gbsv Mini-Challenge 1

1 Wichtigste Resultate

1.1 Adjusting an image in color space

Figure 1 Adjust image brightness. The first image in first row is the original image. The image at right column is adjusted with one brightness factor. The image at the second row is brightened by three brightness factors.

The original image has a low brightness, and in an unnatural reddish color tone. Firstly, I increased the image brightness by applying a brightness factor to all pixel values. At a certain point, some spots are overexposed due to high pixel values in red channel, this is also reflected at the rapidly growth amplitude of pixel value at 255 in the histogram. But the other spots of image have yet not reached a suitable brightness. So, I used one factor for each individual channel. With factors of 1.1 in red channel, 1.4 in blue and 1.3 green channels (image in second row), the image has better brightness without overexposure, and the final color is less reddish.

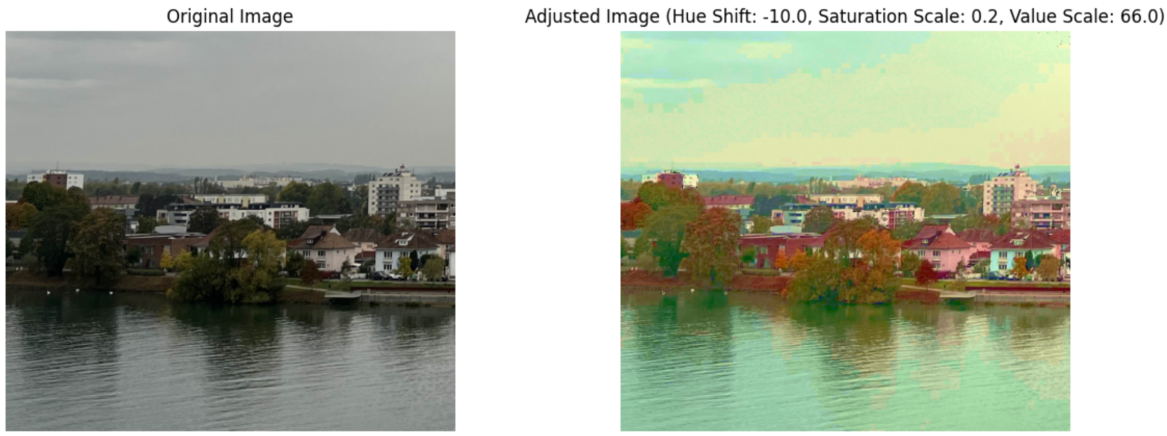

Figure 2 Adjust image in HSV colorspace. Original image (left) is a bit dark and has very plain colors, while the adjusted image (right) looks brighter than original and has intensive colors.

The image (figure 2 left) is adjusted of its hue, saturation, and brightness value. Visually, the image style is changed from a cold cloudy day to a warm sunny day. The adjusted image has significantly higher color saturation. The trees with slightly orange hue shows an autumn atmosphere. The whole image looks brighter than the original. The adjustment reached the expectation. The adjusted image has higher average color intensity than the original image in all three single channels, which indicates the enhanced brightness or saturation or both. In both images, green is the dominant color.

1.2 Filter in spatial domain/time domain by convolution algorithm

Figure 3 Sharpen and blur an image in spatial domain. The second image is sharpened by performing convolution with sharpening kernel. The third image is blurred by passing gaussian blur kernel.

The upper second and third images are filtered with different kernels (sharpen, blur) by convolution algorithm. I added zero-paddings to the image to preserve its shape during the convolution. Tuning the kernel size, sigma, and number of passes could achieve different effects. Larger kernel size, standard deviation, and more passes will lead to stronger sharpening or blurring effect.

Very similarly, I did sharpen and blur the audio signal with 1D kernels of different kernel sizes, kernel standard deviation, number of passes, and evaluate with the same metrics as before. Sharpen a signal will change its dominant frequency and bandwidth. Stronger sharpening power will narrow the bandwidth. In my case, signal is dominant at frequencies between 5000 and 7000 Hz.

Blur a signal means the signal will become smoother by a gaussian kernel. Stronger blurring power will cause more frequencies getting closer to each other, so the dominant frequencies amplitude is getting larger. In my case, the final signal has the bandwidth between 0 and 1000 Hz, it sound more like bass.

1.3 Filter repetitive patterns in spectral domain

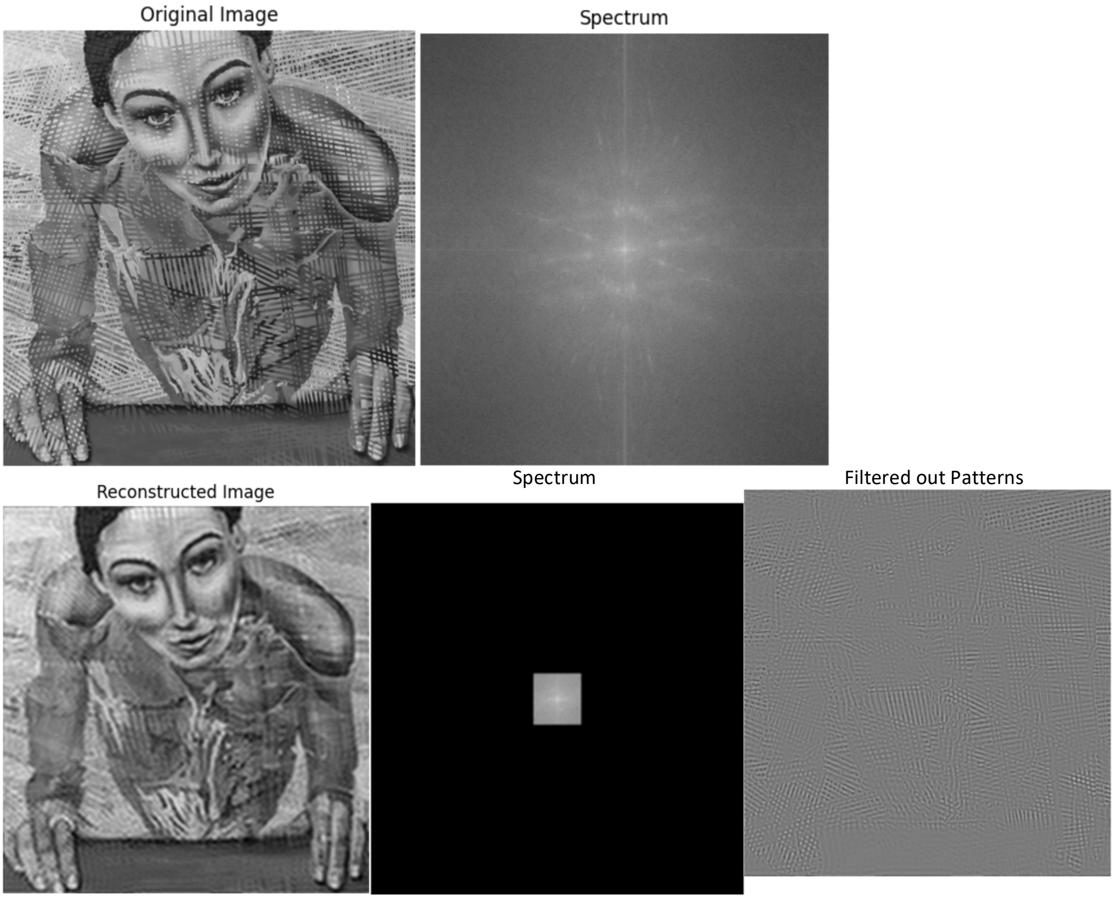

Figure 4 Filter repetitive patterns of image in spectral domain. The original image has many stripes on different directions, the directions are reflected in its spectrum. After removing a large surround area of frequencies, with only the central 122 X 114 area frequencies, most of the repetitive stripes are removed in the reconstructed image. In the image of filtered out patterns, we could see many stripes which are exactly the patterns we want to remove.

By adjusting the filter areas in the spectrum, some patterns in the image will be removed. Finally, when filtering out the large surround area keeping only the central 122 X 114 frequency area, the reconstructed image reached a good effect. Most of the repetitive patterns are removed as I expected, though there are still some blurred stripes. The image details seems are slightly blurred. In the image of filtered out patterns, we could see that not only the strips are removed, but also many facial patterns are removed.

2 Diskussion

2.1 Adjusting an image in color space

RGB space represents colors by red, green, blue channels, where directly increasing (decreasing) the color intensity of one channel (or multi channels) will positively (negatively) influence the brightness of this channel, enhance (reduce) its proportion/dominance in the whole image therefore remix the image color tone. However, mixing with three original colors is hard to precisely get the expected color tone.

Asjusting the hue, saturation, and brightness of an image in HSV space is more intuitive to human perception, and changing each of the property individually will not affect the other two.

I used histogram of separate color channel to evaluate the changes of color intensity distribution and distinguish the dominant color. Subjective visual comparison is also important to evaluate the aesthetics and irrational parts, e.g. the image color tone, atmosphere, saturation, etc.

2.2 Filter in spatial domain/time domain by convolution algorithm

Convolution algorithm filter data by passing different types of kernels to reach effects like blurring, sharpening, edge dection etc. It has as well flexibility of parameters tuning, such as kernel values, kernel size, padding, and stride. All these parameters could be adjusted to achieve different effects.

To evaluate the filter effect, I measured SSIM and PSNR to evaluate the quality of the processed images or signals, higher SSIM and PSNR values are associated with better image quality. Larger kernel size, standard deviation, and more passes will lead to smaller SSIM and PSNR values, this tells a larger difference to the original image, indicates a stronger effect (sharpen or blur) on the image. The histogram of pixel value distribution is helpful to understand the changes after filtering at the aspect of color intensity. For instance, with larger kernel size, standard deviation and more passes, the pixel values distribution will be more extreme, the amplitude of pixel value at 0 and 255 will be larger, smaller of other pixel values. Finally, visual inspection of the image is important to make decision on how sharp or blurry the image should be.

Sharpening or blurring a signal could not be concretely visualized as the image processing. However, we could still filter a signal with sharpen or blur kernel. When increasing the number of sharpening passes, the bandwidth will be decreased, because the sharpening kernel will enhance the frequency in the middle of the frequency range, and suppress the frequency at the two ends of the frequency range. The spectrum looks more symmetric. Stronger blurring power will cause more frequencies getting closer to each other, so the bandwidth will be narrowed, the dominant frequencies amplitude is getting larger, while the amplitude of other frequencies getting smaller.

2.3 Filter repetitive patterns in spectral domain

Filter specific patterns in spectrum domain means removing the corresponding frequency range in the images or signals, while not changing the information in other frequency ranges. Theoretically, if we could know the exact frequencies of the goal patterns, then we could do a perfect filter in spectral domain. However, in practice, we usually do not know the exact frequencies of the goal patterns, and it will be difficult to test all possible frequencies.

Therefore, I started with a rough filter by removing a certain range of frequencies, and then fine tuned the range to get the best result. I also used MSE to quantitively evaluate the difference between the original image and the reconstructed image, because especially for fine tuning the removal frequencies, it is hard to tell how much is changed by just looking at the image. However, I think the most important metric is the subjective evaluation on visual effect of the reconstructed image. In my result, if I further filter out more frequencies, the blurred stripes will also be removed, however, more patterns that I want to remain (finger structure, facial liners, etc.) will also be removed. The final reconstructed image hast he balance between the removal of the stripe patterns and the preservation of the rest information.

Similarly, removing the repetitive patterns (clock ticks) from a music signal in spectral domain will also remove part of the melody, because the removal frequency ranges include not only the goal removal patterns but also other information. In the reconstructed audio, we still hear slightly the clock ticks. MSE helps to distinguish small difference when changing the filter frequencies.

Depending on the exact goal of the task and subjective hearing evaluation, the final result should be able to represent the original music melody with acceptable amount of the repetitive patterns.

3 Reflexion

The minichallenge together with the deep dive are very well organized and structured. It starts from the basic concepts, such as brightness, color balance, HSV color space in image processing, and frequency, amplitude in signal processing, then gradually moves to the more advanced topics. Many topics are easy to understand in image processing, but hard to interpret in audio, such as sharpen or blur audio signals, while the frequency domain of image is harder to interpret than audio. Searching/producing suitable image and audio files and defining task goals is challenging but very helpful for better understanding.

I am not quite satisfied with the part of adjusting image noise level. With more time, I would like to understand how to generate images with different types of noise, because each denoising method is for different types of noise.

4 Code

The gitlab repository is already shared with susanne.suter@fhnw.ch

https://gitlab.fhnw.ch/weiping.zhang/gbsv/-/tree/main