Creating Hybrid Images Using Low-Pass & High-Pass Filtering

Team YOLO - s19 (205, 355, 408, 420)

1. Introduction

In order to create a visual impression that varies according to viewing distance, hybrid pictures mix the low-spatial frequencies of one image with the high-spatial frequencies of another. The purpose of this study is to investigate and assess the generation of hybrid images using image filtering algorithms. The study is based on the research by Oliva and Torralba (2006), which provides a framework for developing hybrid images using multi-scale visual perception.

2. Key Definitions

Hybrid Image

A visual technique that combines a low-frequency (blurred) image with a high-frequency (sharp edge) image to create an image that appears differently at different viewing distances. Up close, the high-frequency image is dominant, while from a distance, the low-frequency image becomes more visible.

Low-Pass Filtering

A process that removes high-frequency details from an image, keeping only the smooth, low-frequency components. This is done using a Gaussian blur, which spreads out intensity values and reduces sharp edges.

High-Pass Filtering

A process that removes low-frequency components while keeping fine details and edges. This is achieved by subtracting a blurred version of the image from the original, leaving only high-frequency elements like edges and textures.

Gaussian Blur

A smoothing technique that reduces image noise and detail by averaging pixel values with their neighbors. It is commonly used in low-pass filtering to remove high-frequency information.

Sigma (σ) in Gaussian Filtering

A parameter that controls the amount of blurring in a Gaussian filter. A higher sigma value results in a stronger blur (more low-frequency retention), while a lower sigma value keeps more details.

Frequency Domain Representation

An alternative way of analyzing images is based on their frequency content rather than pixel values. Low frequencies represent smooth changes, while high frequencies correspond to rapid intensity variations (edges and textures).

Color Channel Processing

Since images are made up of multiple color channels (Red, Green, and Blue - RGB), hybrid image processing must apply low-pass and high-pass filters separately to each channel to maintain color accuracy.

3. Project Steps

I. Problem Identification & Project Planning
II. Data Collection
III. Algorithm Development
IV. Testing with a couple of images
V. Report writing

4. Methodology

The process of creating hybrid images involves the following steps

4.1 Image Acquisition

A pair of photos were chosen, one of which was the high-spatial-frequency (detailed) image, and the other was the low-spatial-frequency (blurred) image.

4.2 Filtering Process

- The first image is subjected to a low-pass filter (Gaussian blur) in order to preserve just the low-frequency elements.
- A low-pass filtered version of the second image is subtracted from the original to create a high-pass filter, which preserves only high-frequency features.

4.3 Image Combination

The hybrid image is then created by combining the two filtered photos. Depending on the viewing distance, the final image appears differently; up close, the high-frequency details are more prominent, while at a distance, the low-frequency image is more apparent.

4.4 Implementation

The hybrid image generation was implemented using Python with the OpenCV and NumPy libraries. The main steps are,

1. Reading the input images.
2. Applying Gaussian blurring to generate low-pass filtered images.
3. Creating a high-pass filtered version by subtracting the blurred image from the original.
4. Merging the processed images to generate the final hybrid image.

5. Results and Discussion

The hybrid images generated demonstrate a technique for producing hybrid images through the use of low-pass and high-pass filters. The objective is to combine two images so that one is prominent when viewed up close, while the other becomes visible from a distance. This effect is accomplished by applying a Gaussian blur (low-pass filter) to one image and extracting the high-frequency details (high-pass filter) from another.

In this project, two methods are used,

1. Adaptive Skin Detection Using Statistical Color Analysis in YCrCb Space
2. Hybrid Image Generation Using Multi-Frequency Blending in Color Images

However, the outputs produced by both methods are quite similar, as shown in Figures 1 and 2.

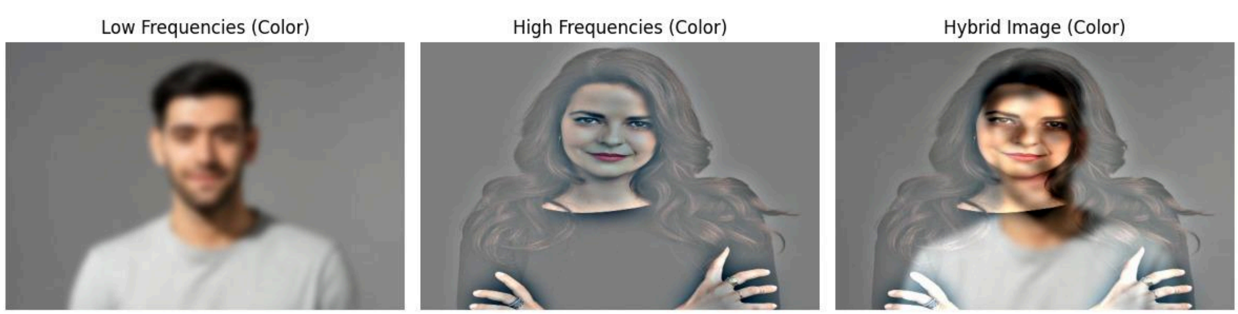

Figure 1: Adaptive Skin Detection Using Statistical Color Analysis in YCrCb Space

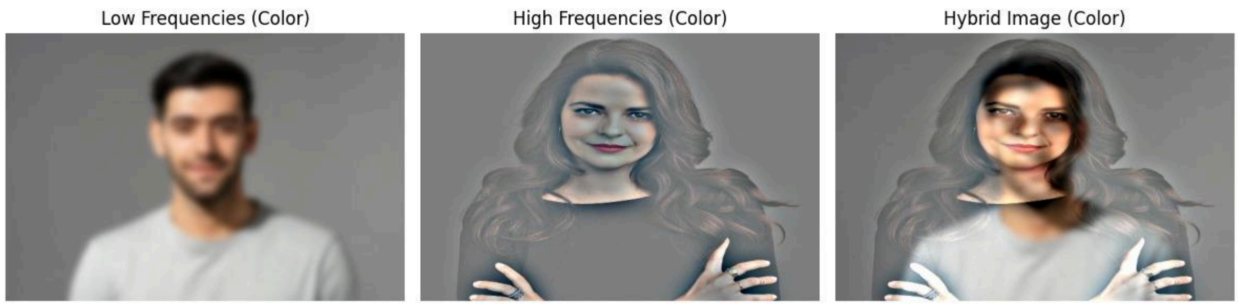

Figure 2: Hybrid Image Generation Using Multi-Frequency Blending in Color Images

This project aimed to find out which image works better as a low-pass image and which works better as a high-pass image. We achieved this by swapping the two images and analyzing their differences. Figure 3 shows these results.

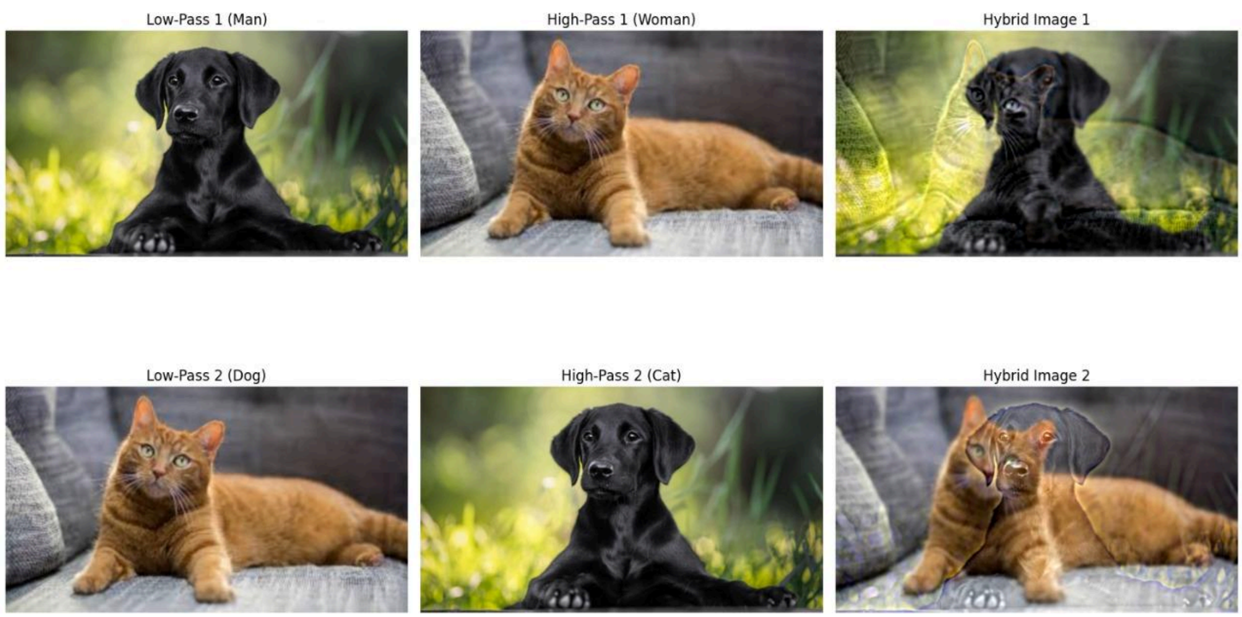

Figure 3: Testing Method 2 with Different Images

Limitations and Possible Improvements

Alignment of Images - *If the images are not aligned well, the hybrid effect may not work as expected. Face alignment techniques could improve results for portrait-based hybrid images.*

Adaptive Sigma Selection - *A fixed sigma might not be optimal for different images. A more adaptive approach, such as using frequency analysis to determine sigma dynamically, could enhance flexibility.*

Edge Artifacts - *The subtraction process for high-pass filtering can introduce artifacts. A more refined frequency domain approach (e.g., Fourier transform filtering) could mitigate these issues.*

6. Task Breakdown

The project was divided into two main tasks,

Task	Team Members
Image Processing, Code Implementation, Experimentation & Results Analysis	S19205, S19355, S19408
Project Reporting & Documentation	S19420

7. Conclusion

In this project, we successfully created a hybrid image by combining two different images using image processing techniques. We used Gaussian blurring to keep the low-frequency details and subtracted the blurred image from the original to get the high-frequency information. This process was done separately for each color channel (BGR) to keep the colors accurate.

The results show that the hybrid image works well, making one image clear when viewed up close and the other more visible from a distance. The choice of sigma values for the Gaussian filters played a big role in balancing the two images.

In the future, we could improve this method by using smarter filtering techniques, better blending methods, or even machine learning to choose the best settings automatically. This project provides a strong base for future research in hybrid image processing, with possible uses in creative designs, hidden data in images, and studies on how people see images.

8. References

1. Szeliski, Richard. *Computer Vision: Algorithms and Applications*.
2. Oliva, A., & Torralba, A. (2006). Hybrid Images. ACM Transactions on Graphics (SIGGRAPH).