HW04 Report

Original JPEG image(for display purpose only):

Part 1. The "Constrained Least Squares Filtering" (CLSF)

In this section, the original image is intentionally blurred using a Gaussian blur with a kernel size of 17x17 and a sigma of 3. Additionally, Gaussian noise with a sigma of 0.03 is added. The image is then segmented into 256x256 pixel blocks for deblurring. During the deblurring phase, the clsf function is applied to each block. Following this process, all blocks are recombined for Poisson stitching.

The clsf process is the critical component of this procedure.

`apply_clsf` Function

- **Purpose**: This function applies the Constrained Least Squares Filtering (CLSF) in the frequency domain to restore images that have been degraded by a known blurring function and contaminated with noise. The function also implements regularization to manage the amplification of noise.
- **Parameters**:
  - `B`: The degraded image array.
  - `H`: The degradation function (often called the point spread function) represented in the array.

- `lambda_reg`: The regularization parameter used to control the trade-off between fidelity to the original data and noise suppression.
- `L`: The Fourier transform of the Laplacian operator, used as part of the regularization term.

- **Process**:
    - Padding: The degraded image `B` is symmetrically padded to center the original data within a larger array. This helps to avoid edge effects during the Fourier transform.
    - Fourier Transform: The Fourier transforms of the padded image (`B_padded`) and the degradation function (`H`) are computed.
    - Spectral Division: A spectral division is performed where the Fourier transform of the degraded image is multiplied by the complex conjugate of the Fourier transform of `H`, and then divided by the sum of the squared magnitude of `H` and the product of `lambda_reg` with the squared magnitude of `L`.
    - Inverse Fourier Transform: The result from the spectral division is then transformed back to the spatial domain using the inverse Fourier transform.
    - Cropping: The central part of the image, corresponding to the original size of `B`, is extracted from the padded array to obtain the restored image.
    - Final Image: The absolute values are taken to ensure the pixel values are real numbers, which represent the intensity values in the restored image.

After blurring:

After deblurring with blocking:

Part 2: Image Stitching with Poission Blending

In this section, a mask is created for the recombined blocks. In the mask, areas overlapping at the edges of the blocks are assigned a value of non-zero, while the remaining parts are set to 0. Subsequently, the `poisson_blending` function is invoked to generate the final image.

`poisson_blending` Function

- **Purpose**: This function performs Poisson image blending to seamlessly combine a source image into a target image. It uses the gradient domain blending technique which ensures that the resulting image retains the gradient of the source image within the blending area defined by a mask.
- **Parameters**:
  - `target_img`: The target image array where the source image will be blended (deblurring with blocking image).
  - `source_img`: The source image array that will be blended into the target image (blurring image).
  - `blend_mask`: A binary mask defining the regions where blending should occur (1 for regions to blend, 0 elsewhere).
- **Process**:
  - Initialization: The shape of the source image is used to determine dimensions and initialize a result image. The number of pixels affected by blending is calculated, taking into account all color channels.

- Processing by Channel: The blending process is conducted separately for each color channel.
  - Gradient Calculation: For the current channel, the discrete Laplacian of the source image is calculated, which captures the difference between each pixel and its immediate neighbors.
  - System Setup: A sparse linear system is constructed where each non-zero entry of the blend mask corresponds to an equation. The system's matrix (A) captures the Laplacian operator, and the vector (b) is populated with the Laplacian values adjusted by the target image's boundary conditions.
  - Sparse Matrix Handling: The sparse matrix operations optimize memory usage and processing time.
  - Solving the System: The sparse linear system is solved to find pixel values that maintain the gradient of the source while fitting smoothly into the target image environment.
  - Updating the Result: The solutions are used to update the blended result image in the areas specified by the mask, ensuring values are within the allowable range for image pixels.

- **Output**: The final output is the blended image where the source image is seamlessly integrated into the target image according to the defined mask, preserving natural gradients and transitions.

After Poission blending:

Reference deblurring without blocking:

From the results, we observe that the deblurred image with Poisson blending is nearly indistinguishable from the deblurring performed without blocking. This makes it well-suited for smartphone photography.