2110431 Introduction to Digital Imaging

2147329 Digital Image Processing and Vision Systems

Homework #2

Deadline : October 5th, 2024 @23:59

Submissions: (1) PDF version of this file

(2) .ipynb file; template in the link below

COLAB TEMPLATE:
[https://colab.research.google.com/drive/1vXUwb4AcX3vDvUTgzqP_1ag3aSHq7OvT?usp=sharing](https://colab.research.google.com/drive/1vXUwb4AcX3vDvUTgzqP_1ag3aSHq7OvT?usp=sharing)

Use these commands in colab to download the images.

```
!wget https://drive.google.com/uc?id=1o0UMPTyUFzX9CaQp-BwYXgkCho1Zo6yL  -O kitty55.png
!wget https://drive.google.com/uc?id=1_-_yN30miNhzR9ZC5DHTiljH6LVq4hZz  -O clean_cat.png
!wget https://drive.google.com/uc?id=1LEwFRI2vjSqQEd68lYwyuJ4JyJYPQX2m  -O
blurry_noisy_cat.png
!wget https://drive.google.com/uc?id=1lnO_PK81O54bLBUprBlo8-2x9smWYDcP  -O moodeng.jpg
```

1. (2 points) Apply Gaussian low pass filter in frequency domain on “Kitty55.png” image which has $M\ x\ N$ pixels. Find the minimum cutoff frequency (C) that still maintain the total image power $P_T$ more than 99%. Where the total image power, $P_T$ is calculated by summing the components of spectrum power at each point $(u, v)$, for $u\ =\ 1, 2, ....\ M\ -\ 1$ and $v\ =\ 1, 2, ..., \ N\ -\ 1$

$$P_T = \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} P(u, v)$$

$P(u, v)$ is the spectrum power provided in the lecture slides

α percent of the image power can be calculated from 100 x $P_{T\_f}$ / $P_{T\_org}$, where $P_{T\_org}$ is the total image power of the original image and $P_{T\_f}$ of the filtered image

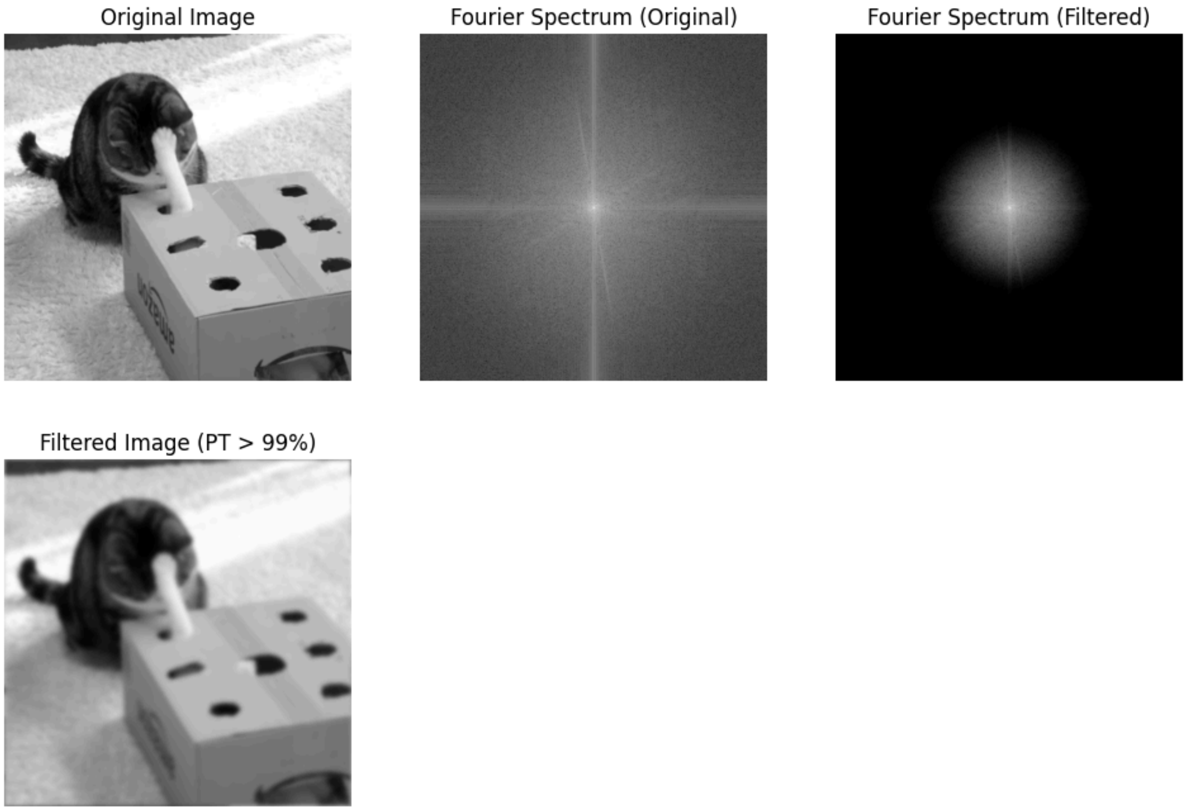
Put your results in the blank box below

Cutoff frequency (C) =

| |
|---|
| 27 |

$\alpha$ =

99.02




## 2. Problem: Restoring blurry and noisy image

You are provided with a blurred and noisy of cat image  blurry_noisy_cat.png and a clean reference image clean_cat.png. You have to restore the image using the **Wiener Filter** and compute the **Structural Similarity Index (SSIM)** between the restored image and the clean reference image.

$$\mathrm{SSIM}(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)}$$

with:

- $\mu_x$ the average of $x$;
- $\mu_y$ the average of $y$;
- $\sigma_x^2$ the variance of $x$;
- $\sigma_y^2$ the variance of $y$;
- $\sigma_{xy}$ the covariance of $x$ and $y$;
- $c_1 = (k_1 L)^2$, $c_2 = (k_2 L)^2$ two variables to stabilize the division with weak denominator;
- $L$ the dynamic range of the pixel-values (typically this is $2^{\#bits\ per\ pixel} - 1$);
- $k_1 = 0.01$ and $k_2 = 0.03$ by default.

SSIM Overview:

The **Structural Similarity Index (SSIM)** is a perceptual metric that quantifies the similarity between two images. It considers changes in luminance, contrast, and structure to measure how close the restored image is to the original clean image. SSIM values range from -1 to 1, where:

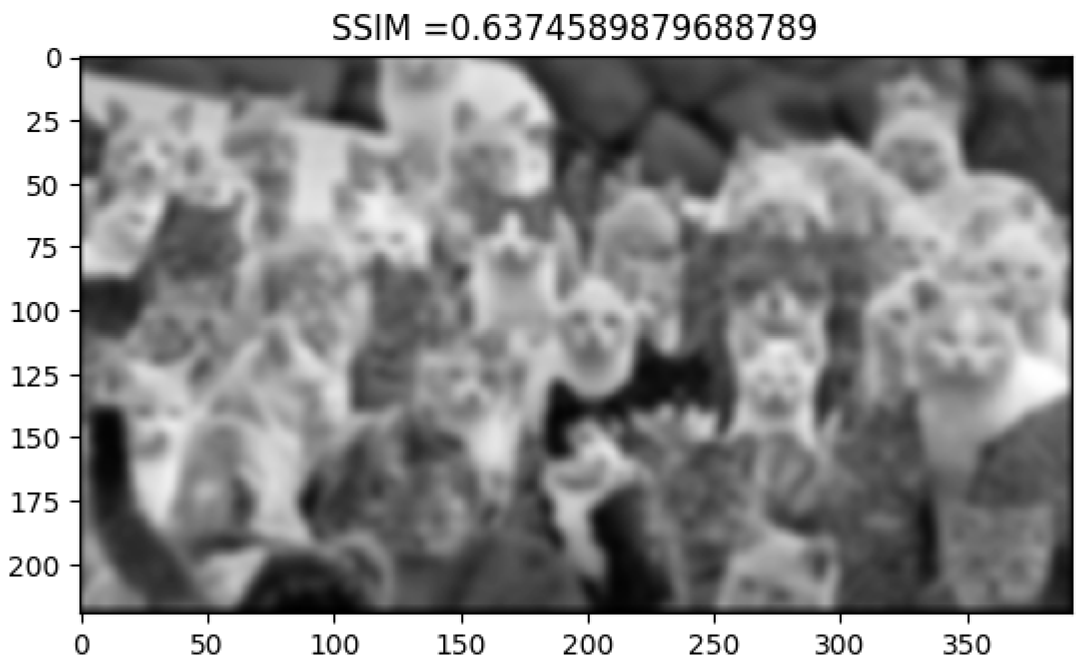
- 1 indicates perfect similarity.
- 0 indicates no similarity.
- Negative values indicate dissimilarity.

(Hint: this metric is available inside skimage.metrics )

Blurry Noisy Cat

Clean Cat Image

Show how to restore the image using Wiener Filter from noise and blur effects and display the result (don't worry if the output is not perfect, just select the best one in your thought),



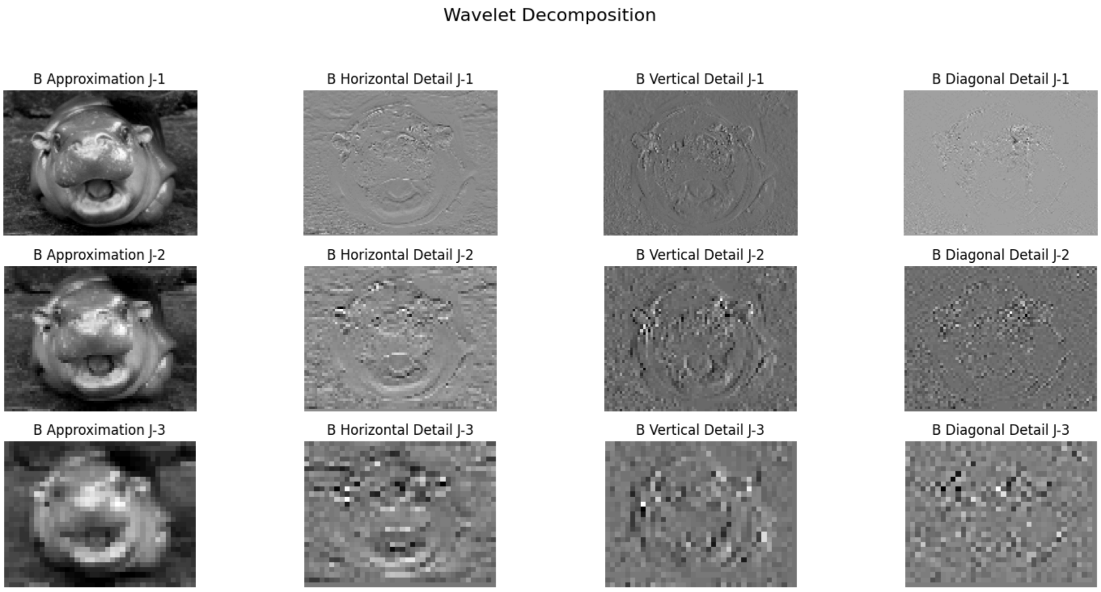

Structural Similarity Index (SSIM) of the restored image

| |
|---|
| 0.6375 |

3. **WAVELETS AND MULTIRESOLUTION PROCESSING**

3.1 You are provided with Nong Moo Deng image moodeng.jpg. Your task is to perform **multi-level wavelet decomposition** using the **Discrete Wavelet Transform (DWT)** and analyze the different layers of decomposition. The DWT breaks the image into four sub-bands: Approximation, Horizontal details, Vertical details, and Diagonal details. You will progressively decompose the image into three levels, visualizing the components at each level.

**Your Wavelet Decomposition Level & Thresholding :**




3.2 For level J-1, remove the right half of the three components - horizontal, vertical and diagonal details - of the 'moodeng' image and then apply inverse Discrete Wavelet Transform to reconstruct the original-sized image with a blur on the right half. You can blur the right side of the image using a grayscale image, but you will receive a 1-point bonus for producing an RGB output.

| |
|---|
| Explain your method and provide the output results |

The right side demonstrates the modified image where the right half has been blurred due to the zeroing of the detail coefficients. This should create a smooth transition between the blurred and clear areas.