Ahmedabad
University

ECE501 : Digital Image Processing

9 - Hybrid Multi-Frequency Image Illusion

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Abstract

This project focuses on the generation of hybrid images through multiresolution analysis and wavelet-based image fusion. Two source images are used: one contributes the low-frequency structural information that dominates perception at a distance, while the other provides the high-frequency details that become visible at close range. Using Gaussian and Laplacian pyramids along with multi-level 2D wavelet decompositions, we constructed hybrid images by fusing approximation and detail coefficients guided by parameterized fusion rules. An automated search was implemented to explore wavelet types, decomposition depths and fusion weights, with each candidate evaluated using a metric that balances structural similarity for far-view perception and edge preservation for near-view perception. Although the system successfully generates hybrids, the resulting images reveal limitations in color handling, spatial consistency and fusion stability, indicating the need for improved optimization and perceptual modeling.

In the next stage, the pipeline will be expanded to examine additional color representations and structural analysis techniques. Experiments will include hybrid-image fusion in YUV and YCbCr color spaces to better isolate luminance and chrominance, along with spatial slicing methods to understand how different image regions contribute to perceptual blending. Furthermore, we will automate the refinement of wavelet-fusion parameters using Particle Swarm Optimization and Bayesian Optimization to search the parameter space more efficiently. These enhancements aim to produce hybrid images that are more perceptually balanced, structurally coherent and robust across viewing distances, ultimately contributing to a more consistent and effective hybrid-image synthesis framework.

Contents

1 What We Have Done

In this project stage, we created a multiresolution analysis and wavelet-based fusion hybrid-image generation pipeline using the OpenCV, NumPy and PyWavelets. There are two pictures concerned on one of low-frequency structure (far-view identity) and on one of high-frequency detail (near-view identity). We first used Gaussian and Laplacian pyramids with the contents of the two images combined in a simple hybrid which comprised of the low pass contents of the first image and high pass contents of the second image and thereafter a reconstruction was done to have a purer hybrid image.

To remove manual tuning, we augmented by an automated search of wavelet-fusion: multi-level 2D wavelet decompositions are computed on the channels of both images, the approximation coefficients and detail coefficients of the 2D decompositions are then fused by rules parameterized by parameters and each candidate hybrid is evaluated by a mathematical metric that simultaneously weights structural similarity between far-view and edge similarity between near-view; by sweeping wavelet-types, wavelet levels and weights on the fusion fuses, the system automatically chooses the optimal hybrid image. Finally, viewing-distance simulation (downsampling and blurring) is performed to make sure that the resulting hybrid is showing the high-frequency identity in the near-range and the low-frequency identity in the far-range.

2 What We Aspire to Do

The following stage of the project will involve the extension of the hybrid-image pipeline by trying more color formats and structural analysis techniques. In order to appreciate the effect of the separation of the luminance and chrominance contents on the balance between the low and high frequency contents, we will test the YUV and YCbCr color spaces. We are also going to experiment with image slicing in order to study the contribution made by various spatial regions towards the perception effect of the hybrid image as a whole.

In addition, we will automate the process of optimization of a wavelet based fusion. Particle Swarm Optimization and Bayesian Optimization will help us to find the most efficient wavelet parameters, including the type of a wavelet, the level of decomposition and fusion weights. Since perceptual and structural measures produce inconsistent and unequal results in producing hybrid images, we will want to obtain more consistent, well balanced and objective results by generating and assessing a series of hybrid images.

References

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