Hybrid Images & Image Enhancement

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Hybrid image

The goal of this part is to create *hybrid image* using the approach described in by Oliva et al. (2006).

In computer vision, a hybrid image is a combination of two different images that are combined in such a way as to produce a new image that appears differently when viewed at different scales or distances. The process of creating a hybrid image involves transforming the frequency content of each of the input images, so that one image dominates the low-frequency content while the other dominates the high-frequency content. This is achieved by applying a low-pass filter to one image and a high-pass filter to the other. When the two filtered images are combined, they form a single image that is visually distinct when viewed at different scales, producing the illusion of changing images.

Process

The steps for creating a hybrid image are as follows:

1. **Select two similar images**: The first step is to select two images with similar content and features, as this makes it easier to combine them and produce a convincing hybrid image.
2. **Align the images**: Resize and rotate the images such that the object on first image will be perfectly located on top of the object on the other image.
3. **Filter the images**: Apply a low-pass filter to one image to extract the low-frequency content, and a high-pass filter to the other image to extract the high-frequency content.
4. **Experiment with weights**: Experiment with different weights to control the relative dominance of the low-pass and high-pass filter.
5. **Combine the filtered images**: Combine the filtered images by adding them, to produce the final hybrid image.

Step 1 - Select images

For this project I've used a photograph of my beautiful cat *Jula*, and a white seal (Flare).

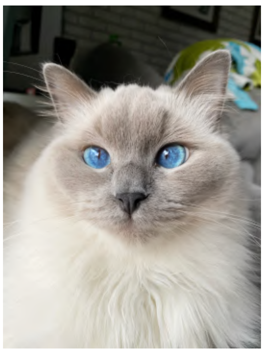

Figure 1: Original image (1)

Figure 2: Original image (2)

Step 2 - Align images

For the better effect we need to make sure both photos are perfectly aligned.

Figure 3: Aligned image (1)

Figure 4: Aligned image (2)

Step 3 - Experiment with sigma values

The value of sigma in a low-pass or high-pass filter has a significant impact on the creation of a hybrid image. Sigma determines the standard deviation of the Gaussian kernel used in the filter, which controls the spread of the smoothing or sharpening effect.

A smaller sigma value in the low-pass filter will result in a sharper transition between the low-frequency and high-frequency content in the hybrid image, as the low-pass filter will have a more limited smoothing effect. On the other hand, a larger sigma value in the low-pass filter will result in a smoother transition between the low- and high-frequency content, as the low-pass filter will have a more aggressive smoothing effect.

Similarly, a smaller sigma value in the high-pass filter will result in a sharper transition between the low-frequency and high-frequency content in the hybrid image, as the high-pass filter will have a more limited sharpening effect. On the other hand, a larger sigma value in the high-pass filter will result in a smoother transition between the low- and high-frequency content, as the high-pass filter will have a more aggressive sharpening effect.

Therefore, the choice of sigma value in the low-pass and high-pass filters is crucial in controlling the balance between the low- and high-frequency content in the hybrid image and determining the appearance of the hybrid image at different viewing scales or distances.

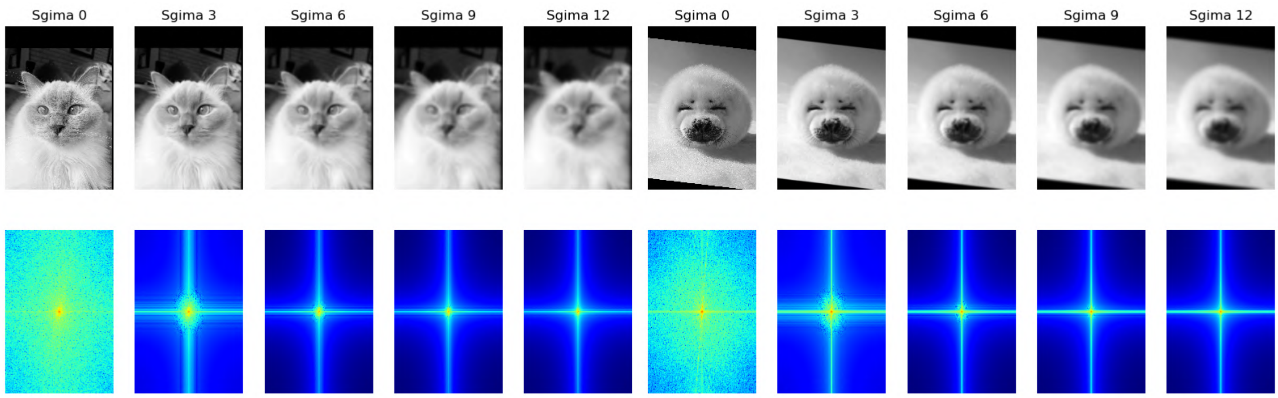

Figure 5: Effect of low-pass filter on both images, where sigma 0 indicates not filtered image.

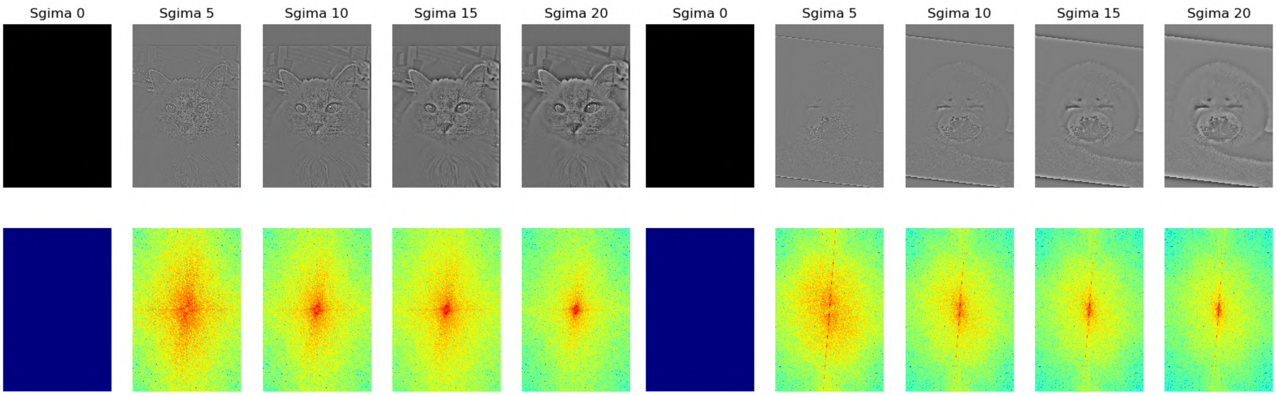

Figure 6: Effect of high-pass filter on both images, where sigma 0 indicates not filtered image.

Step 4 - Choosing the best sigma values

I decided that the best hybrid image for this case is when choosing sigma 7 for the low-pass filter and sigma 8 for the high-pass. This can result in a good balance between the low- and high-frequency content in the hybrid image.

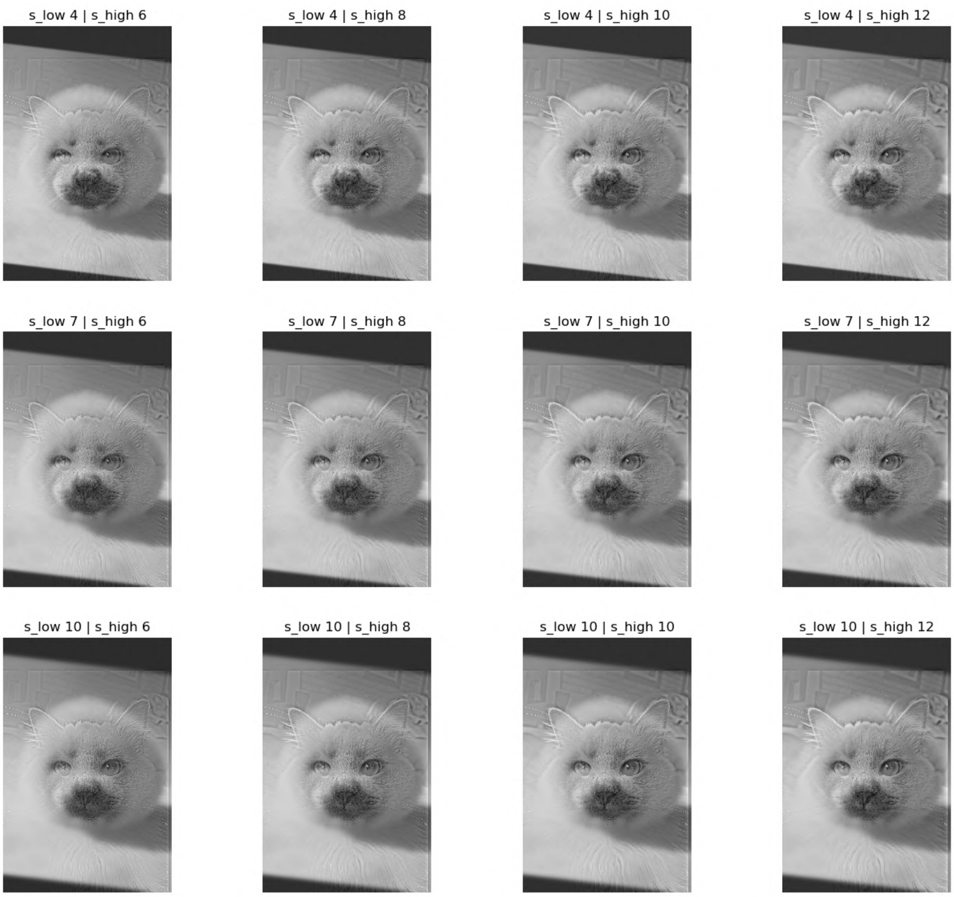

Figure 7: Hybrid image with different sigma values.

Final results

The final result of a hybrid image is a composite image that merges the low-frequency content from one image with the high-frequency content from another image. The low-frequency content provides the overall structure and the dominant features of the image, while the high-frequency content provides the fine details and sharp edges of the image.

Figure 8: Hybrid image with sigma 7 for low-pass filter and sigma 9 for high-pass filter. The final image was cropped for better visualization.

Figure 9: Constructed hybrid image at different scale.

Figure 10: Hybrid image of Jula and my boyfriend.

Figure 11: Hybrid image of Jula and myself.

Gaussian/Laplacian pyramid

The Gaussian pyramid is a sequence of downsampled versions of the original image, where each subsequent level of the pyramid has a reduced spatial resolution. The downsampling is achieved by convolving the image with a Gaussian filter and then subsampling the result. The Gaussian pyramid provides a multi-scale representation of the image, where each level of the pyramid represents a different scale or level of abstraction of the image.

The Laplacian pyramid is a sequence of the difference between each level of the Gaussian pyramid and the upsampled version of the next level. The Laplacian pyramid represents the high-frequency content of the image, which corresponds to the fine details and sharp edges in the image. The Laplacian pyramid provides a multi-scale representation of the image's high-frequency content, where each level of the pyramid represents a different scale or level of detail of the image.

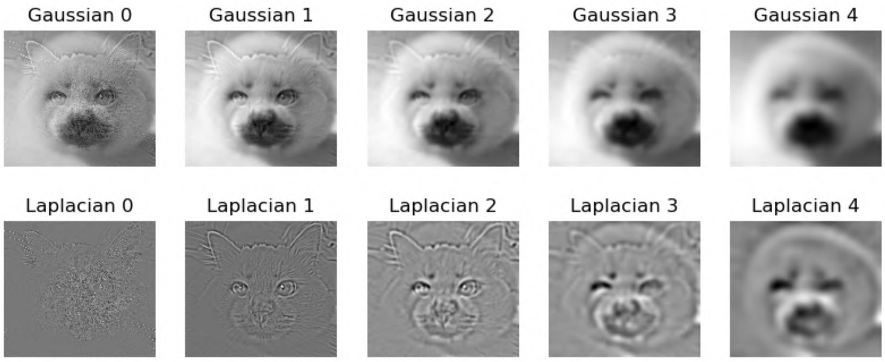

Figure 12: Gaussian/Laplacian pyramid of hybrid image.

Image enhancement

The purpose of image enhancement is to improve the visual quality of an image by adjusting its contrast, brightness, sharpness, and other attributes. Image enhancement techniques can be used to make an image clearer, more detailed, and easier to understand.

Contrast enhancement

Histogram equalization is often considered a good method for contrast enhancement because it works by redistributing the intensities of the pixels in an image such that the resulting histogram is more uniform, which can result in an image with a higher dynamic range and improved contrast.

It's worth noting that histogram equalization is not always the best method for contrast enhancement, as it can sometimes produce over-saturated images or introduce unnatural-looking artifacts. I tried gamma correction and histogram equalization methods to see which gave better results. The gamma correction approach created better contrast, but it tended to darken the image a lot. On the other hand, histogram equalization created a good contrast image without any artifacts and brightness issues.

Figure 13: Comparison between original image and image after histogram equalization.

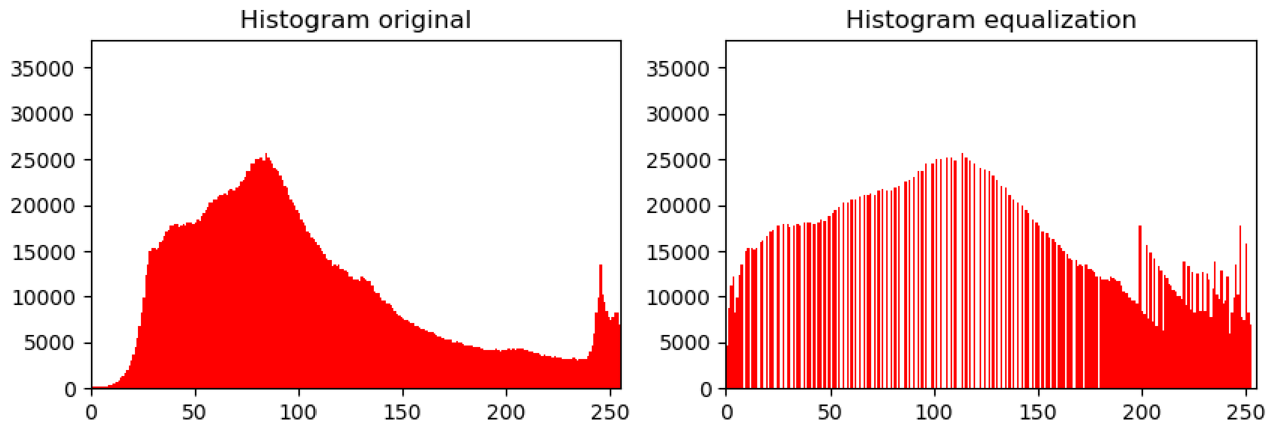

Figure 14: Comparison of histograms for original image and image after histogram equalization.

Color enhancement

Color enhancement is the process of adjusting the colors in an image to make them more vibrant, accurate, or aesthetically pleasing. This is accomplished by applying mathematical algorithms to manipulate the values of the image's pixels.

For this part I decided to use gamma correction on the S (Saturation) channel of HSV color space. The gamma correction function is defined by a single parameter, known as the gamma value, which determines the degree of the non-linearity. I'm aware that gamma function is not specifically designed for this purpose, but I'm really happy with how it turned out so I decided to share my results with you.

Figure 15: Comparison between original image and image after color enhancement.

Color shift

Color shifting refers to the process of adjusting the hue of an image. I decided to mask pixels that correspond to color on the A and B channels of LAB color space (e.g. ¿127 on A channel for red), and use a simple scalar multiplication to boost or weaken the color. Multiplying by a value greater than 1 on A channel boosts the red color without changing green pixels. The same holds for the B channel, multiplying by a value less than 1 boosts the yellow color without changing blue pixels.

Figure 16: Comparison between original image, image with more red, and image with less yellow.

Ultimate enhancement

I decided to use all of the enhancement at once, and the results are fantastic!

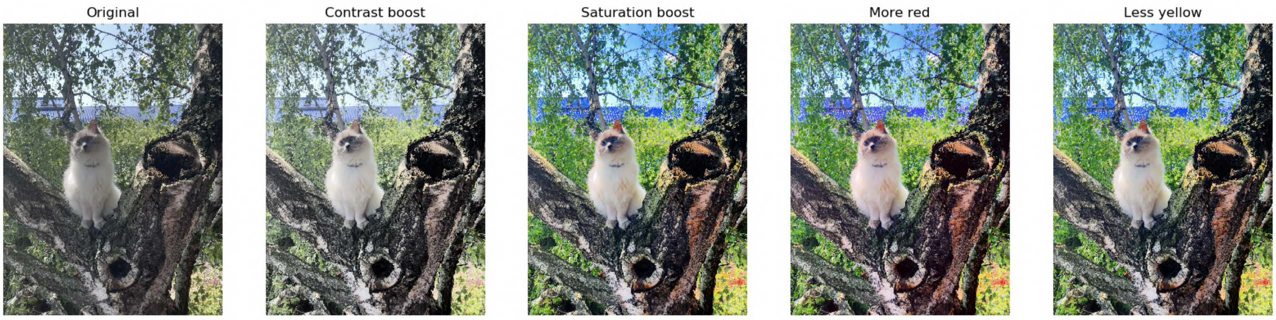

Figure 17: Process of image enhancement.

Figure 18: Comparison between original and enhanced image.

References

Wallpaper Flare. White seal image.

Aude Oliva, Antonio Torralba, and Philippe G. Schyns. 2006. Hybrid images. page 527–532.