Hybrid Multi-Frequency Image Illusion

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***Abstract*—This project aims to merge two different images such that the final image appears to be an image with two interpretations, one image from a certain distance and another image from a different distance. We aim to make a system that is autonomous and can take two input images with different frequency bands and adjust the parameters accordingly to create hybrid multi-frequency image illusions by mixing the two images. Our method uses image processing techniques to extract the low-frequency content of one image with the high-frequency features of another, and combine them into one hybrid image**

***Index Terms*—Hybrid images, low frequency, high frequency, spatial filters, Gaussian filters, Laplacian filters, Fourier filters**

I. Introduction

HYBRID images are images with an interpretation that changes with viewing distance.

The visual effect of a hybrid image relies on spatial frequency of the two images where the low frequencies of the image convey coarse structure seen from afar and the high frequencies convey fine details that are seen up close. One of the images is filtered to retain its low-frequency (blurry) details, while the other image keeps its high-frequency (sharp) features. When these two filtered images are added together, the human visual system perceives a single image whose interpretation changes with distance where one picture is visible up close, while the other emerges when the final image is viewed from afar.

The human visual system analyzes low and high frequencies through separate pathways and the distance or blurring determines whether low-frequency or high-frequency information dominates perception. Up close, our vision focuses on fine details and edges, revealing the high-frequency image. From a distance, the fine details get blurry, allowing the smoother low-frequency image to appear more prominent. Thus, hybrid images demonstrate how spatial frequency affects what we see and how human perception adapts depending on viewing conditions.

II. Methodology

A. Literature Review

We reviewed several academic papers on hybrid images to understand the principles of combining different frequency components. We studied the concepts of low-pass and high-pass filtering and explored various image processing techniques such as Gaussian, Laplacian, and Fourier filters to evaluate their effectiveness in separating and merging frequency components.

We also analyzed how different sigma values influenced the clarity and blending of the final hybrid image to determine the optimal filtering parameters.

B. Image Selection and Pre-processing

We selected two suitable images of a cat and a dog for our experiment. Both images were converted to grayscale to simplify frequency analysis and maintain consistency in intensity values. We then resized them to achieve pixel-to-pixel alignment, ensuring an accurate combination during hybrid image formation.

C. Filtering Each Image

We then applied a Gaussian low-pass filter to the image of the dog to preserve its low-frequency components and remove fine details. For the image of the cat, we applied a high-pass filter by subtracting its low-pass filtered image from the original image, allowing us to retain only the high-frequency details such as edges and textures.

D. Hybrid Image Generation

We combined the two filtered images through pixel-wise addition to create the hybrid image. We then normalized the resulting pixel values and clipped them within the range [0, 255] to ensure valid display intensities. The final image effectively combined the low-frequency features of the image of a dog with the high-frequency features of the image with a cat, producing a perceptual illusion that changes with viewing distance.

III. Results and Discussion

Our approach was able to produce hybrid images, which have two different perceptions depending on the viewing distance. The low-frequency and high-frequency components combined produced the desired final image.

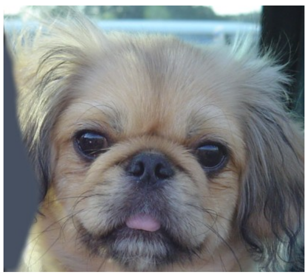
In our experiment, a Gaussian low-pass filter was applied to smooth out the image of a dog resulting in a smooth image that preserved the overall form but not the edge sharpness. The high-pass filtered image of the cat accentuated the fine details (whiskers, eyes, edges) and removed the coarse intensity differences. By integrating these filtered images, the resulting hybrid image showed the features of the cat in closer viewing capacities and the form of the dog was visible when the picture was seen far away.

By testing various sigma (σ) values of the Gaussian filter we found the amount best suitable for our two images. Smaller

σ values produced excessive blending and the low-frequency image was less visible whereas larger σ values produced an excessively blurred image, making the high-frequency image less visible. We got a moderate σ value, which gave the most balanced hybrid perception, and was obtained through the process of trial and error.

The theoretical concept of spatial frequency separation and its effects on human visual perception was proven by our hybrid image results.

In our upcoming reports, we plan on automating our code in such a way that any 2 similar images can be used as an input and our system should assess the appropriate parameters for optimal final image.



(a) Dog

(b) Cat

Fig. 1: Original input images used for hybrid image generation.

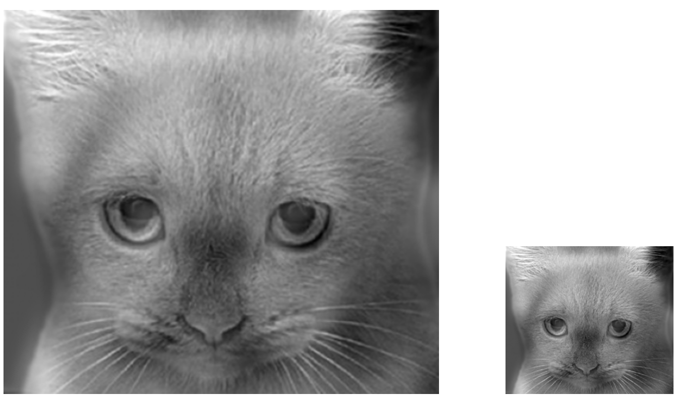


Fig. 2: Output images when viewed from upclose vs far away.

IV. Conclusion

Hybrid images are successfully created by combining low and high frequency images of two different images.

Low-pass filtering extracted smooth structures, while high-pass filtering preserved edges and fine details.

The resulting hybrid image demonstrates an optical illusion, showing different images at close and far viewing distances.

The project illustrates the practical use of image processing techniques such as Gaussian filtering and convolution.

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