922 U0610 電腦視覺
Computer Vision

Homework 10

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I. INTRODUCTION

1.1. Descriptions of Problem

This homework is to do zero crossing edge detection with following rules:

A. Laplacian mask 1 with threshold of 15.

B. Laplacian mask 2 with threshold of 15.

C. Minimum variance Laplacian with threshold of 20.

D. Laplacian of Gaussian with threshold of 3000.

E. Difference of Gaussian with threshold of 1.

1.2. Programming Tools

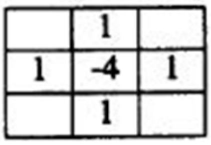
1.2.1. Programming Language: Python3

1.2.2. Programming IDE: Visual Studio Code

II. METHOD

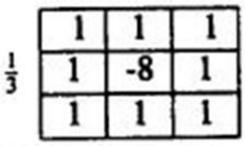
2.1. Algorithms

2.1.1. Laplacian mask 1



	1	
1	-4	1
	1	

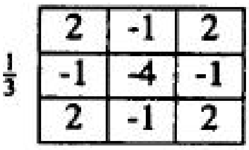
2.1.2. Laplacian mask 2



$\frac{1}{3}$

1	1	1
1	-8	1
1	1	1

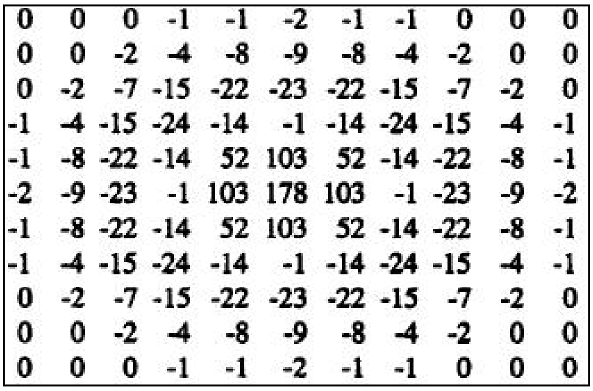
2.1.3. Minimum variance Laplacian



$\frac{1}{3}$

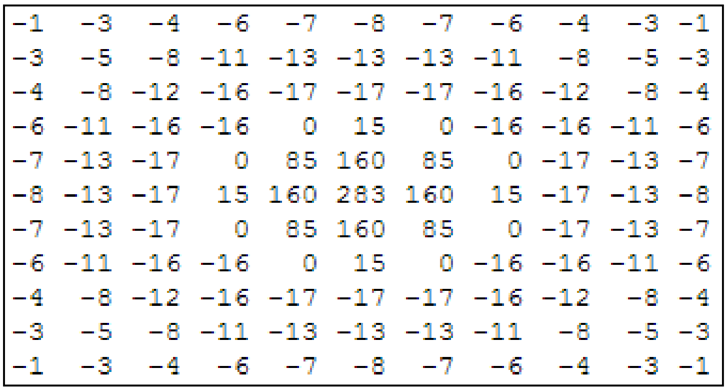
2	-1	2
-1	-4	-1
2	-1	2

2.1.4. Laplacian of Gaussian



0	0	0	-1	-1	-2	-1	-1	0	0	0
0	0	-2	-4	-8	-9	-8	-4	-2	0	0
0	-2	-7	-15	-22	-23	-22	-15	-7	-2	0
-1	-4	-15	-24	-14	-1	-14	-24	-15	-4	-1
-1	-8	-22	-14	52	103	52	-14	-22	-8	-1
-2	-9	-23	-1	103	178	103	-1	-23	-9	-2
-1	-8	-22	-14	52	103	52	-14	-22	-8	-1
-1	-4	-15	-24	-14	-1	-14	-24	-15	-4	-1
0	-2	-7	-15	-22	-23	-22	-15	-7	-2	0
0	0	-2	-4	-8	-9	-8	-4	-2	0	0
0	0	0	-1	-1	-2	-1	-1	0	0	0

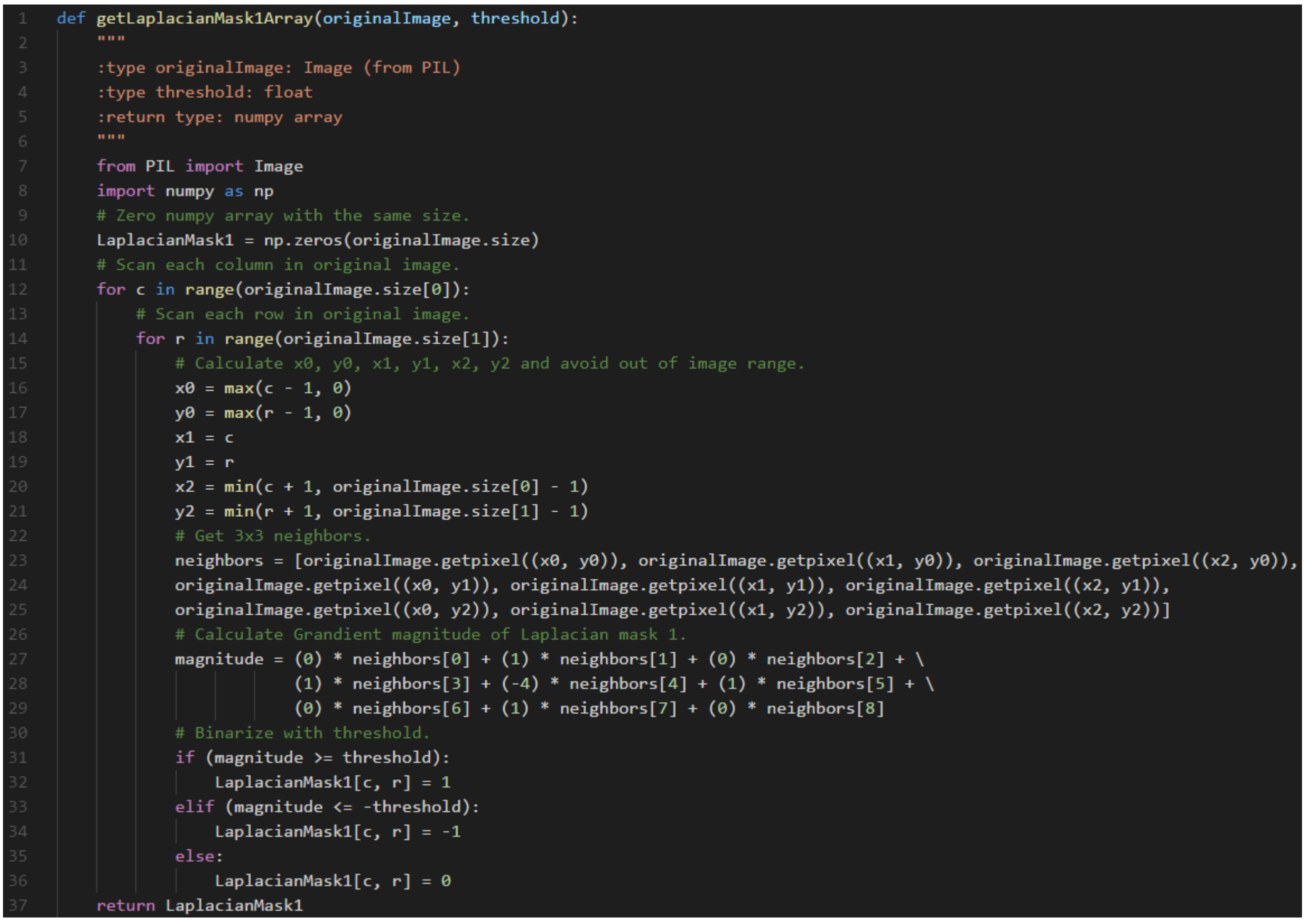
2.1.5. Difference of Gaussian



-1	-3	-4	-6	-7	-8	-7	-6	-4	-3	-1
-3	-5	-8	-11	-13	-13	-13	-11	-8	-5	-3
-4	-8	-12	-16	-17	-17	-17	-16	-12	-8	-4
-6	-11	-16	-16	0	15	0	-16	-16	-11	-6
-7	-13	-17	0	85	160	85	0	-17	-13	-7
-8	-13	-17	15	160	283	160	15	-17	-13	-8
-7	-13	-17	0	85	160	85	0	-17	-13	-7
-6	-11	-16	-16	0	15	0	-16	-16	-11	-6
-4	-8	-12	-16	-17	-17	-17	-16	-12	-8	-4
-3	-5	-8	-11	-13	-13	-13	-11	-8	-5	-3
-1	-3	-4	-6	-7	-8	-7	-6	-4	-3	-1

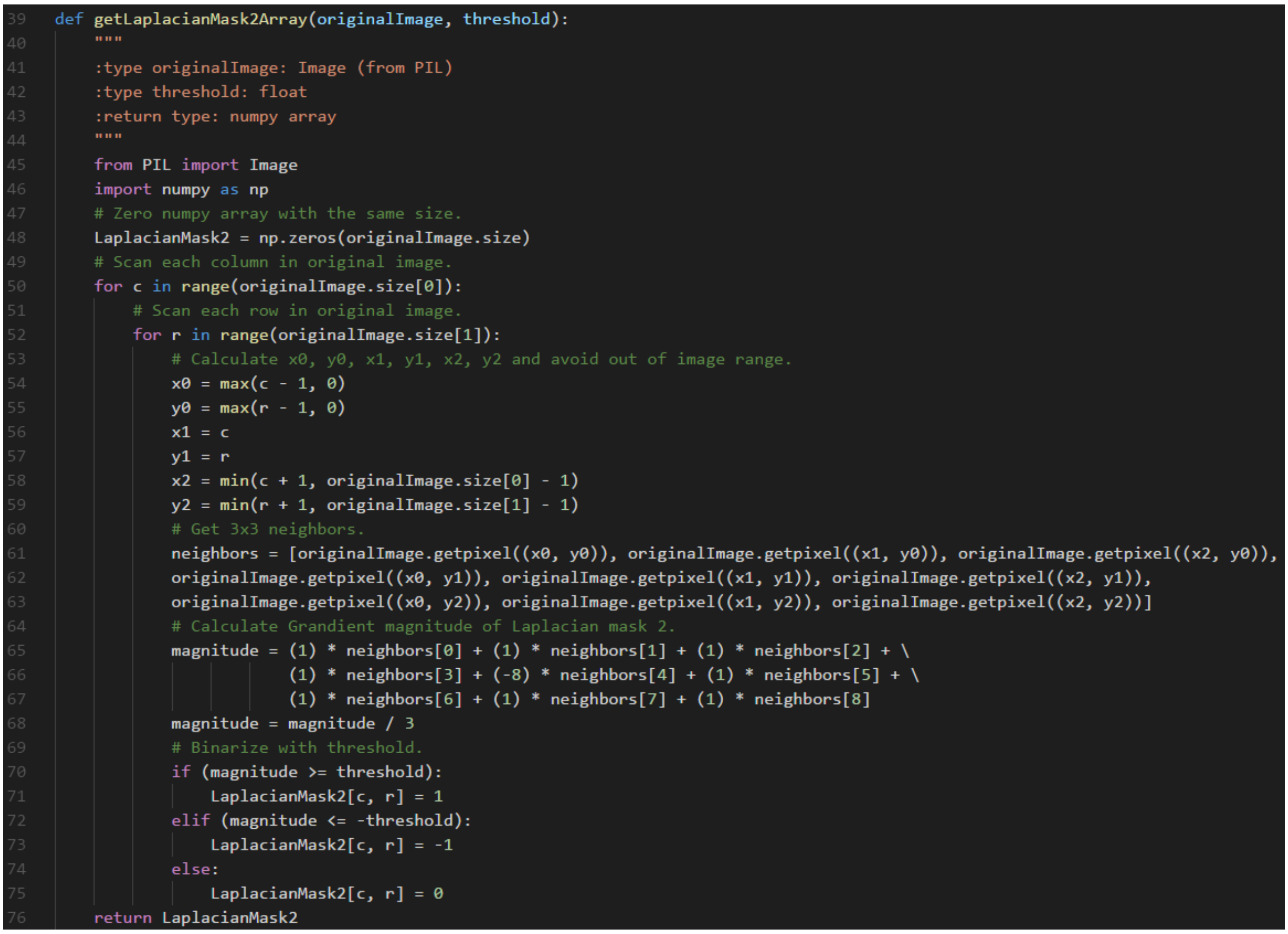
2.2. Code Fragments

2.2.1. Code fragments of this homework



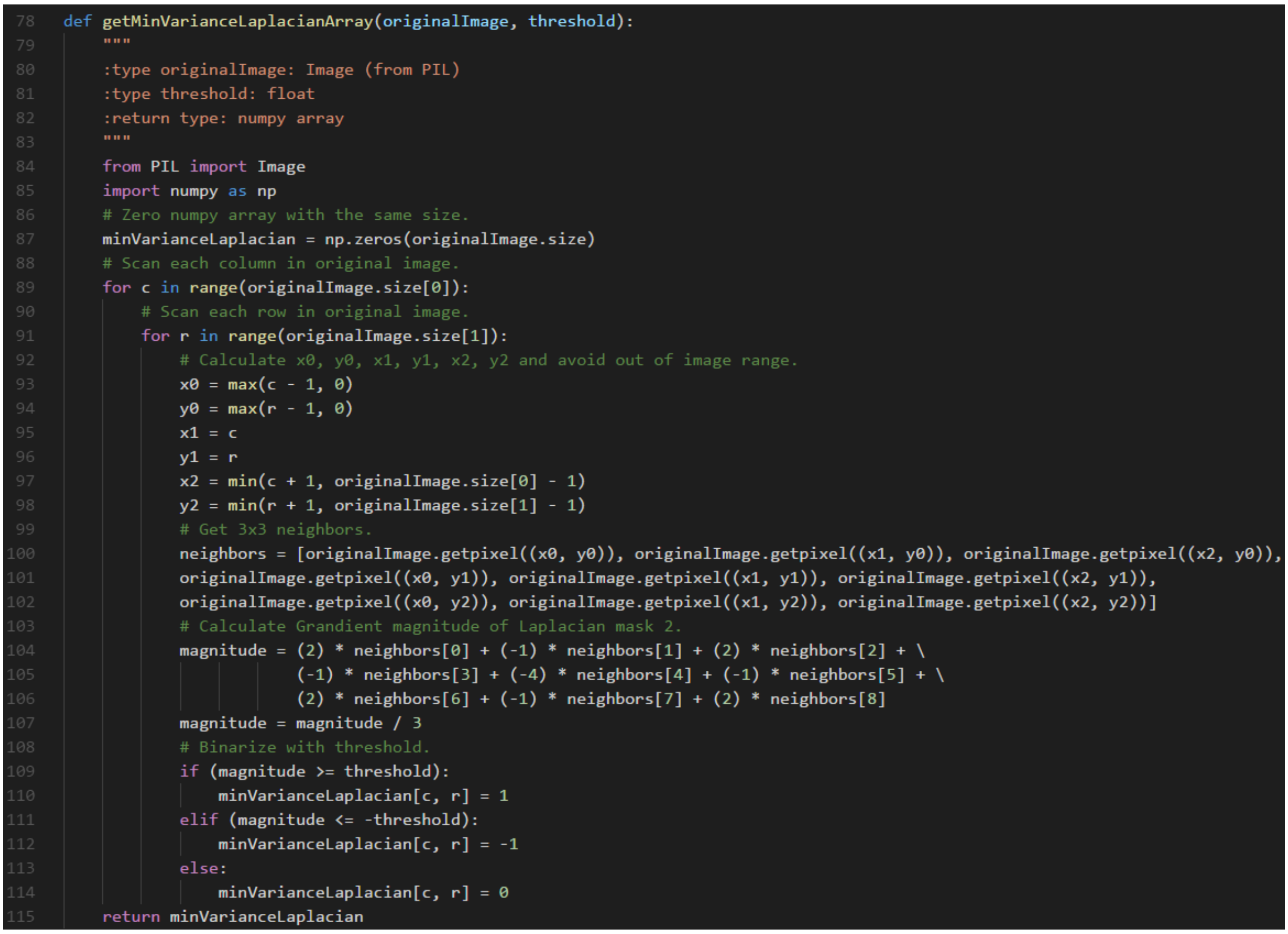
```python
def getLaplacianMask1Array(originalImage, threshold):
    """
    :type originalImage: Image (from PIL)
    :type threshold: float
    :return type: numpy array
    """
    from PIL import Image
    import numpy as np
    # Zero numpy array with the same size.
    LaplacianMask1 = np.zeros(originalImage.size)
    # Scan each column in original image.
    for c in range(originalImage.size[0]):
        # Scan each row in original image.
        for r in range(originalImage.size[1]):
            # Calculate x0, y0, x1, y1, x2, y2 and avoid out of image range.
            x0 = max(c - 1, 0)
            y0 = max(r - 1, 0)
            x1 = c
            y1 = r
            x2 = min(c + 1, originalImage.size[0] - 1)
            y2 = min(r + 1, originalImage.size[1] - 1)
            # Get 3x3 neighbors.
            neighbors = [originalImage.getpixel((x0, y0)), originalImage.getpixel((x1, y0)), originalImage.getpixel((x2, y0)),
            originalImage.getpixel((x0, y1)), originalImage.getpixel((x1, y1)), originalImage.getpixel((x2, y1)),
            originalImage.getpixel((x0, y2)), originalImage.getpixel((x1, y2)), originalImage.getpixel((x2, y2))]
            # Calculate Grandient magnitude of Laplacian mask 1.
            magnitude = (0) * neighbors[0] + (1) * neighbors[1] + (0) * neighbors[2] + \
                        (1) * neighbors[3] + (-4) * neighbors[4] + (1) * neighbors[5] + \
                        (0) * neighbors[6] + (1) * neighbors[7] + (0) * neighbors[8]
            # Binarize with threshold.
            if (magnitude >= threshold):
                LaplacianMask1[c, r] = 1
            elif (magnitude <= -threshold):
                LaplacianMask1[c, r] = -1
            else:
                LaplacianMask1[c, r] = 0
    return LaplacianMask1
```

Figure 2.2.1.1. Code of Laplacian mask 1.



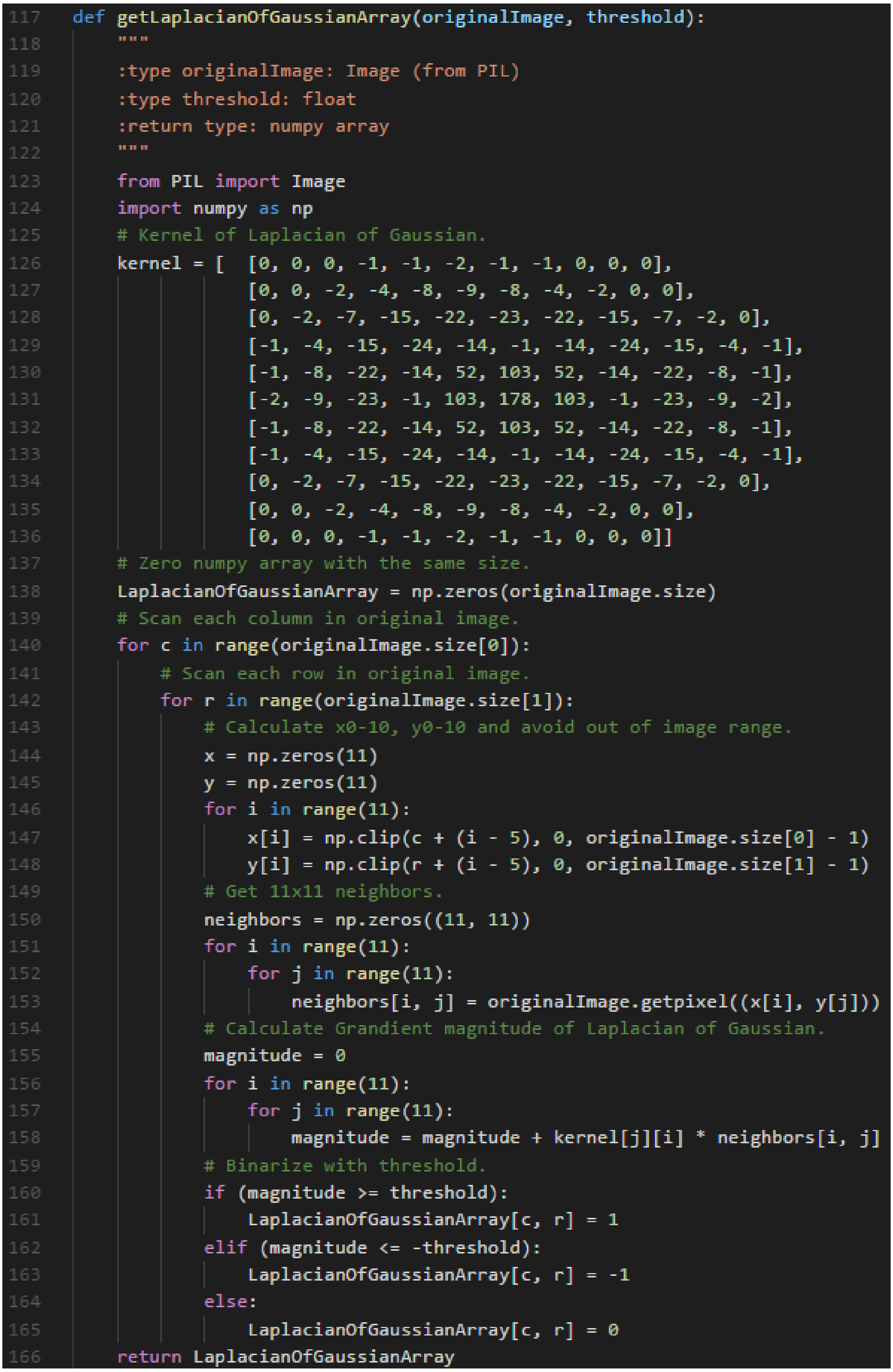
```
def getLaplacianMask2Array(originalImage, threshold):
    """
    :type originalImage: Image (from PIL)
    :type threshold: float
    :return type: numpy array
    """
    from PIL import Image
    import numpy as np
    # Zero numpy array with the same size.
    LaplacianMask2 = np.zeros(originalImage.size)
    # Scan each column in original image.
    for c in range(originalImage.size[0]):
        # Scan each row in original image.
        for r in range(originalImage.size[1]):
            # Calculate x0, y0, x1, y1, x2, y2 and avoid out of image range.
            x0 = max(c - 1, 0)
            y0 = max(r - 1, 0)
            x1 = c
            y1 = r
            x2 = min(c + 1, originalImage.size[0] - 1)
            y2 = min(r + 1, originalImage.size[1] - 1)
            # Get 3x3 neighbors.
            neighbors = [originalImage.getpixel((x0, y0)), originalImage.getpixel((x1, y0)), originalImage.getpixel((x2, y0)),
            originalImage.getpixel((x0, y1)), originalImage.getpixel((x1, y1)), originalImage.getpixel((x2, y1)),
            originalImage.getpixel((x0, y2)), originalImage.getpixel((x1, y2)), originalImage.getpixel((x2, y2))]
            # Calculate Grandient magnitude of Laplacian mask 2.
            magnitude = (1) * neighbors[0] + (1) * neighbors[1] + (1) * neighbors[2] + \
                        (1) * neighbors[3] + (-8) * neighbors[4] + (1) * neighbors[5] + \
                        (1) * neighbors[6] + (1) * neighbors[7] + (1) * neighbors[8]
            magnitude = magnitude / 3
            # Binarize with threshold.
            if (magnitude >= threshold):
                LaplacianMask2[c, r] = 1
            elif (magnitude <= -threshold):
                LaplacianMask2[c, r] = -1
            else:
                LaplacianMask2[c, r] = 0
    return LaplacianMask2
```

Figure 2.2.1.2. Code of Laplacian mask 2.



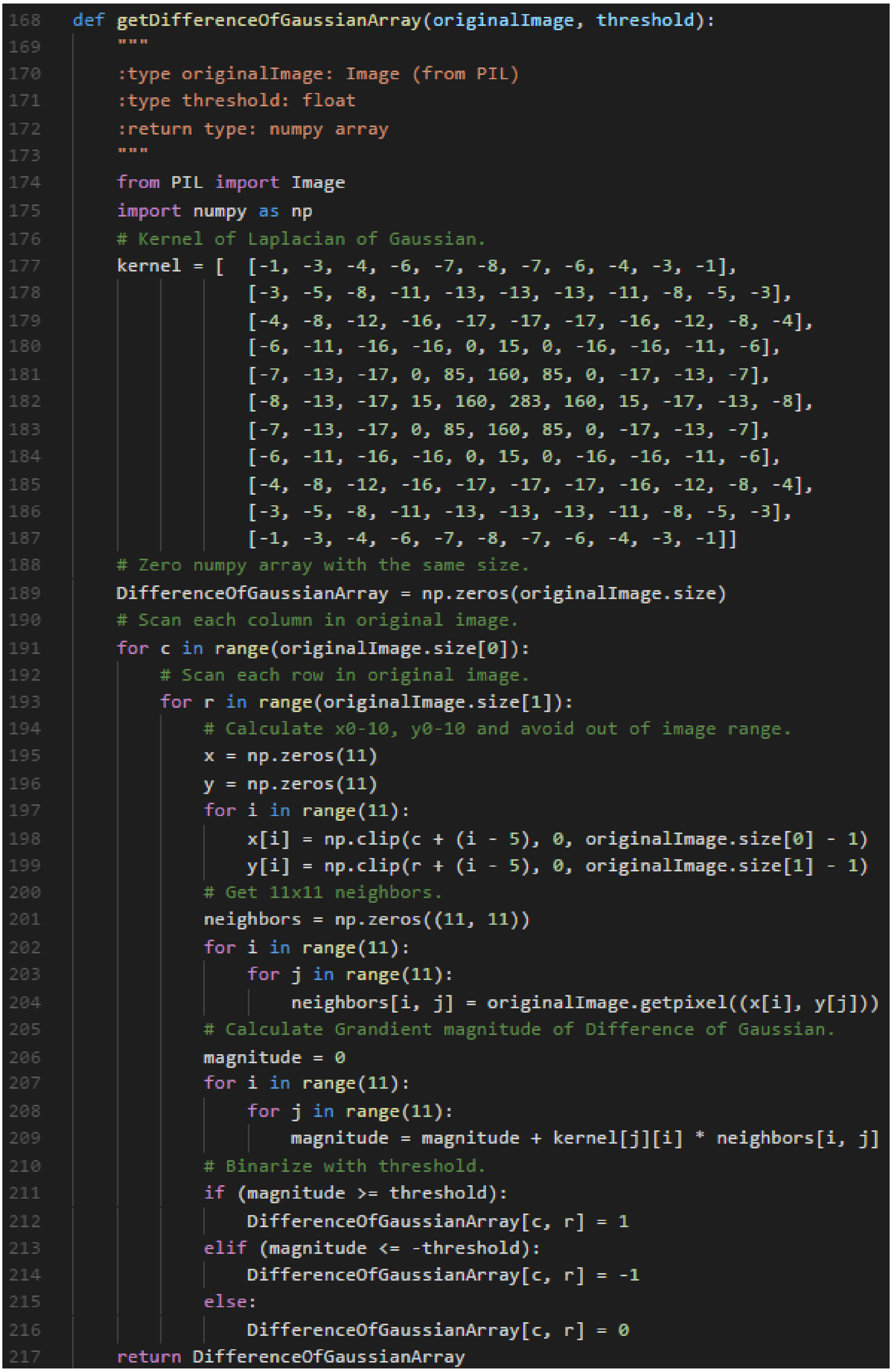
```python
def getMinVarianceLaplacianArray(originalImage, threshold):
    """
    :type originalImage: Image (from PIL)
    :type threshold: float
    :return type: numpy array
    """
    from PIL import Image
    import numpy as np
    # Zero numpy array with the same size.
    minVarianceLaplacian = np.zeros(originalImage.size)
    # Scan each column in original image.
    for c in range(originalImage.size[0]):
        # Scan each row in original image.
        for r in range(originalImage.size[1]):
            # Calculate x0, y0, x1, y1, x2, y2 and avoid out of image range.
            x0 = max(c - 1, 0)
            y0 = max(r - 1, 0)
            x1 = c
            y1 = r
            x2 = min(c + 1, originalImage.size[0] - 1)
            y2 = min(r + 1, originalImage.size[1] - 1)
            # Get 3x3 neighbors.
            neighbors = [originalImage.getpixel((x0, y0)), originalImage.getpixel((x1, y0)), originalImage.getpixel((x2, y0)),
            originalImage.getpixel((x0, y1)), originalImage.getpixel((x1, y1)), originalImage.getpixel((x2, y1)),
            originalImage.getpixel((x0, y2)), originalImage.getpixel((x1, y2)), originalImage.getpixel((x2, y2))]
            # Calculate Grandient magnitude of Laplacian mask 2.
            magnitude = (2) * neighbors[0] + (-1) * neighbors[1] + (2) * neighbors[2] + \
                        (-1) * neighbors[3] + (-4) * neighbors[4] + (-1) * neighbors[5] + \
                        (2) * neighbors[6] + (-1) * neighbors[7] + (2) * neighbors[8]
            magnitude = magnitude / 3
            # Binarize with threshold.
            if (magnitude >= threshold):
                minVarianceLaplacian[c, r] = 1
            elif (magnitude <= -threshold):
                minVarianceLaplacian[c, r] = -1
            else:
                minVarianceLaplacian[c, r] = 0
    return minVarianceLaplacian
```

Figure 2.2.1.3. Code of Minimum variance Laplacian.



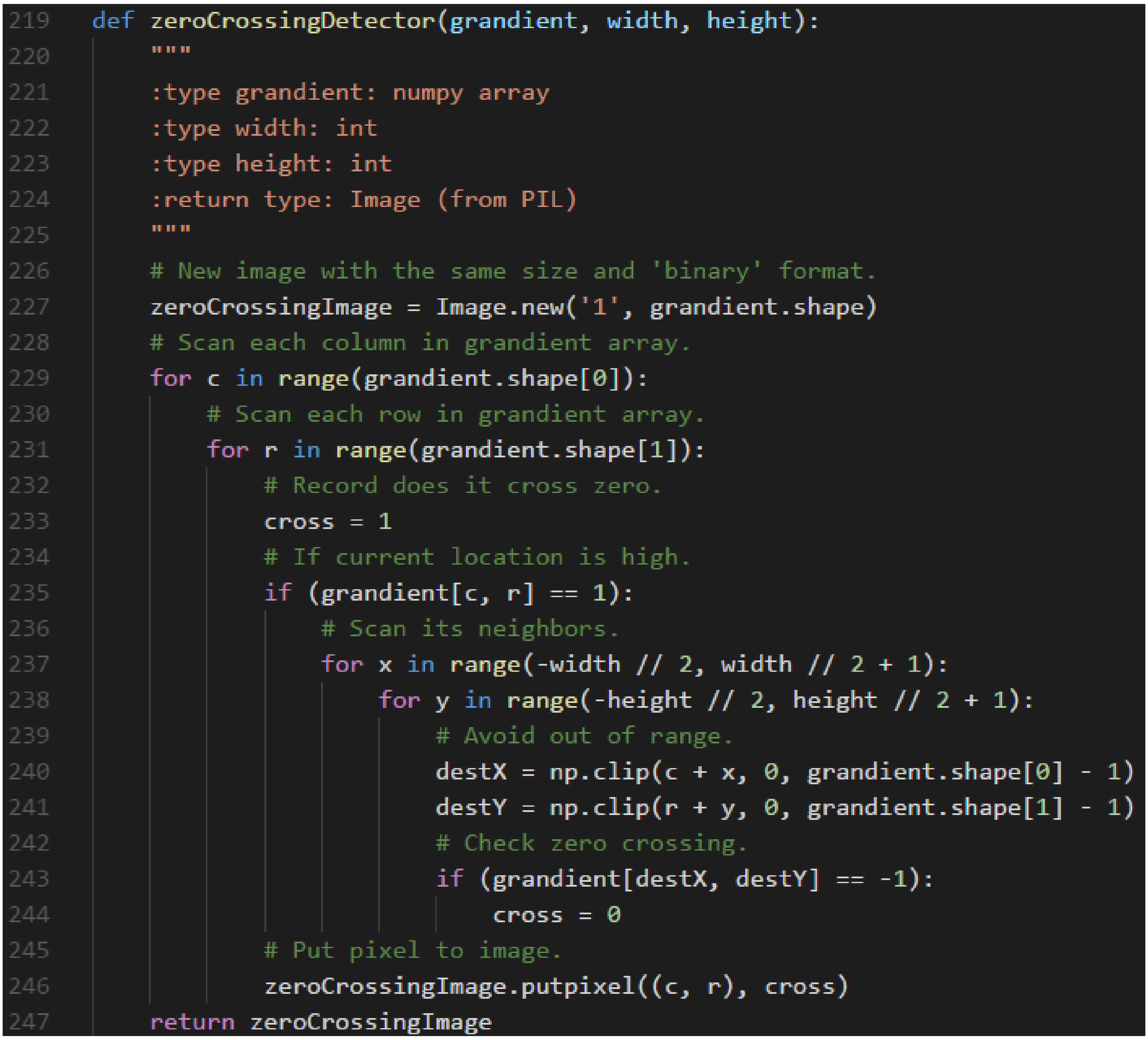
```python
def getLaplacianOfGaussianArray(originalImage, threshold):
    """
    :type originalImage: Image (from PIL)
    :type threshold: float
    :return type: numpy array
    """
    from PIL import Image
    import numpy as np
    # Kernel of Laplacian of Gaussian.
    kernel = [  [0, 0, 0, -1, -1, -2, -1, -1, 0, 0, 0],
                [0, 0, -2, -4, -8, -9, -8, -4, -2, 0, 0],
                [0, -2, -7, -15, -22, -23, -22, -15, -7, -2, 0],
                [-1, -4, -15, -24, -14, -1, -14, -24, -15, -4, -1],
                [-1, -8, -22, -14, 52, 103, 52, -14, -22, -8, -1],
                [-2, -9, -23, -1, 103, 178, 103, -1, -23, -9, -2],
                [-1, -8, -22, -14, 52, 103, 52, -14, -22, -8, -1],
                [-1, -4, -15, -24, -14, -1, -14, -24, -15, -4, -1],
                [0, -2, -7, -15, -22, -23, -22, -15, -7, -2, 0],
                [0, 0, -2, -4, -8, -9, -8, -4, -2, 0, 0],
                [0, 0, 0, -1, -1, -2, -1, -1, 0, 0, 0]]
    # Zero numpy array with the same size.
    LaplacianOfGaussianArray = np.zeros(originalImage.size)
    # Scan each column in original image.
    for c in range(originalImage.size[0]):
        # Scan each row in original image.
        for r in range(originalImage.size[1]):
            # Calculate x0-10, y0-10 and avoid out of image range.
            x = np.zeros(11)
            y = np.zeros(11)
            for i in range(11):
                x[i] = np.clip(c + (i - 5), 0, originalImage.size[0] - 1)
                y[i] = np.clip(r + (i - 5), 0, originalImage.size[1] - 1)
            # Get 11x11 neighbors.
            neighbors = np.zeros((11, 11))
            for i in range(11):
                for j in range(11):
                    neighbors[i, j] = originalImage.getpixel((x[i], y[j]))
            # Calculate Grandient magnitude of Laplacian of Gaussian.
            magnitude = 0
            for i in range(11):
                for j in range(11):
                    magnitude = magnitude + kernel[j][i] * neighbors[i, j]
            # Binarize with threshold.
            if (magnitude >= threshold):
                LaplacianOfGaussianArray[c, r] = 1
            elif (magnitude <= -threshold):
                LaplacianOfGaussianArray[c, r] = -1
            else:
                LaplacianOfGaussianArray[c, r] = 0
    return LaplacianOfGaussianArray
```

Figure 2.2.1.4. Code of Laplacian of Gaussian.



```python
def getDifferenceOfGaussianArray(originalImage, threshold):
    """
    :type originalImage: Image (from PIL)
    :type threshold: float
    :return type: numpy array
    """
    from PIL import Image
    import numpy as np
    # Kernel of Laplacian of Gaussian.
    kernel = [  [-1, -3, -4, -6, -7, -8, -7, -6, -4, -3, -1],
                [-3, -5, -8, -11, -13, -13, -13, -11, -8, -5, -3],
                [-4, -8, -12, -16, -17, -17, -17, -16, -12, -8, -4],
                [-6, -11, -16, -16, 0, 15, 0, -16, -16, -11, -6],
                [-7, -13, -17, 0, 85, 160, 85, 0, -17, -13, -7],
                [-8, -13, -17, 15, 160, 283, 160, 15, -17, -13, -8],
                [-7, -13, -17, 0, 85, 160, 85, 0, -17, -13, -7],
                [-6, -11, -16, -16, 0, 15, 0, -16, -16, -11, -6],
                [-4, -8, -12, -16, -17, -17, -17, -16, -12, -8, -4],
                [-3, -5, -8, -11, -13, -13, -13, -11, -8, -5, -3],
                [-1, -3, -4, -6, -7, -8, -7, -6, -4, -3, -1]]
    # Zero numpy array with the same size.
    DifferenceOfGaussianArray = np.zeros(originalImage.size)
    # Scan each column in original image.
    for c in range(originalImage.size[0]):
        # Scan each row in original image.
        for r in range(originalImage.size[1]):
            # Calculate x0-10, y0-10 and avoid out of image range.
            x = np.zeros(11)
            y = np.zeros(11)
            for i in range(11):
                x[i] = np.clip(c + (i - 5), 0, originalImage.size[0] - 1)
                y[i] = np.clip(r + (i - 5), 0, originalImage.size[1] - 1)
            # Get 11x11 neighbors.
            neighbors = np.zeros((11, 11))
            for i in range(11):
                for j in range(11):
                    neighbors[i, j] = originalImage.getpixel((x[i], y[j]))
            # Calculate Grandient magnitude of Difference of Gaussian.
            magnitude = 0
            for i in range(11):
                for j in range(11):
                    magnitude = magnitude + kernel[j][i] * neighbors[i, j]
            # Binarize with threshold.
            if (magnitude >= threshold):
                DifferenceOfGaussianArray[c, r] = 1
            elif (magnitude <= -threshold):
                DifferenceOfGaussianArray[c, r] = -1
            else:
                DifferenceOfGaussianArray[c, r] = 0
    return DifferenceOfGaussianArray
```

Figure 2.2.1.5. Code of Difference of Gaussian.



```
def zeroCrossingDetector(grandient, width, height):
    """
    :type grandient: numpy array
    :type width: int
    :type height: int
    :return type: Image (from PIL)
    """
    # New image with the same size and 'binary' format.
    zeroCrossingImage = Image.new('1', grandient.shape)
    # Scan each column in grandient array.
    for c in range(grandient.shape[0]):
        # Scan each row in grandient array.
        for r in range(grandient.shape[1]):
            # Record does it cross zero.
            cross = 1
            # If current location is high.
            if (grandient[c, r] == 1):
                # Scan its neighbors.
                for x in range(-width // 2, width // 2 + 1):
                    for y in range(-height // 2, height // 2 + 1):
                        # Avoid out of range.
                        destX = np.clip(c + x, 0, grandient.shape[0] - 1)
                        destY = np.clip(r + y, 0, grandient.shape[1] - 1)
                        # Check zero crossing.
                        if (grandient[destX, destY] == -1):
                            cross = 0
            # Put pixel to image.
            zeroCrossingImage.putpixel((c, r), cross)
    return zeroCrossingImage
```

Figure 2.2.1.6. Code of zero crossing detector.

III. RESULTS

3.1. Original Image

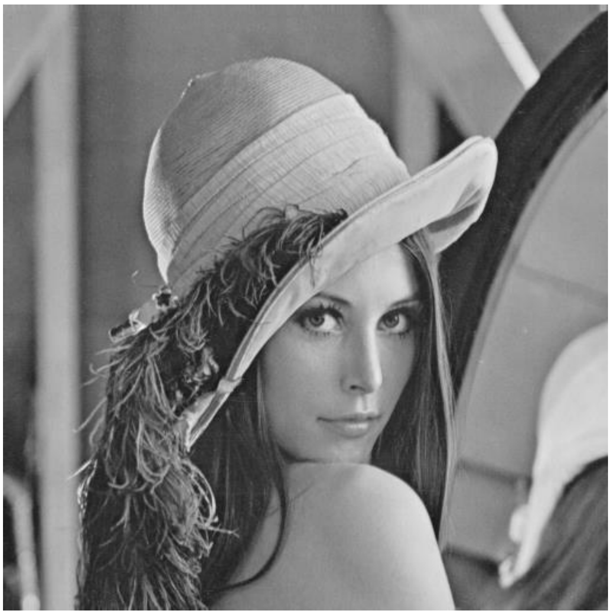


Figure 3.1. Original lena.bmp.

3.2. Result of Laplacian Mask 1 with Threshold of 15

Figure 3.2.1. Original lena.bmp.

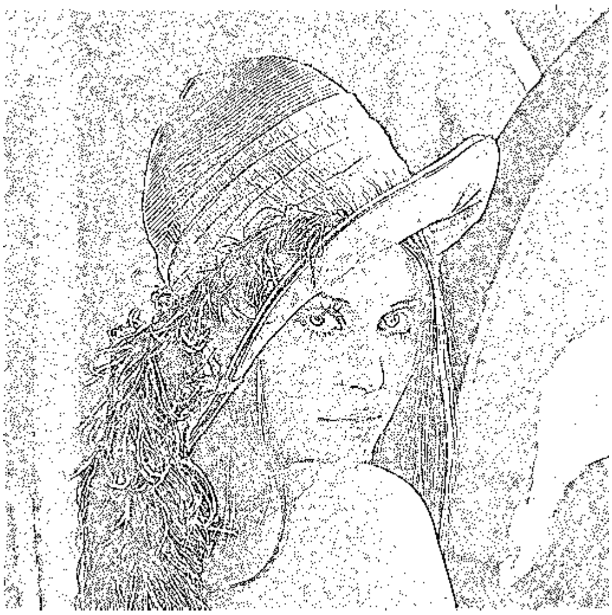


Figure 3.2.2. Laplacian Mask 1.bmp.

3.3. Result of Laplacian Mask 2 with Threshold of 15

Figure 3.3.1. Original lena.bmp.

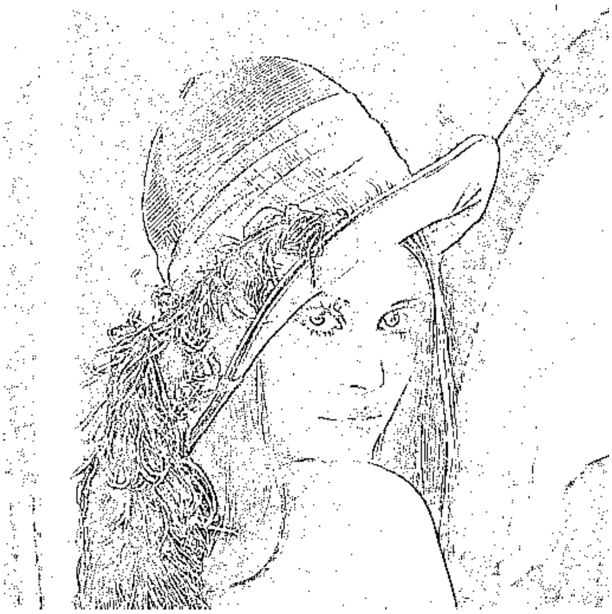


Figure 3.3.2. Laplacian Mask 2.bmp.

3.4. Result of Minimum Variance Laplacian with Threshold of 20

Figure 3.4.1. Original lena.bmp.

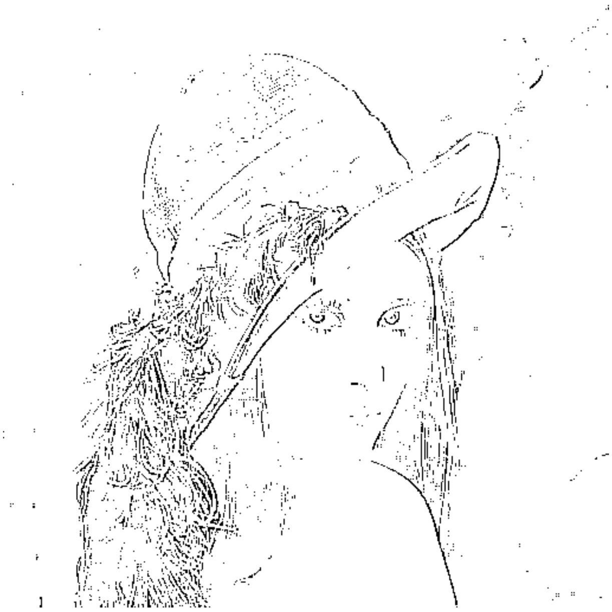


Figure 3.4.2. min-Variance Laplacian.bmp.

3.5. Result of Laplacian of Gaussian with Threshold of 3000

Figure 3.5.1. Original lena.bmp.

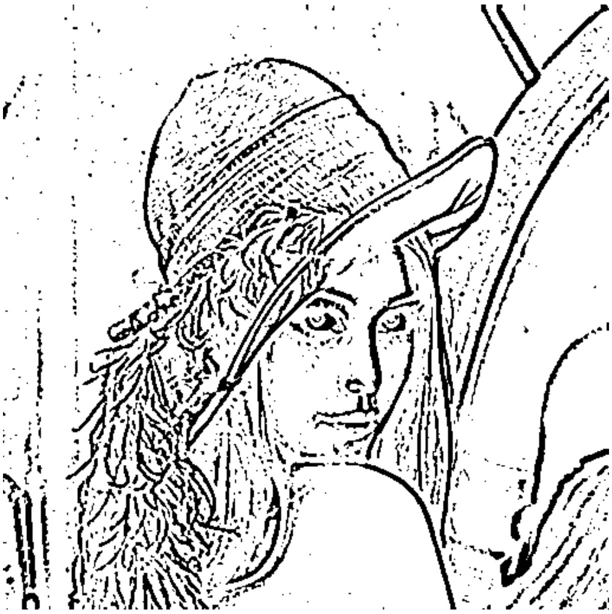


Figure 3.5.2. Laplacian of Gaussian.bmp.

3.6. Result of Difference of Gaussian with Threshold of 1

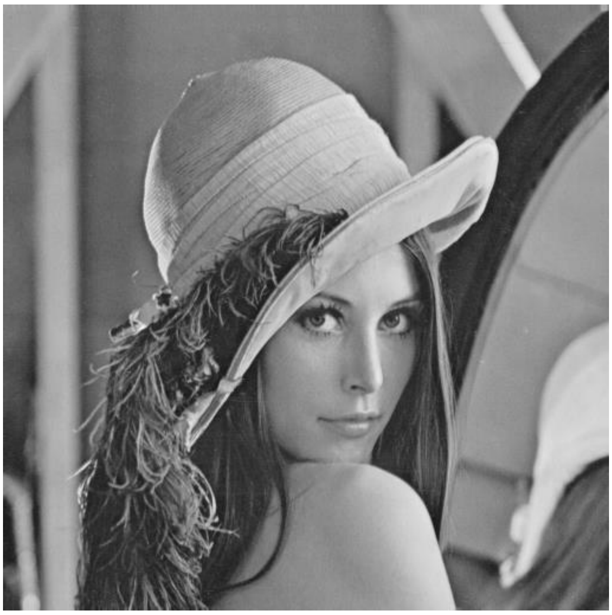


Figure 3.6.1. Original lena.bmp.

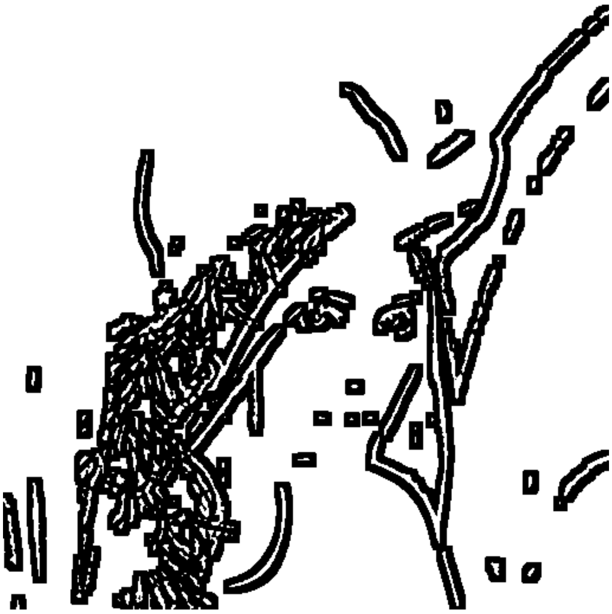


Figure 3.6.2. Difference of Gaussian.bmp.