizontal Edges



Diagonal edges

Results



Original

+



Combined edges

=

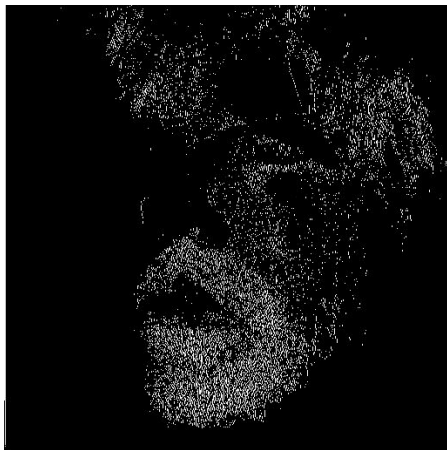


Enhanced Edge image

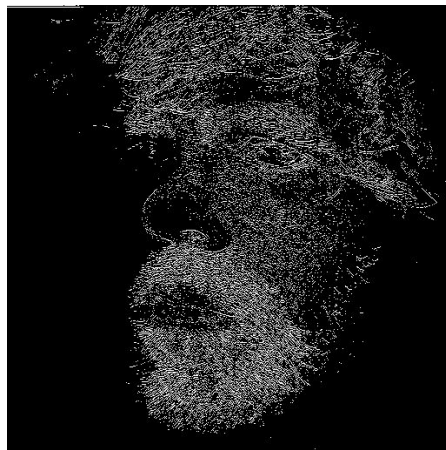
Results



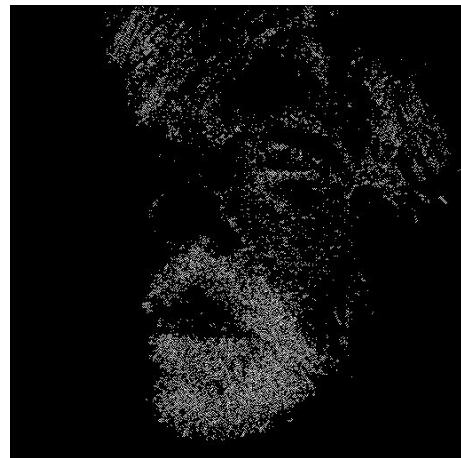
Original



Vertical Edge



Horizontal Edges



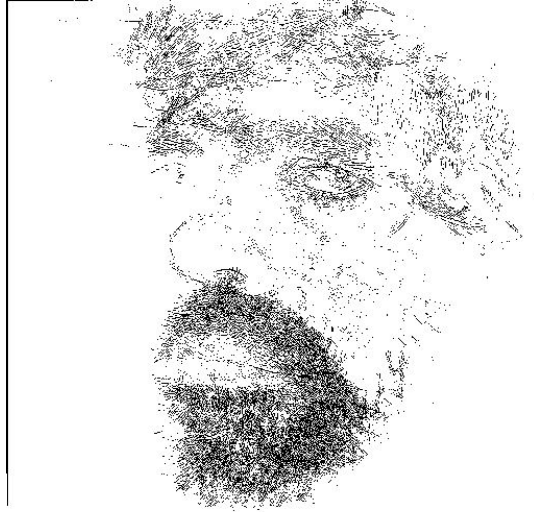
Diagonal edges

Results



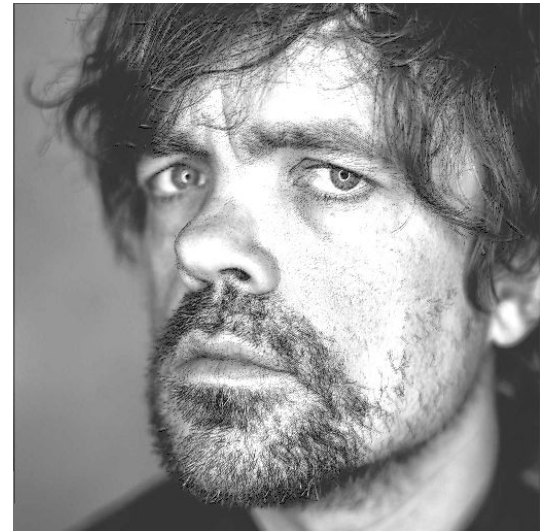
Original

+



Combined edges

=

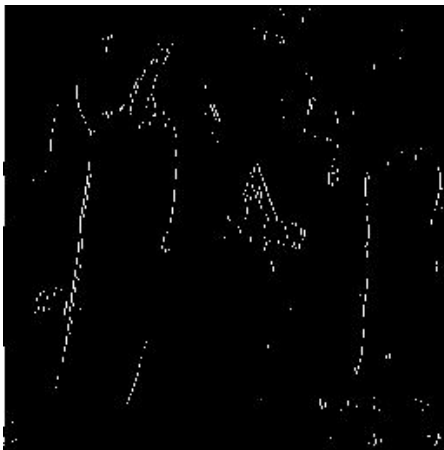


Enhanced Edge image

Results



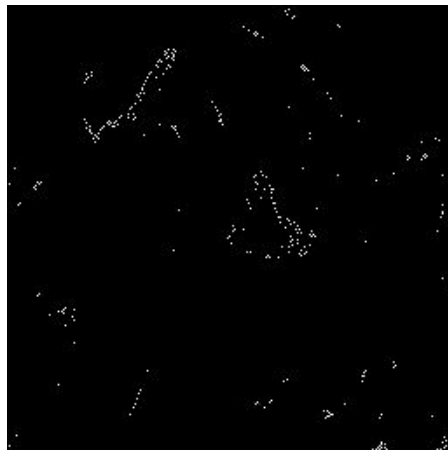
Original



Vertical Edge



Horizontal Edges



Diagonal edges

Results



Original

+



Combined edges

=



Enhanced Edge image

PARAMETER TUNING

Parameters to be tuned:

- Weight of the edge mapping while superimposing
- Overall Threshold
- DB4 threshold

Weight of Edge Mapping

DB4 threshold = 15
Overall Threshold = $1e5$



0.01



0.05

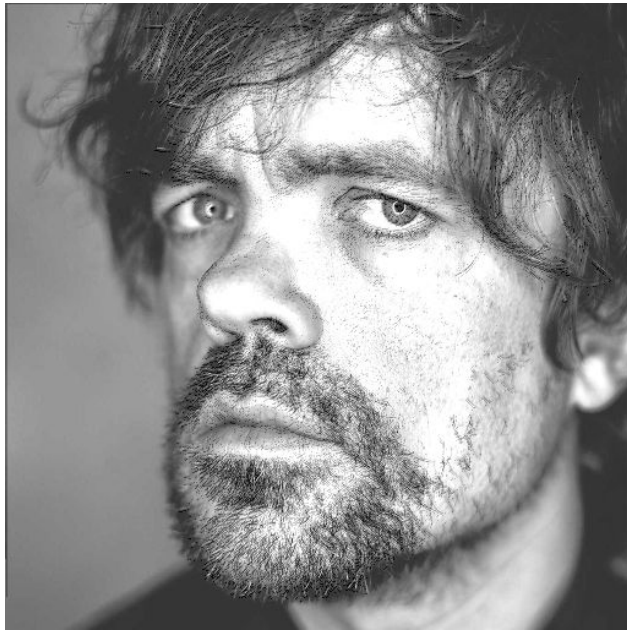


0.1

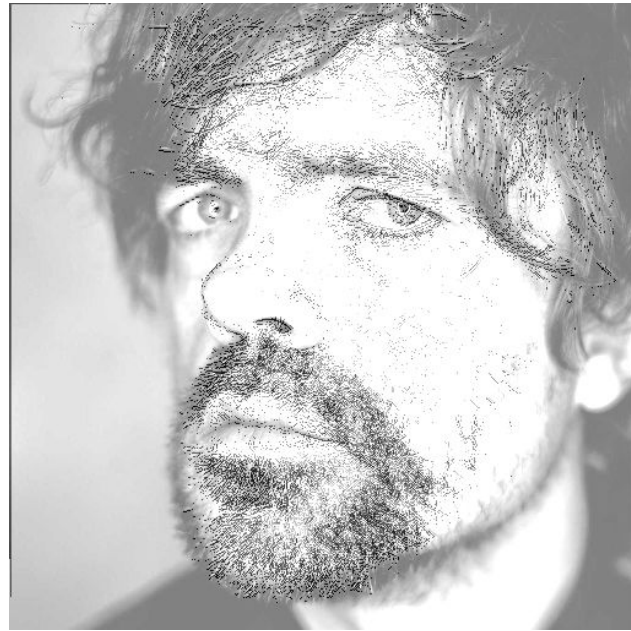
Weight of Edge Mapping



0.15



0.20



0.50

Weight of Edge Mapping



0.01



0.05



0.1

Weight of Edge Mapping



0.15



0.20



0.50

Overall Threshold

Weight of edge mapping = 0.15
DB4 threshold = 15



Original Image



overall threshold = 1e3



enhanced edges

Overall Threshold

Weight of edge mapping = 0.15
DB4 threshold = 15



Original Image



overall threshold = 1e4



enhanced edges

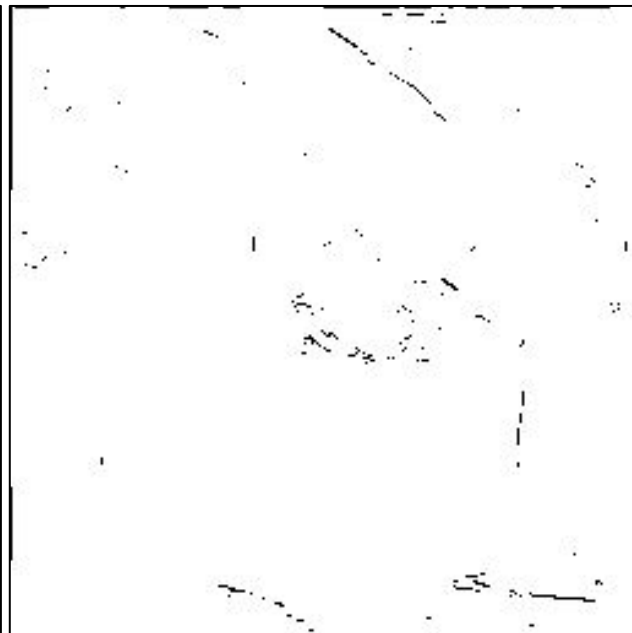
Overall Threshold



overall threshold = 10^5



overall threshold = 10^6



overall threshold = 10^7

Overall Threshold (Enhanced Images)



overall threshold = $1e3$



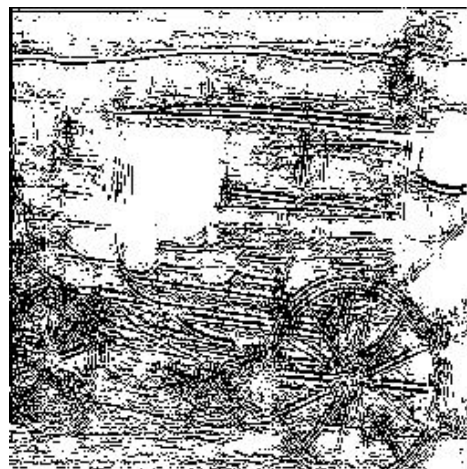
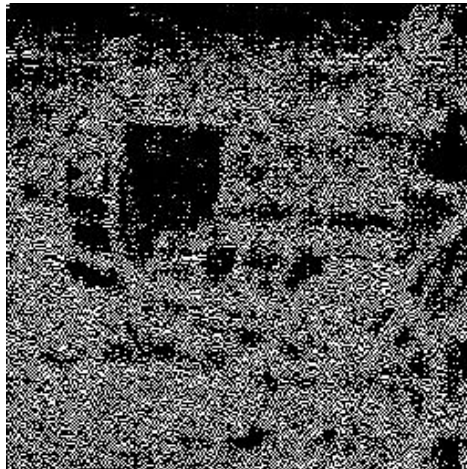
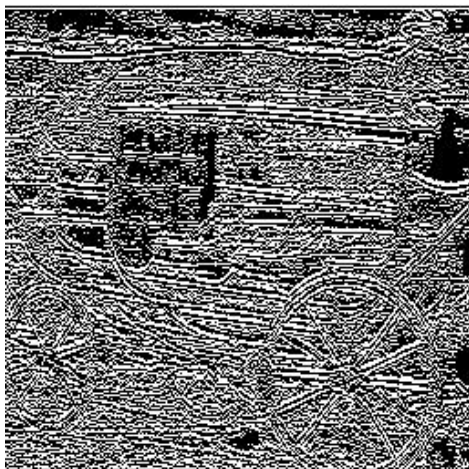
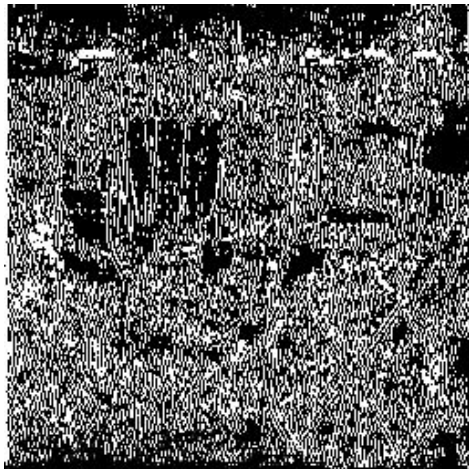
overall threshold = $1e5$



overall threshold = $1e7$

DB4 Threshold

Weight of edge mapping = 0.15
Overall Threshold = $1e5$

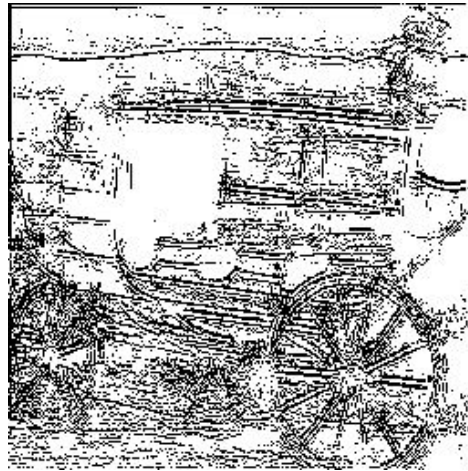


DB4 Threshold = 1

DB4 Threshold

Weight of edge mapping = 0.15

Overall Threshold = $1e5$

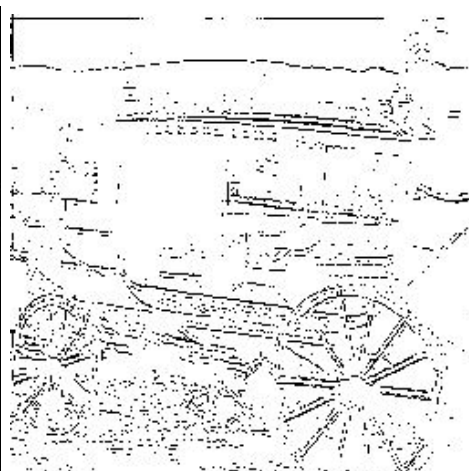


DB4 Threshold = 5

DB4 Threshold

Weight of edge mapping = 0.15

Overall Threshold = $1e5$



DB4 Threshold = 30

DB4 Threshold (Enhanced Images)



Original Image



DB4 threshold = 1



DB4 threshold = 5

DB4 Threshold (Enhanced Images)



DB4 Threshold = 10



DB4 threshold = 15



DB4 threshold = 30

Conclusions

- Edge Enhancement can be done by, first, discovering the edge mappings through edge detection methods, second, superimposing the edge mappings on the image with some weight.
- As the superimposing weight increases, edge contrast increases, but color loss occur.
- As the threshold limit is low, more noise used to occur while edge enhancement, due to the appearance of minor edges also.

APPENDIX

[1] - L. Zhang and P. Bao, “Edge detection by scale multiplication in wavelet domain,” Pattern Recognition Letters, Vol. 23, No. 14, pp. 1771-1784, December 2002

[2] - [Google Colab File for implementation](#)

[3] - [Images used in the analysis](#)