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HomeWork 2

1.Add Guassian Noise and Compute SNR:

In [60]:
```
import cv2
import numpy as np
import matplotlib.pyplot as plt

# Load the image and convert to grayscale
image = cv2.imread('nature.jpg', cv2.IMREAD_GRAYSCALE)
image = image.astype(np.float32)

# Parameters for Gaussian noise
std_dev = 20  # Standard deviation
mean = 0  # Mean of noise
num_noisy_images = 10

noisy_images = []
for i in range(num_noisy_images):
    noise = np.random.normal(mean, std_dev, image.shape).astype(np.float32)
    noisy_image = np.clip(image + noise, 0, 255)  # Clip values
    noisy_images.append(noisy_image)
noise_power = np.mean([np.var(noisy_image - image) for noisy_image in noisy_imag

# Compute the signal power
signal_power = np.var(image)

# Compute the SNR in decibels (dB)
snr_db = 10 * np.log10(signal_power / noise_power)


print(f"Signal Power: {signal_power}")
print(f"Noise Power: {noise_power}")
print(f"SNR (dB): {snr_db}")
```

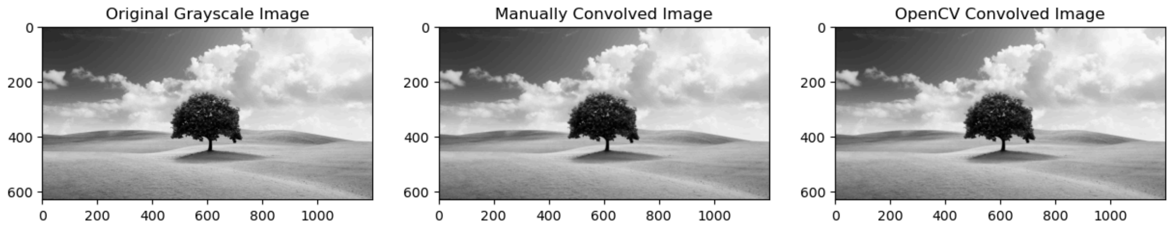
```
Signal Power: 3449.133056640625
Noise Power: 374.7096252441406
SNR (dB): 9.640151262283325
```

2. Implement a Convolution Filter for Smoothing

In [63]:
```
import cv2
import numpy as np
import matplotlib.pyplot as plt
import time

def manual_convolution(image, kernel):
    kernel_height, kernel_width = kernel.shape
```

```
    pad_height = kernel_height // 2
    pad_width = kernel_width // 2

    padded_image = np.pad(image, ((pad_height, pad_height), (pad_width, pad_widt
    output_image = np.zeros_like(image)

    for i in range(image.shape[0]):
        for j in range(image.shape[1]):
            output_image[i, j] = np.sum(kernel * padded_image[i:i + kernel_heigh

    return output_image

image = cv2.imread('nature.jpg', cv2.IMREAD_GRAYSCALE)

kernel = np.ones((3, 3)) / 9.0

start_manual = time.time()
smoothed_image_manual = manual_convolution(image, kernel)
end_manual = time.time()

start_opencv = time.time()
smoothed_image_opencv = cv2.filter2D(image, -1, kernel)
end_opencv = time.time()

print(f"Manual convolution time: {end_manual - start_manual:.5f} seconds")
print(f"OpenCV convolution time: {end_opencv - start_opencv:.5f} seconds")

plt.figure(figsize=(15, 5))
plt.subplot(1, 3, 1)
plt.imshow(image, cmap='gray')
plt.title("Original Grayscale Image")
plt.subplot(1, 3, 2)
plt.imshow(smoothed_image_manual, cmap='gray')
plt.title("Manually Convolved Image")
plt.subplot(1, 3, 3)
plt.imshow(smoothed_image_opencv, cmap='gray')
plt.title("OpenCV Convolved Image")
plt.show()
```

```
Manual convolution time: 3.45901 seconds
OpenCV convolution time: 0.01544 seconds
```



3. Convolution with Stride:

In [66]:

```
import numpy as np
import cv2
import matplotlib.pyplot as plt

def convolution_with_stride(image, kernel, stride=2):
    image_h, image_w = image.shape
    kernel_h, kernel_w = kernel.shape
    pad_h = kernel_h // 2
```

```
    pad_w = kernel_w // 2
    padded_image = np.pad(image, ((pad_h, pad_w), (pad_h, pad_w)), mode="constan
    output_h = ((image_h - kernel_h) // stride) + 1
    output_w = ((image_w - kernel_w) // stride) + 1

    output_image = np.zeros((output_h, output_w), dtype=np.float32)

    for i in range(0, output_h * stride, stride):
        for j in range(0, output_w * stride, stride):
            region = padded_image[i:i+kernel_h, j:j+kernel_w]  # Extract 3x3 reg
            output_image[i//stride, j//stride] = np.sum(region * kernel)  # Comp

    return output_image
image = cv2.imread("jug.jpg", cv2.IMREAD_GRAYSCALE)

kernel = np.ones((3, 3)) / 9.0
stride_values = [1, 2, 3]

plt.figure(figsize=(15, 5))

for idx, stride in enumerate(stride_values, 1):
    smoothed_image_stride = convolution_with_stride(image, kernel, stride=stride

    plt.subplot(1, len(stride_values), idx)
    plt.imshow(smoothed_image_stride, cmap="gray")
    plt.title(f"Stride = {stride}")
    plt.axis("off")

plt.figure(figsize=(5,5))
plt.imshow(image, cmap="gray")
plt.title("Original Grayscale Image")
plt.axis("off")

plt.show()
```

Stride = 1

Stride = 2

Stride = 3

Original Grayscale Image

4. Compute and Apply a Gaussian Smoothing Filter:

Gaussian smoothing is a technique to remove noise and smooth an image. It applies a Gaussian filter

cv2.filter2D() applies the Gaussian filter to the image.

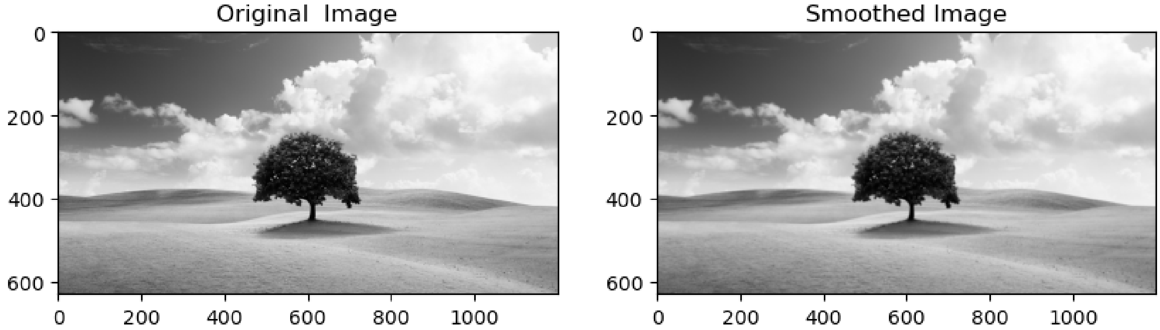
It smooths out details and removes noise. After applying Gaussian smoothing, the image becomes less noisy and smoother.

In [69]:

```
import cv2
import numpy as np
import matplotlib.pyplot as plt

def gaussian_kernel(size, sigma):
    ax = np.linspace(-(size // 2), size // 2, size)
    xx, yy = np.meshgrid(ax, ax)
    kernel = np.exp(-(xx**2 + yy**2) / (2 * sigma**2))
    return kernel / np.sum(kernel)

image = cv2.imread('NATURE.jpg', cv2.IMREAD_GRAYSCALE)

kernel_size = 5
sigma = 1.0
gaussian_kernel_2d = gaussian_kernel(kernel_size, sigma)
print("Gaussian Kernel (5x5):\n", gaussian_kernel_2d)

smoothed_image = cv2.filter2D(image, -1, gaussian_kernel_2d)

plt.figure(figsize=(10, 5))
```

```
plt.subplot(1, 2, 1)
plt.imshow(image, cmap='gray')
plt.title("Original  Image")
plt.subplot(1, 2, 2)
plt.imshow(smoothed_image, cmap='gray')
plt.title("Smoothed Image")
plt.show()
```

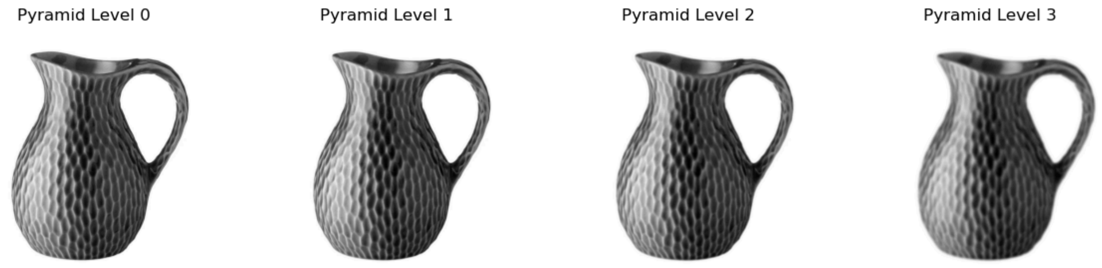
```
Gaussian Kernel (5x5):
 [[0.00296902 0.01330621 0.02193823 0.01330621 0.00296902]
 [0.01330621 0.0596343  0.09832033 0.0596343  0.01330621]
 [0.02193823 0.09832033 0.16210282 0.09832033 0.02193823]
 [0.01330621 0.0596343  0.09832033 0.0596343  0.01330621]
 [0.00296902 0.01330621 0.02193823 0.01330621 0.00296902]]
```



5. Gaussian Pyramid Construction:

In [72]:

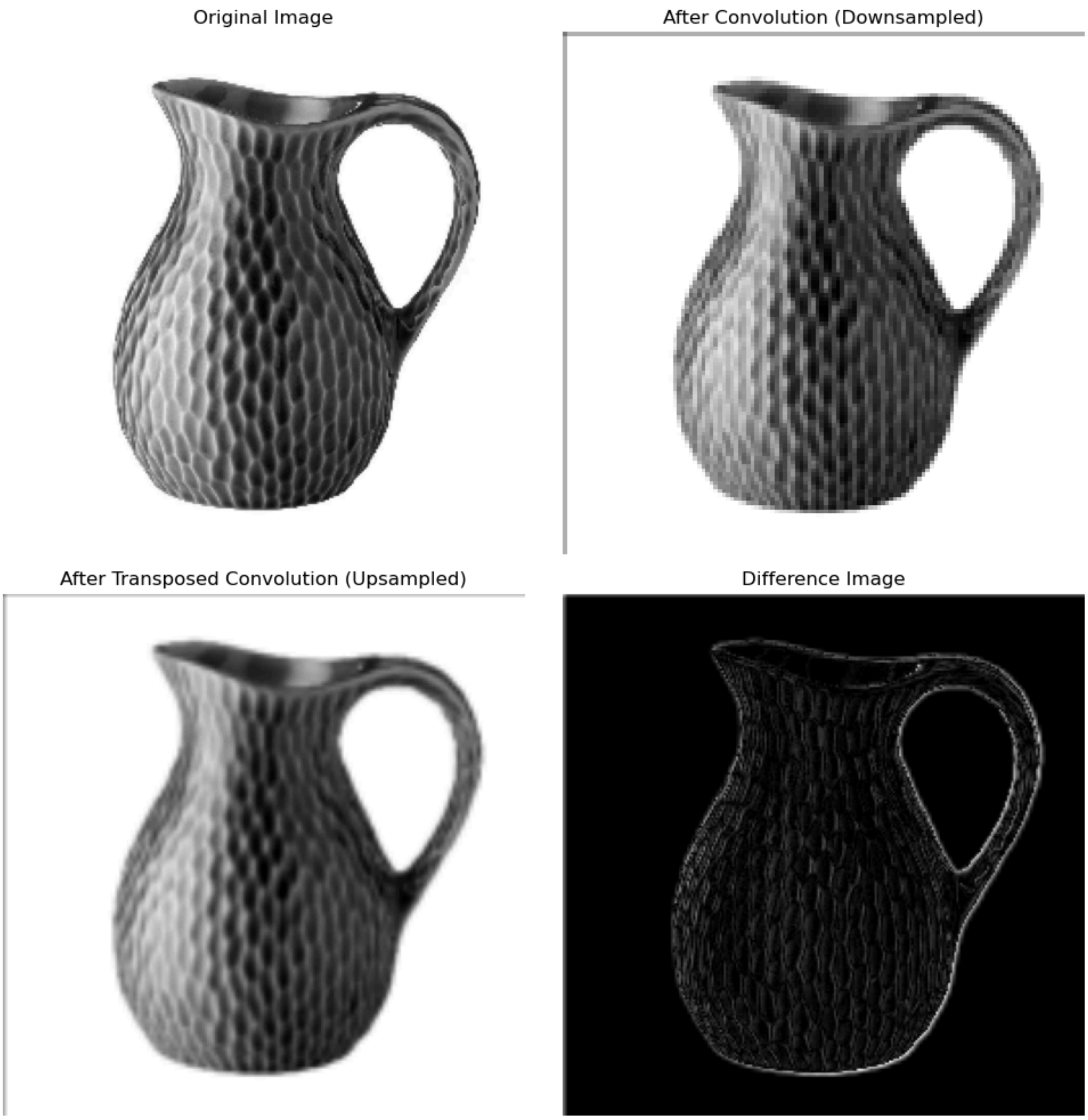
```
import cv2
import numpy as np
import matplotlib.pyplot as plt

# Function to generate a Gaussian Pyramid
def gaussian_pyramid(image, levels=3):
    pyramid = [image]  # Start with original image
    for _ in range(levels):
        image = cv2.pyrDown(image)  # Downsample
        pyramid.append(image)
    return pyramid

image = cv2.imread("jug.jpg", cv2.IMREAD_GRAYSCALE)
pyramid_layers = gaussian_pyramid(image, levels=3)

resized_pyramid_layers = [cv2.resize(layer, (image.shape[1], image.shape[0])) fo
plt.figure(figsize=(15, 5))

for i, layer in enumerate(resized_pyramid_layers, 1):
    plt.subplot(1, len(resized_pyramid_layers), i)
    plt.imshow(layer, cmap="gray")
    plt.title(f"Pyramid Level {i-1}")
    plt.axis("off")

plt.show()
```



6. Transposed Convolution

In [75]:

```
import torch
import torch.nn.functional as F
import cv2
import numpy as np
import matplotlib.pyplot as plt

image_path = "jug.jpg"
image = cv2.imread(image_path, cv2.IMREAD_GRAYSCALE)
image = cv2.resize(image, (256, 256))  # Resize to fixed size
image_tensor = torch.tensor(image, dtype=torch.float32).unsqueeze(0).unsqueeze(0

# Define a 3x3  kernel and normalize
gaussian_kernel = torch.tensor(
    [[[[1, 2, 1],
       [2, 4, 2],
       [1, 2, 1]]]], dtype=torch.float32
)  # Shape: [1, 1, 3, 3]
gaussian_kernel /= gaussian_kernel.sum()  # Normalize
conv_result = F.conv2d(image_tensor, gaussian_kernel, stride=2, padding=1)  # St

trans_conv_result = F.conv_transpose2d(conv_result, gaussian_kernel, stride=2, p
# Convert tensors to numpy arrays for visualization
original_image = image_tensor.squeeze().numpy()
downsampled_image = conv_result.squeeze().detach().numpy()
upsampled_image = trans_conv_result.squeeze().detach().numpy()
downsampled_image /= downsampled_image.max()
upsampled_image /= upsampled_image.max()
upsampled_image_resized = cv2.resize(upsampled_image, (256, 256), interpolation=

diff_image = np.abs(original_image - upsampled_image_resized)

fig, axes = plt.subplots(2, 2, figsize=(10, 10))
titles = ["Original Image", "After Convolution (Downsampled)",
          "After Transposed Convolution (Upsampled)", "Difference Image"]
images = [original_image, downsampled_image, upsampled_image_resized, diff_image
for ax, img, title in zip(axes.ravel(), images, titles):
    ax.imshow(img, cmap="gray")
    ax.set_title(title)
    ax.axis("off")
plt.tight_layout()
plt.show()
```

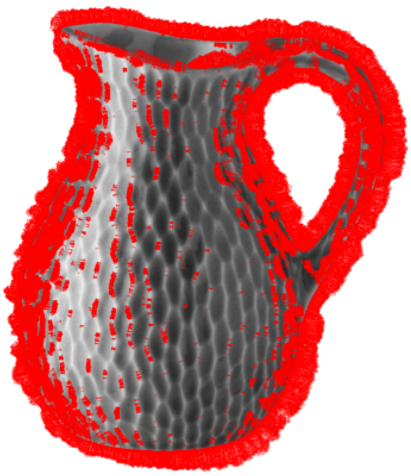


7. Image Gradients and Histogram of Gradient Directions

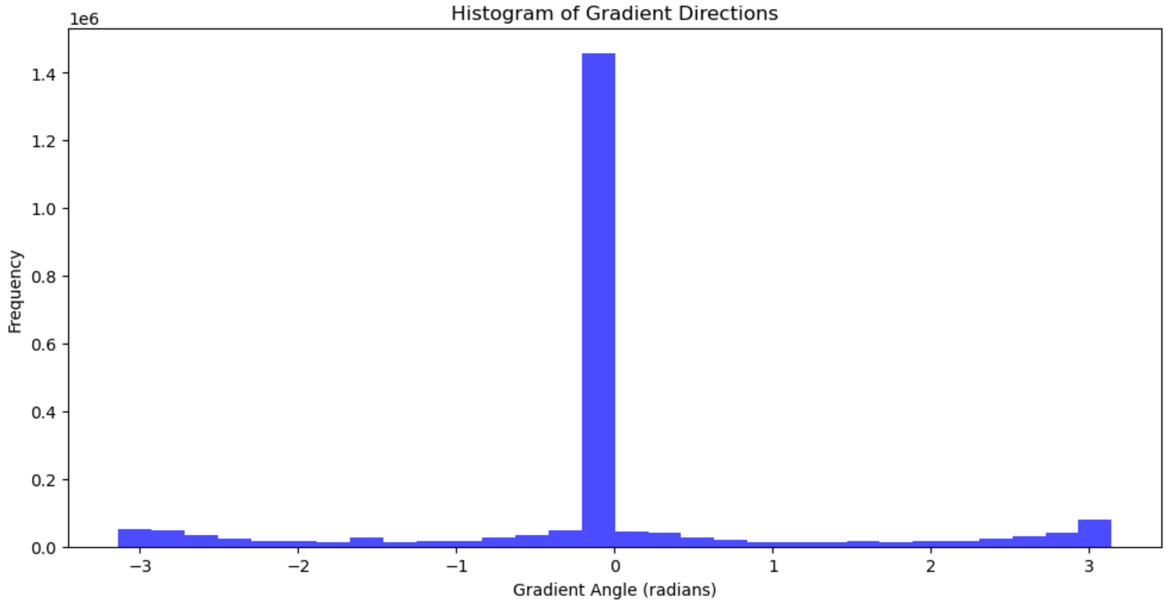
In [78]:
```python
import cv2
import numpy as np
import matplotlib.pyplot as plt
image = cv2.imread("jug.jpg", cv2.IMREAD_GRAYSCALE)

grad_x = cv2.Sobel(image, cv2.CV_64F, 1, 0, ksize=3)  # X-gradient
grad_y = cv2.Sobel(image, cv2.CV_64F, 0, 1, ksize=3)  # Y-gradient

# Compute magnitude and direction of the gradient
magnitude = np.sqrt(grad_x**2 + grad_y**2)
direction = np.arctan2(grad_y, grad_x)
image_with_vectors = cv2.cvtColor(image, cv2.COLOR_GRAY2BGR)
threshold = 100
strong_magnitudes = magnitude > threshold
y_coords, x_coords = np.where(strong_magnitudes)
for y, x in zip(y_coords, x_coords):
    dx = int(grad_x[y, x] / 10)  # Scale for visualization
    dy = int(grad_y[y, x] / 10)
    start_point = (x, y)
```

```
    end_point = (x + dx, y + dy)
    cv2.arrowedLine(image_with_vectors, start_point, end_point, (0, 0, 255), 1,

plt.figure(figsize=(10, 10))
plt.subplot(2, 1, 1)
plt.imshow(cv2.cvtColor(image_with_vectors, cv2.COLOR_BGR2RGB))  # Convert BGR t
plt.title("Image with Gradient Vectors")
plt.axis("off")

plt.subplot(2, 1, 2)
plt.hist(direction.ravel(), bins=30, color='blue', alpha=0.7)
plt.title("Histogram of Gradient Directions")
plt.xlabel("Gradient Angle (radians)")
plt.ylabel("Frequency")
plt.tight_layout()
plt.show()
```

Image with Gradient Vectors



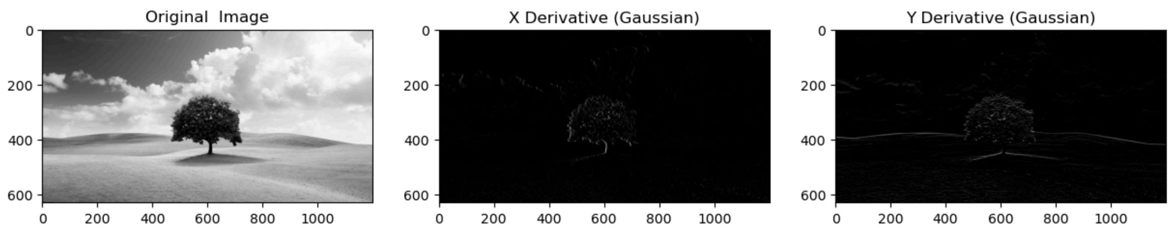
Histogram of Gradient Directions



8. Gaussian Derivatives Gradients

In [81]:
```
import cv2
import numpy as np
import matplotlib.pyplot as plt
```

```
def gaussian_1d(size, sigma):
    k = size // 2
    x = np.arange(-k, k+1)
    gaussian = np.exp(-x**2 / (2 * sigma**2)) / (np.sqrt(2 * np.pi) * sigma)
    return gaussian / gaussian.sum()

def gaussian_derivative_1d(size, sigma):
    k = size // 2
    x = np.arange(-k, k+1)
    gaussian_derivative = -x * np.exp(-x**2 / (2 * sigma**2)) / (sigma**3 * np.s
    return gaussian_derivative / np.sum(np.abs(gaussian_derivative))

kernel_size = 5
sigma = 1.0

# Compute 1D filters
gaussian_x = gaussian_1d(kernel_size, sigma).reshape(1, -1)
gaussian_y = gaussian_1d(kernel_size, sigma).reshape(-1, 1)

gaussian_derivative_x = gaussian_derivative_1d(kernel_size, sigma).reshape(1, -1
gaussian_derivative_y = gaussian_derivative_1d(kernel_size, sigma).reshape(-1, 1

image = cv2.imread("nature.jpg", cv2.IMREAD_GRAYSCALE)
# Detect X derivative
image_x_derivative = cv2.filter2D(image, -1, gaussian_derivative_x)
image_x_derivative = cv2.filter2D(image_x_derivative, -1, gaussian_y)

image_y_derivative = cv2.filter2D(image, -1, gaussian_derivative_y)
image_y_derivative = cv2.filter2D(image_y_derivative, -1, gaussian_x)
plt.figure(figsize=(15, 5))
plt.subplot(1, 3, 1)
plt.imshow(image, cmap="gray")
plt.title("Original  Image")
plt.subplot(1, 3, 2)
plt.imshow(image_x_derivative, cmap="gray")
plt.title("X Derivative (Gaussian)")
plt.subplot(1, 3, 3)
plt.imshow(image_y_derivative, cmap="gray")
plt.title("Y Derivative (Gaussian)")
plt.show()
```

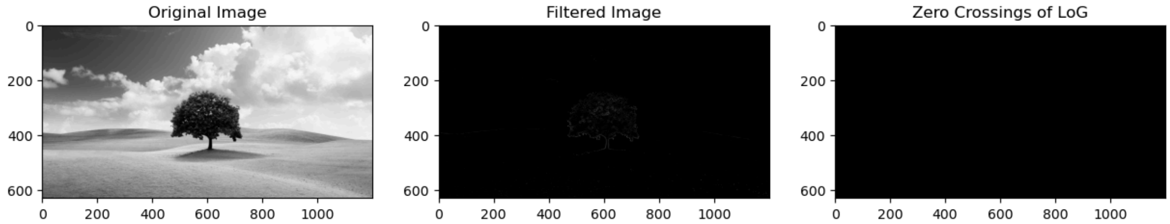


9. Laplacian of Gaussian (LoG) Edge Detection

In [84]:

```
import cv2
import numpy as np
import matplotlib.pyplot as plt
def laplacian_of_gaussian(size, sigma):
    x = np.linspace(-size//2, size//2, size)
    y = np.linspace(-size//2, size//2, size)
    xx, yy = np.meshgrid(x, y)
```

```
    g = np.exp(-(xx**2 + yy**2)/(2*sigma**2))
    log = -(1/(np.pi*sigma**4)) * (1 - (xx**2 + yy**2)/(2*sigma**2)) * g
    return log / np.sum(np.abs(log))

def apply_log(image, size, sigma):
    log_filter = laplacian_of_gaussian(size, sigma)
    log_filtered_image = cv2.filter2D(image, -1, log_filter)
    return log_filtered_image

def detect_zero_crossings(log_image):
    zero_crossings = np.zeros_like(log_image, dtype=np.uint8)

    zero_crossings[:, :-1] |= (log_image[:, :-1] > 0) & (log_image[:, 1:] < 0)
    zero_crossings[:, 1:] |= (log_image[:, :-1] < 0) & (log_image[:, 1:] > 0)

    zero_crossings[:-1, :] |= (log_image[:-1, :] > 0) & (log_image[1:, :] < 0)
    zero_crossings[1:, :] |= (log_image[:-1, :] < 0) & (log_image[1:, :] > 0)

    return zero_crossings

image = cv2.imread('nature.jpg', cv2.IMREAD_GRAYSCALE)

size = 5
sigma = 1.0
log_filtered_image = apply_log(image, size, sigma)

zero_crossings = detect_zero_crossings(log_filtered_image)

plt.figure(figsize=(15, 5))
plt.subplot(1, 3, 1)
plt.imshow(image, cmap='gray')
plt.title("Original Image")
plt.subplot(1, 3, 2)
plt.imshow(log_filtered_image, cmap='gray')
plt.title("Filtered Image")
plt.subplot(1, 3, 3)
plt.imshow(zero_crossings, cmap='gray')
plt.title("Zero Crossings of LoG")
plt.show()
```



In [ ]: