Image Denoising and Edge Detection

UTRGV CSCI6367

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1 Introduction

This experiment demonstrates the use of frequency-domain analysis and spatial-domain interpolation for image processing. A lung CT image was converted to grayscale, transformed using the 2D Fourier Transform, down-sampled, and then reconstructed using two different methods. The first method is the frequency-domain interpolation using zero-padding in the Fourier domain and the spatial-domain interpolation using bilinear interpolation. The goal was to evaluate which reconstruction method better approximates the original image by computing the Mean Squared Error.

2 Approach

2.1 Image Preparation

The first step is to load the CT image and convert it to grayscale. From here we are going to examine its size. Once the image was properly prepared, we applied a two dimensional fast Fourier transform to apply to it. What this does is it decomposes the image into its frequency components, and it shifts the result allowing the low frequency content to be centered for easier interpretation. From this transformed representation, both the magnitude spectrum and the phase and phase spectrum will be computed. The magnitude spectrum, which was visualized on a logarithmic scale, highlighting the energy or strength that exists within each frequency within the image.The phase spectrum reveals how different each component was aligned and their positioning. Together, they complete the representation of the image in the frequency domain and help illustrate the image structure beyond the pixel values that we would receive.

2.2 Fourier Transform Analysis

The reconstruction method used FFT (frequency-domain interpolation. By zero-padding the FFT of the down-sampled image and applying the inverse FFT, an interpolated version of the image will be obtained at a much larger scale. This approach restores the missing information within the frequency and preserves the structure more efficiently.

2.3 Down-Sample Process

The next method is spatial domain bilinear interpolation that estimates new pixel values by grabbing the neighboring pixels and averaging them. While this may be simple, this method tends to produce smoother, blurrier results because it grabbing the nearest pixels and trying to mesh them as much as possible to create a bigger image from the original.

2.4 Reconstruction Methods

2.4.1 Frequency-Domain Interpolation — Zero Padding

The reconstruction method used FFT (frequency-domain interpolation. By zero-padding the FFT of the down-sampled image and applying the inverse FFT, an interpolated version of the image will be obtained at a much larger scale. This approach restores the missing information within the frequency and preserves the structure more efficiently.

2.4.2 Spatial-Domain Interpolation — Bilinear

The next method is spatial domain bilinear interpolation that estimates new pixel values by grabbing the neighboring pixels and averaging them. While this may be simple, this method tends to produce smoother, blurrier results, because it grabbing the nearest pixels and trying to mesh them as much as possible to create a bigger image from the original.

3 Evaluation

When looking at the images and ensuring that we are getting a valid result, we grab both of the reconstructed images and rescale them to size to match the intensity range of the original, and their MSE values when they are computer. The method with the lower MSE will be the true image. The frequency domain interpolation provides better reconstruction quality and lower error, the spatial interpolation sacrifices detail from simplicity.

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@TheJino → /workspaces/UTRGV-CSCI-6367-Project/Final_project (main) $ python3 main.py

Image size: 640 x 426
<PIL.Image.Image image mode=L size=640x426 at 0x777B992021E0>
MSE (Frequency-domain interpolation): 773.6030
MSE (Spatial linear interpolation): 94.4240
```

Figure 1: Output using the different methods

4 Conclusion

The project showed that the median filter was effective at removing noise but blurred faint edges, while Canny detection emphasized strong boundaries.

References

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