Assignment - Difference Pyramid

Construct two difference-pyramids for an image in the collection provided for this course. The first pyramid should have four levels, and the second should have 8. Analyze the results of each pyramid and discuss how you can utilize them to compress the image, i.e., reduce the file size of the image stored on disk. Submit your report on the Canvas platform.

Difference Pyramid Analysis

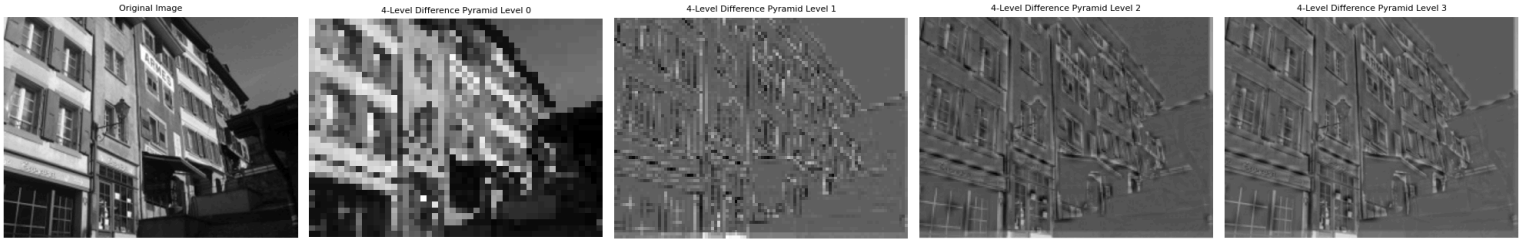
A difference pyramid represents the discrepancy between successive levels of an image pyramid. The objective is to capture the "differences" or changes as we traverse the pyramid levels, allowing for potential compression benefits. The up-pyramid is formed by recursively down-sampling the image, reducing its size at each level. The down-pyramid is constructed by successively up-sampling the smallest image from the up-pyramid, thus increasing its size at each level. The difference pyramid is computed by subtracting the corresponding levels of the down-pyramid from the up-pyramid.

The primary importance of the difference pyramid lies in its capacity for image compression. The pyramid's higher-level images are typically sparse, meaning they contain numerous zero or near-zero values, as they encapsulate the information lost during the up- and down- sampling processes. This inherent sparsity is of great significance for image compression.
When considering compression methodologies, the difference pyramid offers an opportunity for significant storage reduction. The higher levels of the pyramid, which are sparse, can be compressed using standard techniques like run-length encoding. By effectively compressing these difference images, we can significantly decrease the image's storage requirements.

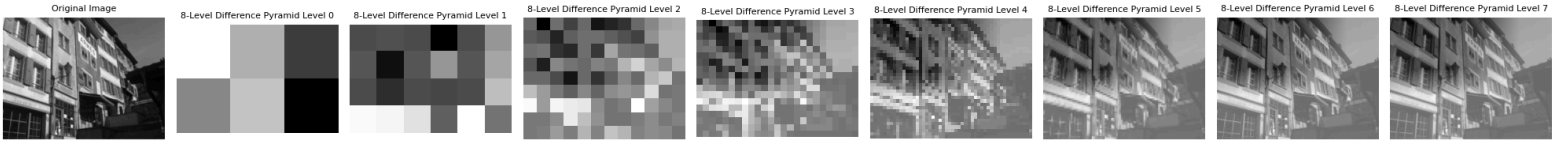
In practical applications, the difference pyramid's representation can be exploited to store only select levels, especially those that contain substantial image data. This allows for a balance between image fidelity and storage efficiency. While there is a trade-off in terms of image quality, many applications find this compromise acceptable, especially when storage space is at a premium.

The difference pyramid offers a systematic approach to understanding and capturing image discrepancies across pyramid levels. Its potential for image compression makes it a valuable tool in the domain of computer vision.

Observations:



4-Level Difference Pyramid Output:
The first level displays the image in its lowest resolution. This representation is crucial as it captures the coarsest features of the image. As we progress through the subsequent levels, the images mainly showcase the "differences" or changes introduced by the down-sampling and up-sampling processes. These levels encapsulate the details that are missed in the preceding pyramid levels. The sparse nature of these difference images (with many areas appearing close to black) indicates that there are regions with minimal changes.



8-Level Difference Pyramid Output:
Again, the first level is the coarsest representation. The subsequent levels seem to capture more nuanced details due to the increased depth of the pyramid. We see finer and finer details being captured as the difference between levels. Similar to the 4-level output, the sparsity in these images indicates regions with negligible changes. However, due to the greater depth, the difference images in the 8-level pyramid are generally sparser than their 4-level counterparts.

Analysis for Image Compression:
The value of a difference pyramid in image compression lies in the sparsity of the difference images. Since many values in these images are close to zero (or are zero), they can be efficiently compressed using various techniques, such as run-length encoding or thresholding methods. The more sparse the image, the greater the compression rate achievable. Considering the outputs, the 8-Level pyramid has higher levels of sparsity, especially in the deeper levels. This suggests that there might be greater potential for compression using the 8-Level pyramid as compared to the 4-Level pyramid. However, the trade-off here is between compression efficiency and the computational cost of handling more levels. Difference pyramids provide an effective mechanism to capture image details in a manner that's conducive to compression. By efficiently storing these differences and employing appropriate compression techniques, we can significantly reduce the file size of the image stored on disk without compromising too much on the image quality.