Assignment 1:
Image Filtering and Compression

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Part 1. Laplacian image pyramid

The main goal of this section is to develop a pair of functions to create a Laplacian pyramid from a specific image and then reconstruct it from its Laplacian pyramid. The processes include half the original image by taking every other row and column, then up sample the down sampled image with zeros in row and column to make it the same size as last down sampled image. As the final step of creating Laplacian pyramid, keep the last layer with the last down sampled image without up sampling, then use the last layer of the Laplacian pyramid as a key to iteratively up sampled the layer to recreate the original image.

In my implementation, I tried the "cameraman.png" as my source image with grayscale, and make a 6 levels of Laplacian pyramid to recreate it, except the last layer, the layer of each level is the difference between last down sampled image and the current up sampled image. Therefore, each layer contains less information of the original image, and the image size will be halved in each layer. Here are the results of applying Laplacian pyramid and recreating (figure 1), just for continence, I make each layer appear as the same size to see the clearer differences between each layer.

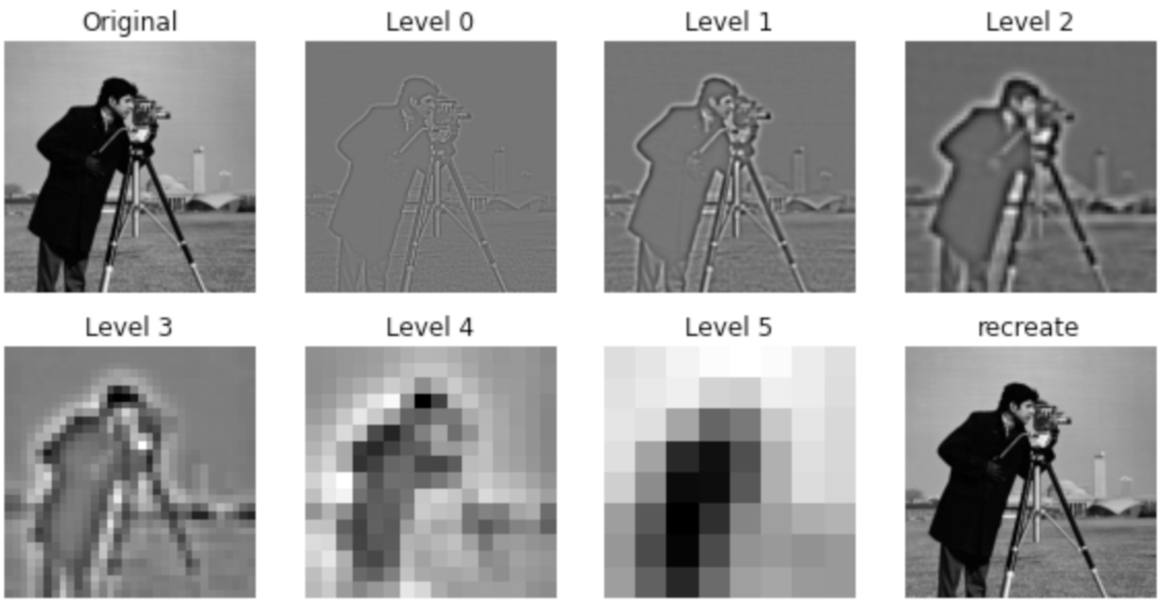

Figure 1. Laplacian pyramid with 6 levels and the recreate image of "cameraman.png"

The ensure the Laplacian pyramid is correctly developed, the error between original image and the recreated image should be 0 (figure 2).

```
#error between original image and recreated image
error = sum((test_img - recreate_img).flatten())
print(error)
```

```
0.0
```

Figure 2. error between original image and recreated image

Part 2. Quantization and compression

The main goal in this section is to develop a quantize function to divide the image's pixel values into 2^b bins and replace all pixels in a given bin with the mean pixel value in that bin. Combining the quantization with Laplacian pyramid, each layer of Laplacian pyramid will be quantized to a compressed image. Moreover, as the rule, lower levels will be applied on more compression.

In my implementation, within the same numbers of levels Laplacian pyramid, the bin of each level dominates the compression, as the 5 levels pyramid, the recreated picture seems to match the original figure more by increasing the bins of each level. The figure below (figure 3), shows four bitslevels recreated pictures, the bins of each level of pyramid of the four images are [1,2,3,4], [2,3,4,5], [3,4,5,6], [4,5,6,7]. Based on the quantization algorithm, the less bins used, the less contrast of the image, because the pixels in a specific range have been replaced by the mean of that range.

Figure 3. (bin of lowest level, compression) of the 5 levels Laplacian pyramid

Moreover, with same bins of the previous 4 levels of level 5 and level 6 Laplacian pyramids, the level 6 Laplacian pyramid provides more information on the 5 level of pyramid which with the larger bin, so the more Laplacian pyramid levels the more information will be provided. However, the compression size will be slightly larger. The figure below, shows the effects of three bin level, which are [1,2,3,4,5], [2,3,4,5,6], [3,4,5,6,7] of level 6 pyramid.

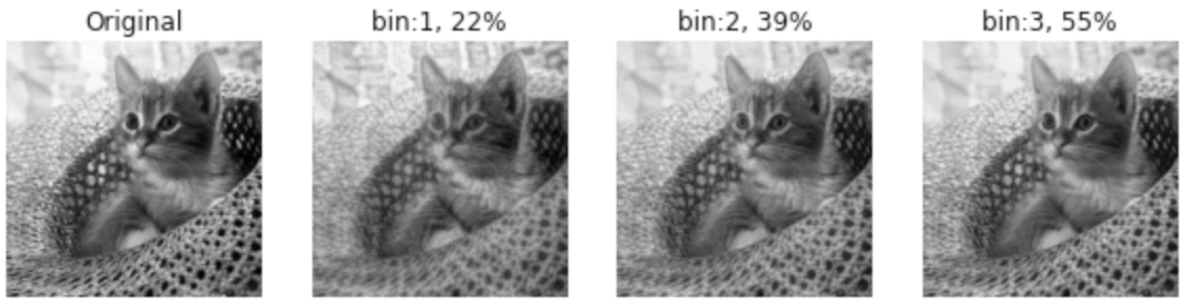

Figure 4. (bin of lowest level, compression) of the 5 levels Laplacian pyramid

Therefore, based on the implementation, in order to maintain the balance between compression size and the image information, the Laplacian pyramid with 5 levels with the bins [2,3,4,5] of the first four levels will give a smaller compressed picture with reasonable contrast.

Part 3 Evaluation in the frequency domain

The main goal of this section is to compute the Fourier transform of the original image and the compressed image to evaluate the effect of the compression method in the frequency domain. The figures below show the image of original cat.png and the compressed one by using level 5 pyramid with the bin [2,3,4,5] of the previous four levels in phase (figure 5) and magnitude (figure 6).

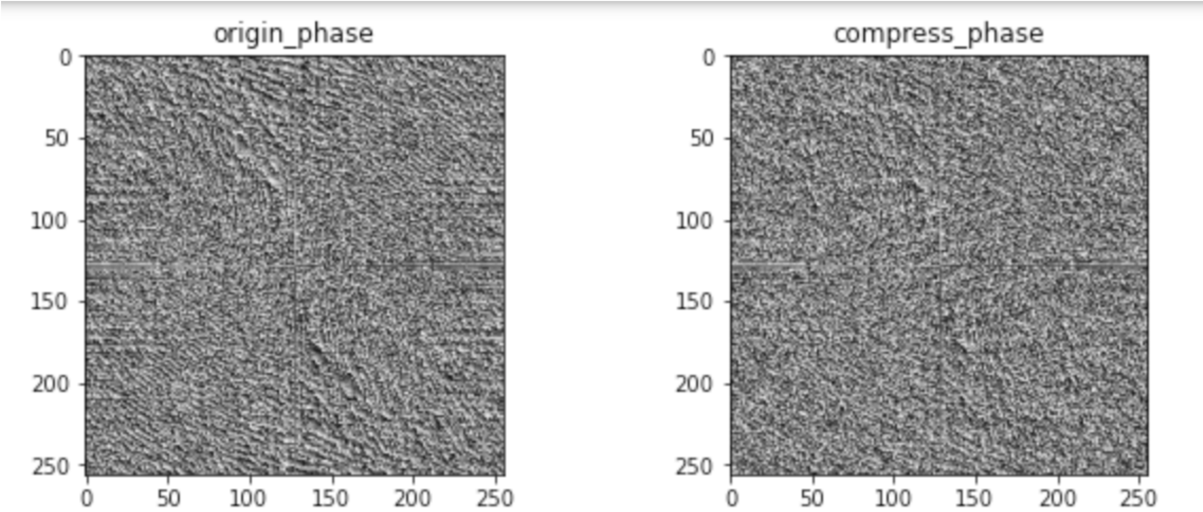

Figure 5. Original image phase V.S. compressed image phase

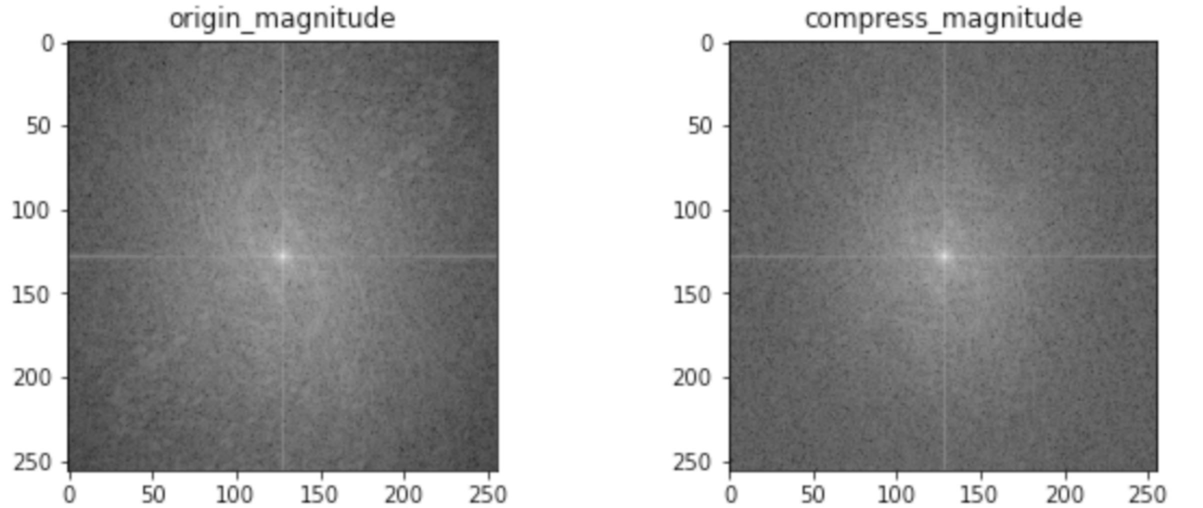

Figure 5. Original image log magnitude V.S. compressed image log magnitude

The phase of Fourier transform is mainly the main pattern of the image, after compressing, the image will lose some details information, but it will remain the same pattern. As the phase images, the original one has more details, but the compressed one is blurred in some area, but it remains the same pattern.

The magnitude of Fourier transform is mainly the frequency of light condition changing in the image, after compressing, the pixel values within the same range has been replaced by the mean of the range, therefore, the light condition changing in some area will be smaller than the original one. However, the frequency is not changing, the magnitude image of the compressed image shows still the same frequency, but the size of the changes is smaller.