TC. ÜSKÜDAR ÜNİVERSİTESİ

Digital Image Processing

MIDTERM EXAM ASSIGNMENT

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Introduction

This report serves as the Midterm Exam Assignment for the Digital Image Processing course at Üsküdar University. The primary objective of this study is to demonstrate the practical application of various fundamental and advanced image processing techniques, including image enhancement, filtering, geometric transformation, and frequency domain analysis.

All operations documented herein are performed on the **ISIC 2018 Skin Lesion Dataset**, a specialized and comprehensive collection of dermatoscopic images. A core requirement of this assignment is to execute and compare all processing steps across both RGB (color) and Grayscale formats, providing a comparative analysis of the impact of each technique on single-channel intensity data versus three-channel color data. The structured analysis aims to evaluate the suitability of each technique for preprocessing medical images for feature extraction and pattern recognition.

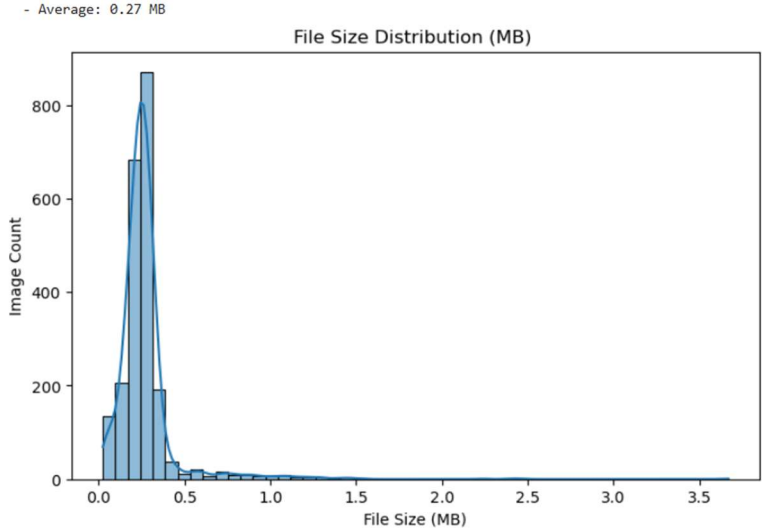
1. Data Loading (Veri Yükleme)

- **Goal:** To set up the project environment by importing necessary libraries and organizing the image file paths into a structured pandas Data Frame (train_df) for subsequent processing.
- **Explanation:** This section ensures all required libraries (pandas, numpy, cv2, matplotlib, os) are imported. Since the dataset was delivered without a metadata CSV, we utilize an iterative file search (os.walk) to traverse all class subfolders within the main Train directory, extracting every .jpg file path and its corresponding unique identifier (image_id). This robust approach ensures all images are collected and indexed, forming the foundation of our image processing pipeline.
- **Expected Output:** A printout of the Data frame head and the count of images collected from all subfolders.

```
Data frame successfully created from image files.
************************************************************
        The First 5 Rows Of DataFrame
************************************************************
       image_id                                          path  \
0  ISIC_0025780  C:\Users\vraja\Skin cancer ISIC The Internatio...
1  ISIC_0025803  C:\Users\vraja\Skin cancer ISIC The Internatio...
2  ISIC_0025825  C:\Users\vraja\Skin cancer ISIC The Internatio...
3  ISIC_0025953  C:\Users\vraja\Skin cancer ISIC The Internatio...
4  ISIC_0025957  C:\Users\vraja\Skin cancer ISIC The Internatio...

               class
0  actinic keratosis
1  actinic keratosis
2  actinic keratosis
3  actinic keratosis
4  actinic keratosis
************************************************************
Total Number Of Images:2239
```

```
Resolution (Height x Width): 450 x 600
************************************************
Channel Count Verification: 3 (RGB, 3 channels)
************************************************
File Size (MB):
  - Minimum: 0.02 MB
  - Maximum: 3.67 MB
  - Average: 0.27 MB
```



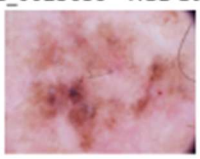
2. Image Loading and Visualization (Görüntü Yükleme ve Görselleştirme)

2.1. Random Image Selection and Comparison

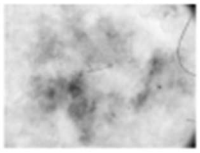
- **Goal**: To visually compare the **RGB (Color)** and **Grayscale** versions of the images, which is necessary before applying processing techniques that require specific color spaces.
- **Explanation:** Nine random images are loaded and converted from OpenCV's default BGR format to RGB for accurate display. They are simultaneously converted to grayscale using a weighted average of the R, G, and B channels. The pairs are displayed side-by-side.
- **Expected Output:** A figure displaying 9 rows of image pairs (RGB on the left, Grayscale on the right).

RGB and Grayscale Comparison of 9 Randomly Selected Images

ISIC_0025659 - RGB State

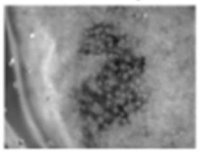


ISIC_0025659 - Grayscale State



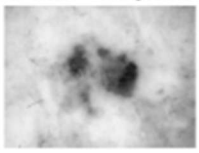
ISIC_0033705 - RGB State

ISIC_0033705 - Grayscale State

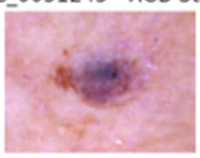


ISIC_0024925 - RGB State

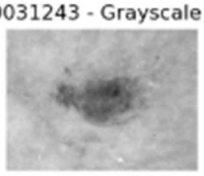
ISIC_0024925 - Grayscale State



ISIC_0031243 - RGB State

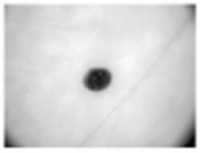


ISIC_0031243 - Grayscale State



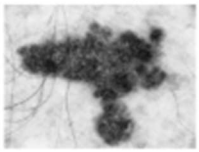
ISIC_0030070 - RGB State

ISIC_0030070 - Grayscale State



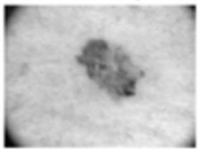
ISIC_0025885 - RGB State

ISIC_0025885 - Grayscale State



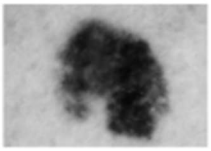
ISIC_0000154 - RGB State

ISIC_0000154 - Grayscale State



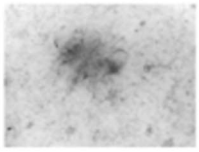
ISIC_0000172 - RGB State

ISIC_0000172 - Grayscale State



ISIC_0030321 - RGB State

ISIC_0030321 - Grayscale State



2.2. Statistical Properties

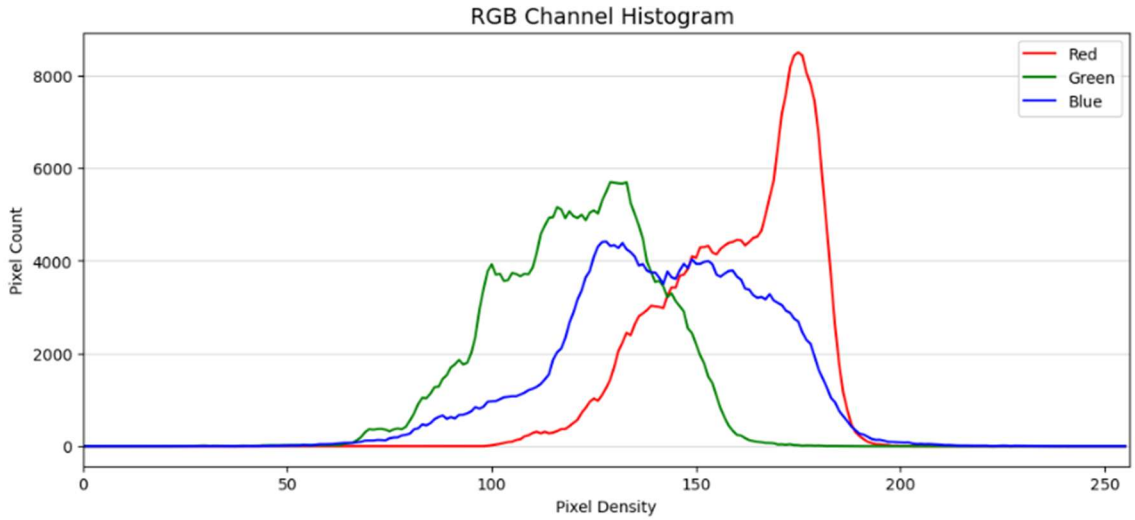
- **Goal:** To quantify the intensity distribution of the images by calculating basic descriptive statistics.
- **Explanation:** For a single randomly selected image, the minimum, maximum, mean, and standard deviation are calculated for the grayscale image and for each of the red, green, and blue channels independently.
- **Expected Output:** A Markdown table comparing the calculated statistics for all four formats (R, G, B, Grayscale).

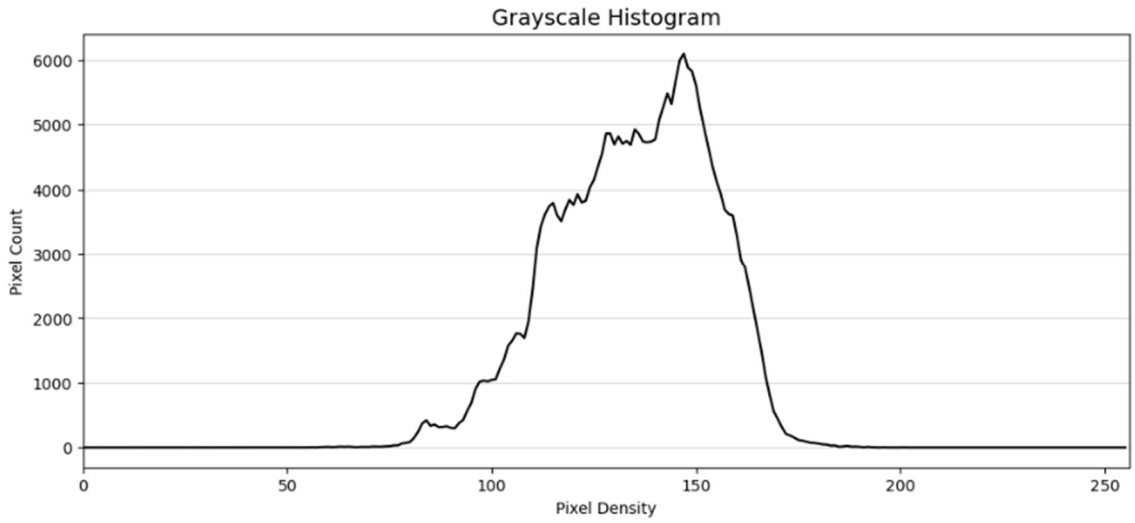
****
Image ID: ISIC_0027608 Statistical Comparison
****

Image Format	Minimum	Maximum	Mean	Standard Deviation
RGB - Red	97	215	160.34	17.27
RGB - Green	22	197	120.49	19.08
RGB - Blue	37	250	141.99	24.62
Grayscale	55	205	134.86	18.56

2.3. Histogram Plotting and Analysis

- **Goal:** To visualize the pixel intensity distribution and analyze the tonal range, contrast, and color balance of the images.
- **Explanation:** Two types of histograms are plotted:
  - **RGB Histogram:** Displays the density distribution for the red, green, and blue channels separately.
  - **Grayscale Histogram:** Shows the single-channel intensity distribution.
- **Expected Output:** Two separate plots (RGB layered, Grayscale singular) and a detailed analysis of the concentration of tones and the effect of the color-to-grayscale conversion.





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3. Image Processing and Enhancement (Görüntü İşleme ve İyileştirme)

3.1. Contrast Stretching

- **Goal:** To enhance the visual contrast by stretching the image's existing pixel range to utilize the full 0-255 dynamic range.
- **Explanation:** Contrast stretching is applied to the grayscale image (single channel) and separately to each R, G, and B channel of the color image. This linear transformation improves detail visibility by maximizing the intensity difference between the darkest and brightest pixels.
- **Expected Output:** A visualization comparing the original and stretched images, with commentary on the improvement in contrast.

3.2. Histogram Equalization

- **Goal:** To automatically adjust the image contrast by flattening the intensity distribution into a more uniform histogram.
- **Explanation:**
  - **Grayscale:** Equalization is applied directly.
  - **RGB:** To prevent color distortion, the image is converted to the **YCrCb** color space. Equalization is applied **only to the Y (Luminance) channel** before converting the image back to RGB.
- **Expected Output:** A visualization comparing the original and the histogram-equalized images, with a focus on color preservation in the RGB result.
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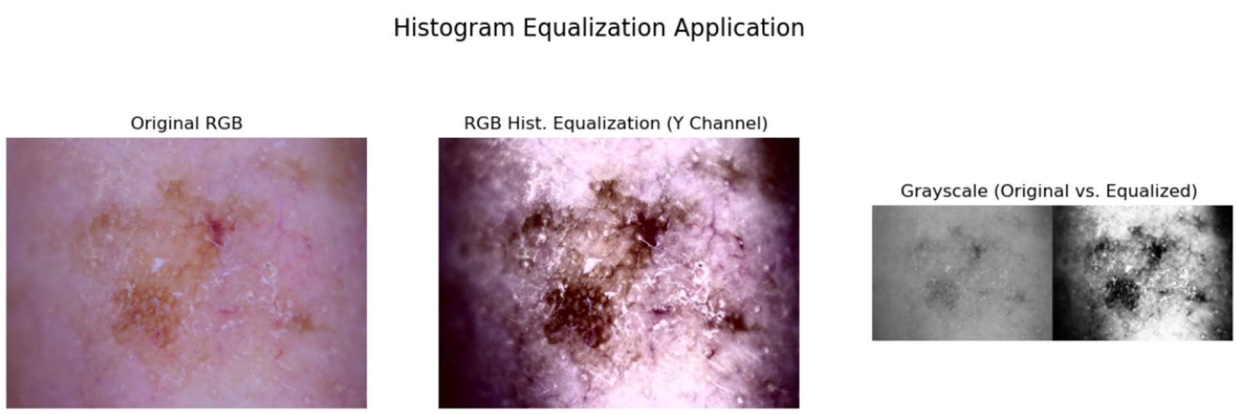
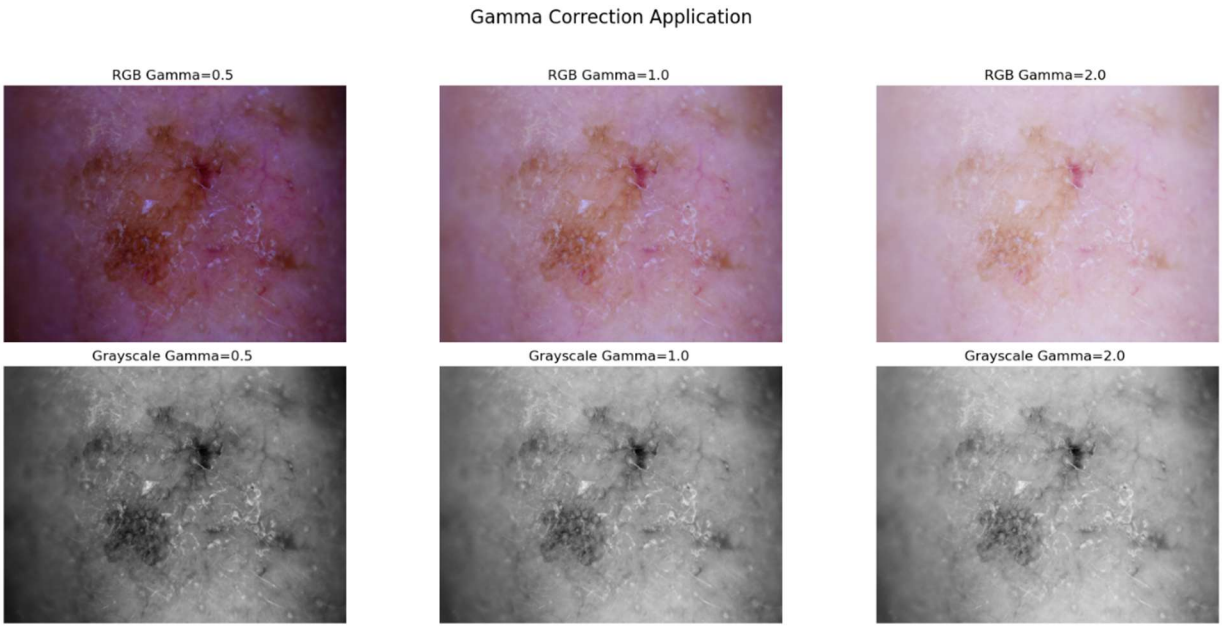


3.3. Gamma Correction

- **Goal:** To non-linearly adjust the image brightness and control contrast in specific tonal ranges (shadows or highlights).
- **Explanation:** Gamma correction is applied to both formats using three different gamma values: 0.5 (brightening), 1.0 (original), and 2.0 (darkening).
- **Expected Output:** A set of visualizations for the different gamma values, with an analysis of how $\gamma < 1.0$ reveals shadow details and $\gamma > 1.0$ compresses highlights.



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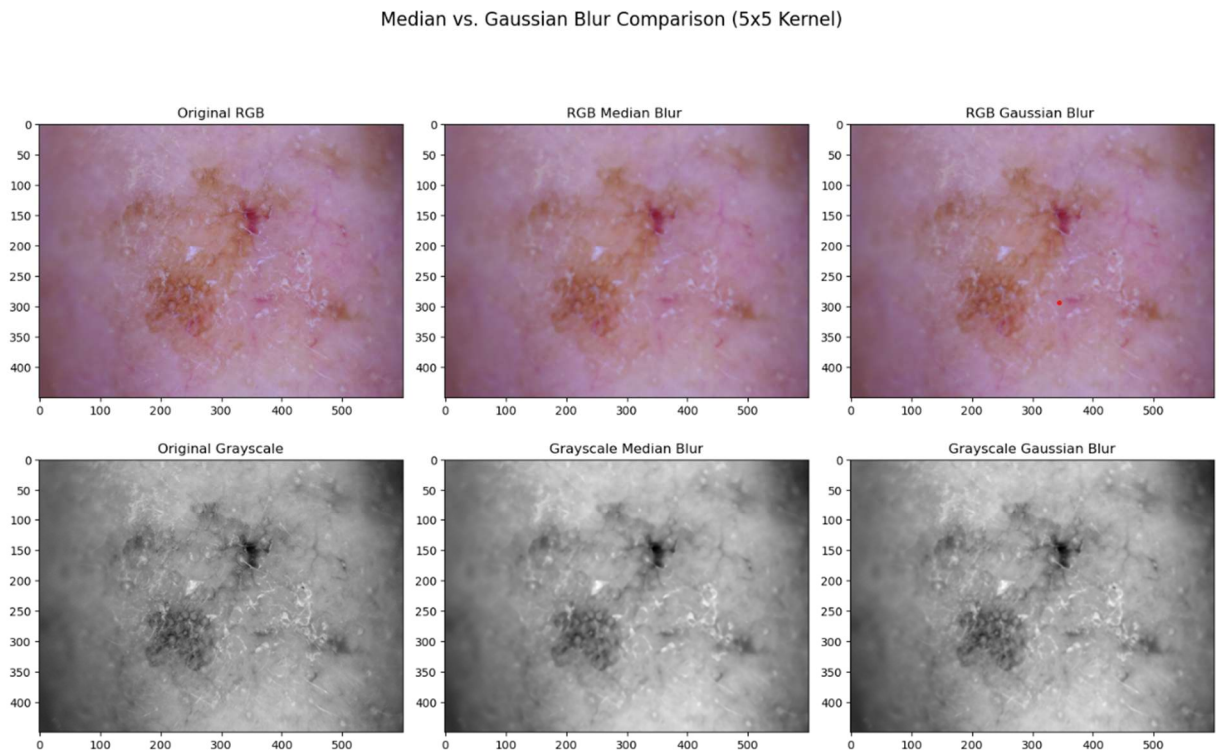
4. Noise Reduction (Gürültü Azaltma)

4.1. Median Blur and 4.2. Gaussian Blur

- **Goal:** To compare the effectiveness of two primary smoothing filters in reducing noise while assessing their impact on image detail and edge preservation.
- **Explanation:** Both the **Median Blur** (which uses the median value, effective against salt-and-pepper noise) and the **Gaussian Blur** (which uses a weighted average, effective against Gaussian noise) are applied to the RGB and Grayscale images using the same kernel size.
- **Expected Output:** A 2×3 visualization grid comparing the original, Median blurred, and Gaussian blurred versions, with an analysis comparing their ability to preserve edges versus the loss of fine detail.



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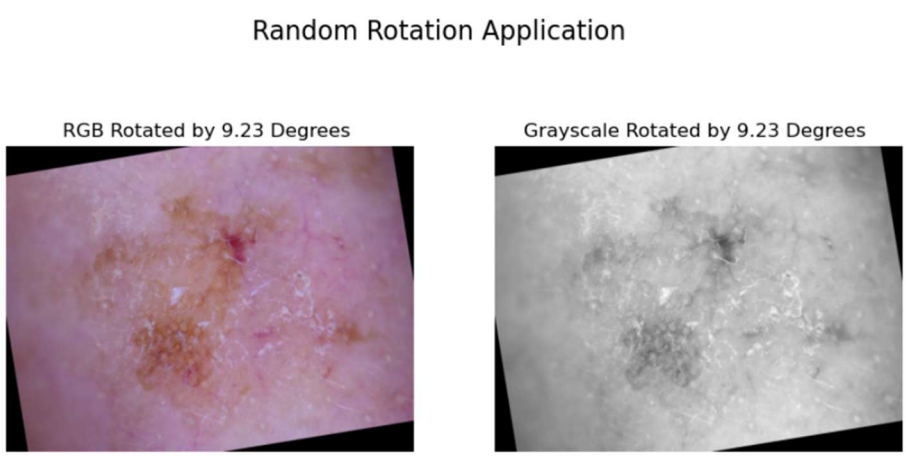
5. Rotation and Flipping (Döndürme ve Ayna Çevirme)

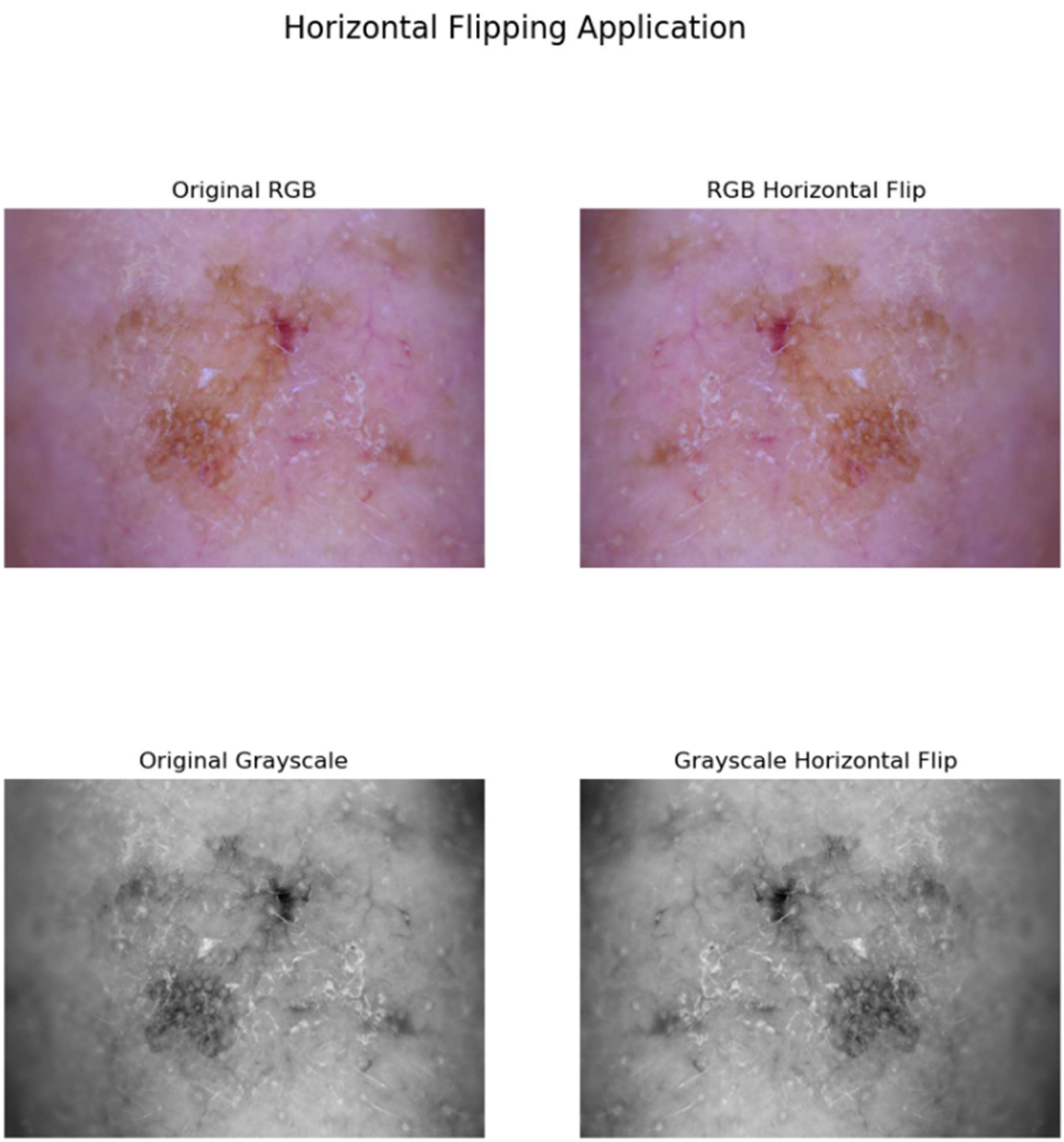
5.1. Random Rotation

- **Goal:** To apply a minor geometric transformation, mimicking slight camera tilt, for potential data augmentation purposes.
- **Explanation:** The images are rotated by a random angle between 0^0 and 10^0 using an affine transformation matrix.
- **Expected Output:** A side-by-side display of the rotated RGB and Grayscale images.



5.2. Horizontal Flipping

- **Goal:** To apply mirroring to observe the biological symmetry (or asymmetry) of the skin lesion.
- **Explanation:** A horizontal mirror flip (reversing along the Y-axis) is applied to both formats.
- **Expected Output:** A 2 × 2 grid comparing the original and flipped versions, with an analysis of the observed symmetry differences in the lesion.



6. Frequency Domain Filtering (FFT)

6.1. Fourier Transform and Spectrum

- **Goal:** To convert the spatial domain image into the frequency domain to analyze its frequency components.
- **Explanation:** The **grayscale** image is transformed using the **Fast Fourier Transform (FFT)**. The resulting complex numbers are centered and logarithmically scaled to visualize the **magnitude spectrum**, where the center represents low frequencies (global structure) and the edges represent high frequencies (details/edges).

6.2. Low Pass Filter (LPF)

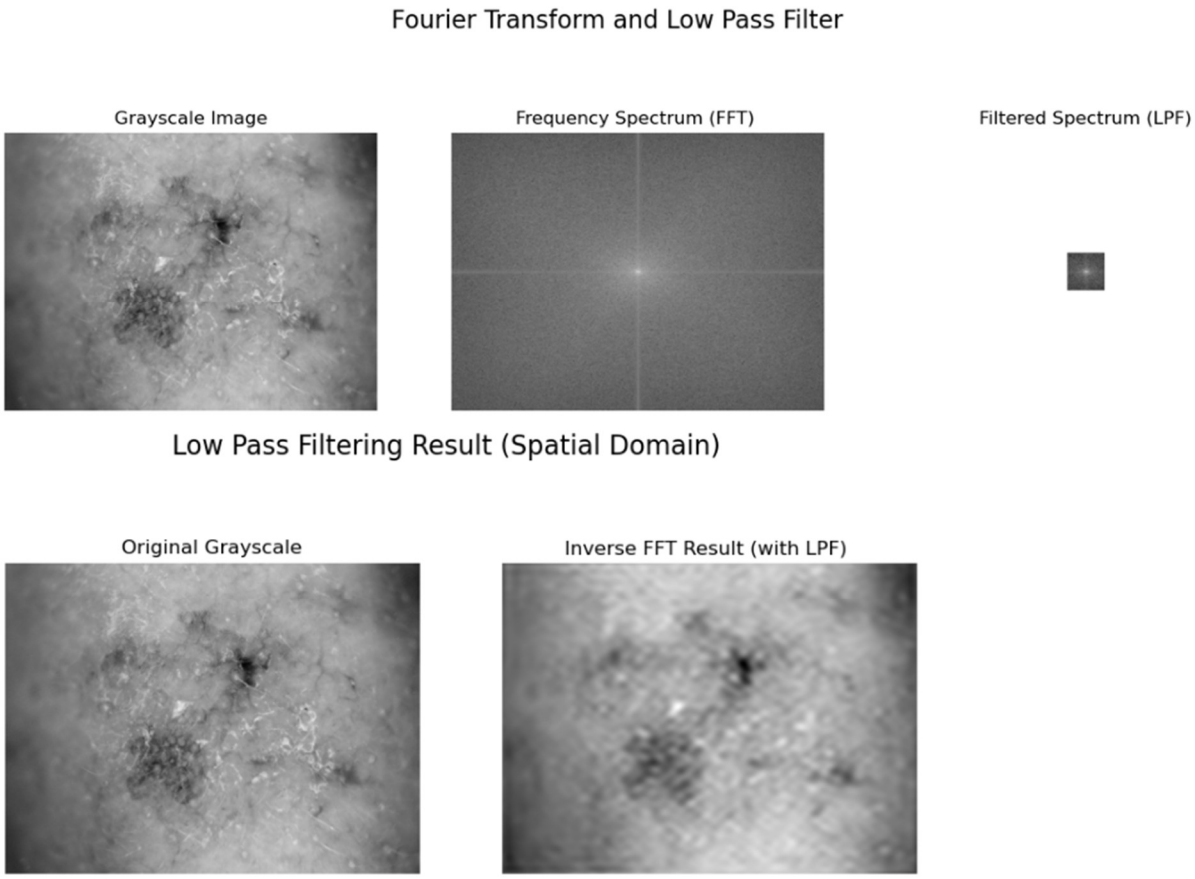
- **Goal:** To remove high-frequency components (details, noise) and retain only low-frequency components (smooth transitions, overall shape).
- **Explanation:** A simple mask (white central area) is created and multiplied with the shifted frequency spectrum, blocking high-frequency signals.

6.3. Inverse Fourier Transform (IFFT)

- **Goal:** To reconstruct the filtered image back into the spatial domain.
- **Explanation:** The filtered spectrum is inversely shifted and then processed using the **Inverse FFT (IFFT)**.
- **Expected Output:** A visualization comparing the original grayscale image with the reconstructed (and blurred) image, followed by a detailed interpretation of the blurring effect caused by LPF.

Comparison of FFT Results and Grayscale

- **FFT Spectrum Analysis:** The center of the spectrum represents **low frequencies** (slowly changing intensity, image outlines). The outer areas represent **high frequencies** (sharp edges, details, and noise).
- **Effect of LPF:** By applying the Low Pass Filter (LPF), we block the high frequencies, preserving only the low-frequency components.
- **IFFT Result:** The image reconstructed via the Inverse FFT is **blurred** compared to the original grayscale image. This is because the LPF successfully removed the high-frequency information, which corresponds to the sharp details and edges in the spatial domain. The result is like Gaussian smoothing but achieved through frequency manipulation.



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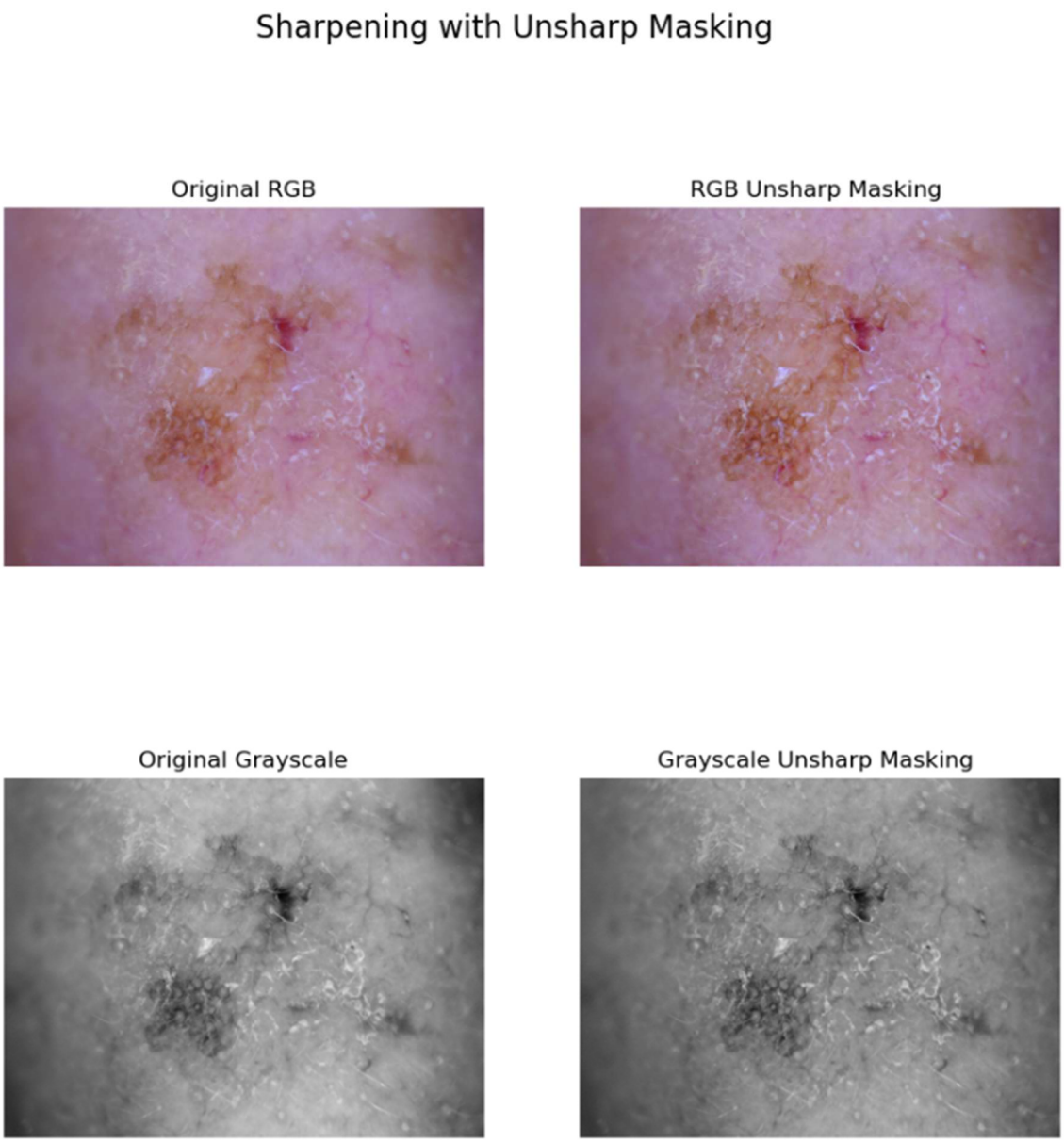
7. Sharpening and Interpolation

7.1. Unsharp Masking

- **Goal:** To enhance the sharpness and perceived detail of the image.
- **Explanation:** The image is sharpened using the **Unsharp Masking** technique, which involves subtracting a blurred version of the image from the original (amplifying edge information). This is applied to both RGB and Grayscale image.
- **Expected Output:** A comparison of the original and sharpened images, analyzing the increase in edge contrast.

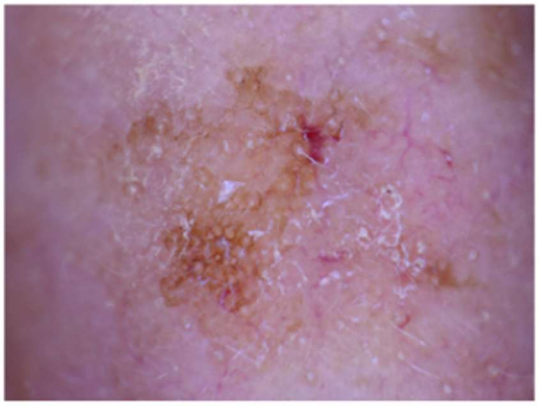


7.2. Bicubic Interpolation

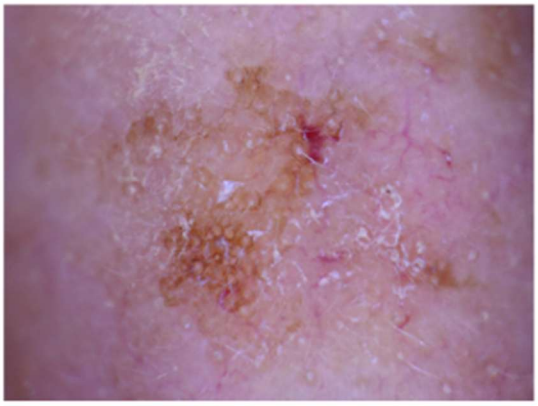
- **Goal:** To enlarge the sharpened images (2x magnification) using a high-quality resampling technique and assessing the resulting image quality.
- **Explanation:** The sharpened RGB and Grayscale images are resized to twice their original dimensions using **Bicubic Interpolation**. This method uses a 4 × 4 neighborhood to estimate new pixel values, providing a smoother result than bilinear interpolation.
- **Expected Output:** A comparison of the original size sharpened image and the 2 × 2 enlarged version, with an analysis of how Bicubic interpolation helps preserve the enhanced edge details during upscaling.

Image Enlargement with Bicubic Interpolation

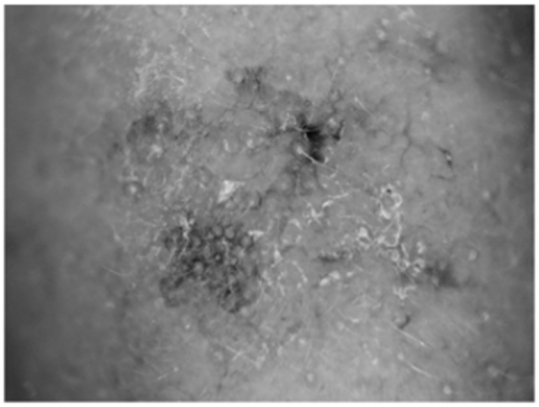
Sharpened RGB (Original Size)



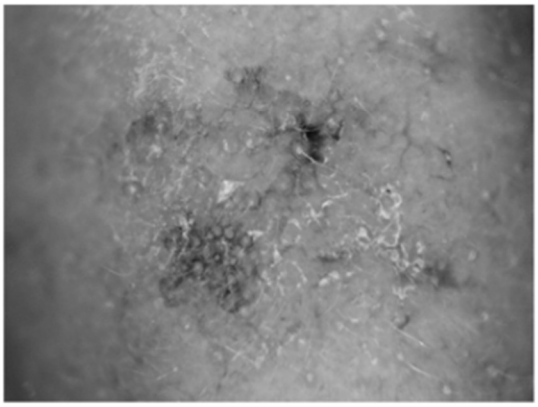
RGB Bicubic Interpolation (2x)



Sharpened Grayscale (Original Size)



Grayscale Bicubic Interpolation (2x)



Overall Conclusion and Summary of Findings:

This assignment successfully demonstrated the critical role of digital image processing in the preparation and analysis of medical imagery, specifically using the ISIC 2018 Skin Lesion Dataset. By systematically applying techniques across both RGB (Color) and Grayscale formats, several key insights were derived:

1. Image Enhancement and Contrast Stretching proved effective in linearly maximizing the dynamic range of pixel intensities, yielding immediate visual improvement, particularly in low-contrast grayscale images. Histogram Equalization (YCrCb method for RGB) was superior for color images as it increased contrast by adjusting only the Luminance (Y) channel, preventing color distortion while significantly enhancing detail. Gamma Correction showed precise control over the image's tonal mapping; using $\gamma < 1.0$ was essential for revealing details hidden in the dark shadows of the skin lesions.

2. Filtering and Noise Management A clear distinction was observed between noise reduction techniques: Median Blur excelled at suppressing impulse noise while efficiently preserving sharp edges, making it highly suitable for diagnostic images where boundaries are crucial. Gaussian Blur, while effective for uniform (Gaussian) noise, inevitably caused detail loss and edge softening, a trade-off that may be undesirable for fine dermatoscopic features.

3. Frequency and Geometric Analysis the Fast Fourier Transform (FFT) successfully converted the grayscale image into the frequency domain, clearly separating structural information (low frequencies) from noise and detail (high frequencies). The application of the Low Pass Filter (LPF) demonstrated that removing high frequencies directly resulted in a loss of sharpness and a smoothing effect in the spatial domain, confirming the spectral representation of image components. Geometric transformations (Rotation and Flipping) confirmed the biological asymmetry common in skin lesions, emphasizing their value for data augmentation in machine learning pipelines to ensure model robustness against orientation changes.

4. Final Processing Chain The combination of Unsharp Masking and subsequent Bicubic Interpolation resulted in a high-quality, enlarged output. Sharpening amplified edge information, which was then accurately preserved and smoothly rendered by the Bicubic method during 2× magnification.

In conclusion, the choice of processing technique must be tailored to the image format and the analytical goal. For feature extraction from medical images, methods like YCrCb Equalization and Median Filtering are generally preferred due to their ability to enhance contrast and manage noise without compromising critical spatial (edge) or color information.