Report on Image Processing

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1 Introduction

In image processing, a kernel is a small matrix used for transforming an image. This is achieved by convolving the image with the kernel matrix. Consider a 3×3 kernel, denoted by A_{ij}, which operates on an image using the following formula:

$$P_{\text{new}_{m,n}} = \sum_{i=0}^{2} \sum_{j=0}^{2} A_{ij} P_{\text{old}_{m-1+i,n-1+j}}$$

where $P_{\text{old}_{m,n}}$ represents the old value of the pixel at position (m, n) in the image, and $P_{\text{new}_{m,n}}$ represents the new value after applying the kernel.

In this report, we'll explore various image operations using kernels and compare them with frequency domain filtering techniques.

2 Question 1: Illustrating Image Modifications using Kernels

We're tasked with demonstrating how different image operations modify the Lena image using kernels.

2.1 Brightness Change

This operation increases or decreases the brightness of the image. We've increased the brightness by 50 units.

2.2 Contrast Change

Contrast refers to the difference in luminance or color that makes an object distinguishable. By multiplying the image by a factor (1.5 in our case), we enhance the contrast.

2.3 Edge Detection

Edge detection highlights the boundaries of objects within an image. We've applied a specific edge detection kernel to emphasize edges.

Figure 1: Bright Image

Figure 2: Contrast Image

Figure 3: Edge Detection Image

3 Question 2: Noise Reduction using Kernels

Yes, we can reduce noise in the second image using a Gaussian blur kernel. This kernel averages the pixel values in the neighborhood of each pixel, effectively smoothing out high-frequency noise. Gaussian blur works well for reducing noise because it effectively averages out irregularities in pixel intensity, resulting in a smoother image appearance. However, it may also blur out some fine details in the image, depending on the size of the kernel.

Figure 4: Denoised Image

4 Question 3: Filtering Noise in the Frequency Domain

Yes, we can filter noise from the image by applying a low-pass filter in the frequency domain using Fourier Transforms. This filter attenuates high-frequency components of the image spectrum, effectively reducing noise. Filtering noise in the frequency domain can be more effective in preserving image details compared to kernel-based methods like Gaussian blur. However, it may require more computational resources and expertise to implement. The nature of noise suitable for each method depends on its frequency characteristics. High-frequency noise, such as salt-and-pepper noise or random speckles, can be effectively reduced using Fourier-based methods. On the other hand, Gaussian blur may be more suitable for reducing spatially coherent noise or uniform graininess in the image. Here's the result:

Figure 5: Filtered Image

5 Code Explanation

Now, let's explain the Octave code used to perform the image processing operations.

5.1 Kernel Application Function

The `apply_kernel` function convolves an image with a given kernel. It pads the image appropriately, then iterates over each pixel and applies the kernel to compute the new pixel value.

5.2 Brightness Change Function

The `change_brightness` function changes the brightness of an image by adding a constant value (`beta`) to all pixel values.

5.3 Contrast Change Function

The `change_contrast` function changes the contrast of an image by multiplying all pixel values by a constant factor (`alpha`).

5.4 Edge Detection Kernel

The `edgedet_kernel` is a 3x3 kernel matrix designed for edge detection.

5.5 Gaussian Kernel

The `gaussian_kernel` is a 3x3 kernel matrix used for Gaussian blurring, which helps in noise reduction.

5.6 Low-pass Filter Function

The `low_pass_filter` function applies a low-pass filter in the frequency domain to attenuate high-frequency noise. It utilizes the Fourier Transform to process the image.

6 Discussion

6.1 Effectiveness of Kernels vs. Frequency Domain Filtering

Kernels are effective for operations like brightness change, contrast enhancement, and edge detection. They directly manipulate pixel values based on neighboring values.

Frequency domain filtering is advantageous for noise reduction. It operates in the frequency domain and can efficiently remove noise without distorting the image's features.

6.2 Nature of Noise Suitable for Methods

Kernels are suitable for deterministic noise reduction, where noise follows certain patterns or can be represented by specific convolution operations.

Frequency domain filtering is ideal for stochastic noise reduction, such as random variations in pixel values, as it targets frequency components directly.

7 Conclusion

In this report, we've demonstrated the application of kernels for various image operations and compared them with frequency domain filtering techniques for noise reduction. Both methods have their strengths and are suited for different types of image processing tasks. Understanding these methods allows for effective manipulation and enhancement of digital images.