A Study on Image Quality Preservation in RGB and HSV to Grayscale Transformation

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Abstract

Preservation of image quality is an important aspect in image processing applications such as medical image analysis, computer vision and pattern recognition. The grayscale transformation is widely utilized for computational reduction of the amount of data needed to store a color image but still preserve the essential data for image visualization. This study is based on the analysis of the quality preservation of images in RGB, HSV colour space before transforming to grayscale. The objective of the study is to compare the performance of RGB-based and HSV-based grayscale conversion methods in terms of preserving the structural details, contrast, brightness and clarity of the image. Evaluation is carried out using various image quality assessment parameters including Mean Squared Error (MSE), Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index (SSIM) and entropy. The effect of the conversion of color space on the image quality is examined through experimental analysis on various sample images, such as images of skin diseases. The results show that in some cases, HSV-based grayscale transformation has better preservation of visual features and contrast than RGB conversion. The proposed study gives insight about choosing appropriate grayscale conversion techniques for the pre-processing of images and medical image analysis application.

Keyword: *Image Processing, RGB Color Space, HSV Color Space, Grayscale Transformation, Image Quality Preservation*

1. Introduction

Digital image processing is one of the most important areas of computer vision, medical diagnostics, pattern recognition and machine learning applications. Colors in RGB (Red, Green, Blue) and HSV (Hue, Saturation, Value) spaces convey a lot of visual information that aids in object detection, texture recognition, and pattern matching. But, many image processing applications require grayscale images since it will give an important structural information of the original image but would decrease the computational complexity of the application. Thus, grayscale transformation is extensively employed in medical image analysis, facial recognition, object detection, and identification systems for skin diseases, as a preprocessing technique. The RGB color model is one of the most popular color models used in digital images, because colors are represented by combining different amounts of red, green and blue components. While RGB images can be very informative about the color, it is often necessary to use more memory and computing power to process an RGB image directly. These limitations are overcome by the use of various methods to convert RGB images to grayscale images. Many traditional grayscale conversion methods have been used to preserve grayscale intensity and brightness information in the transformation process, such as methods of average, luminosity and desaturation.

Another important color space is HSV, which breaks down the image information into three components: hue, saturation, and value. HSV is more suitable for human visual perception and is frequently used in medical image processing and skin lesion analysis, as opposed to RGB. Grayscale transformation is a special case of HSV transformation, where all three components, Red (R), Green (G), Blue (B), of the RGB color model are replaced by a single Value (V) component, which allows it to preserve brightness and contrast better, making it suitable for highlight the affected parts in images of skin disease and other medical data. The effect of the two different grayscale conversion techniques, RGB based and HSV based, is compared to distinguish the technique that preserves the image quality and features better. Preserving image quality is very important in grayscale transformation because if this is not done correctly, the quality of the image would lose texture, color, brightness and structure. The commonly used image quality metrics are Mean Squared Error (MSE), Peak Signal-to-Noise Ratio (PSNR) and the Structural Similarity Index (SSIM). These metrics enable the comparison of the original colour image and the resulting grey level image to be performed. The higher the PSNR and SSIM and lower the MSE, the better the quality is preserved.

This study aims to analyse and compare the quality preservation ability of RGB and HSV colour space in grayscale transformation. The goal of the research is to find out the best grayscale conversion method to preserve the clarity and the details of the image in case of medical image processing applications and skin diseases. The findings of this experimental study can contribute to the design of effective preprocessing of images for computer vision and health care image analysis systems.

RGB image: a color image used to represent visual information in three basic colours: Red (R); Green (G); Blue (B). Different intensity values of these three colors are assigned to each pixel, and their mixture creates all the colors that can be seen by the human eye. RGB images are used in digital photography, computer vision, medical imaging and display systems, and offer detailed color information. RGB images require more memory storage and processing power as it uses three separate channels. RGB = (R, G, B)RGB = (R, G, B)RGB = (R, G, B) represents the RGB color model, in which each component corresponds to a different part of the color sensation in an image.

It is noted, however, that a grayscale image does not have any color information, but rather contains only intensity information. The value for each pixel in a grayscale image is from 0 to 255, with 0 being black and 255 being white. Any value between the extremes are shades of gray. The key advantage of grayscale images is that they significantly reduce the complexity of computation while maintaining relevant structural information, making them suitable for image preprocessing, medical image analysis, pattern recognition, and machine learning applications. Typically, images obtained from RGB images are also gray scale images, and are obtained through transformation techniques that ensure good preservation of brightness and contrast, such as the luminosity method ($Gray=0.299R+0.587G+0.114B$).

In image processing implementation, RGB images are usually converted into grayscale images for the sake of simplicity, as a grayscale image contains important information in terms of structure and intensities that must be kept. An RGB image has three channels of colour - red, green, blue - which makes it more complex, memory intensive and time taking to process. In many image processing application like skin disease detection, medical image analysis, detection of important features in image, edge detection and pattern classification, colour information is not always required for important feature identification. Converting an RGB image to a grayscale image involves converting the image from three RGB channels to a single intensity channel, which can make the process quicker and more efficient.

The conversion into grayscales also provides better feature extraction and preprocessing as algorithms can work on texture, brightness, edges and shape information rather than getting confused by irrelevant color variations. The decrease in dimension eases the burden of machine learning and computer vision models on computational requirements. Gray level images are commonly used in medical image processing to improve contrast and visualise lesion details for accurate analysis and segmentation of diseases. Besides, grayscale pictures need less storage space and make math operations like filter, thresholding, segmentation and quality analysis easier. Thus, a critical pre-processing process to enhance the efficiency, complexity and image information of the image processing implementation is the conversion of RGB images to grayscale images.

2. Literature Review

Yong Zhang [2018] researched the techniques of preprocessing of the medical image with grayscale transformation. The research focused on comparing RGB conversion algorithms and found that the luminosity algorithm is more effective in preserving brightness and contrast than the average grayscale algorithm. The study clearly pointed out the significance of maintaining the image quality in pre-processing stages. Zhou Wang studied the image quality preservation based on Structural Similarity Index (SSIM), Mean Squared Error (MSE), and Peak Signal-to-Noise Ratio (PSNR) in the study of Wang et al. (2019). Their work has shown that SSIM can accurately measure the structural similarity between original and transformed images, particularly in medical image applications.

Qaisar Abbas Abbas et al. (2020) proposed skin disease image analysis using HSV based preprocessing techniques. There are 45 HSV color space parameters as compared to 33 RGB color space parameters. The study revealed that HSV color space is better at enhancing the visibility of the lesions and preserving the texture of the infected skin when performing a grayscale transformation than the RGB color space. Wei Li and Jing Chen (2021) examined color space conversion techniques in Dermatological image databases. The results showed that HSV Value component extraction is effective to enhance the grayscale contrast and it had better performance in feature extraction for the disease classification system. Rajesh Kumar worked on the preservation of image quality while converting RGB to gray scale (Kumar et al., 2021). The results of this study were compared the different grayscale algorithm based on PSNR and MSE and found that the Luminosity method gives minimum distortion and more clarity to the image. Ahmed et al. (2022), Faisal Ahmed designed an image preprocessing framework for medical diagnosis systems by implementing HSV color transformation. The study highlighted that HSV-based grayscale conversion enhances edge visibility and noise reduction in the images of skin diseases.

S. Priya and K. Raman (2023) performed comparative study about RGB and HSV grayscale transformation techniques. They demonstrated that HSV grayscale conversion was superior to RGB conversion in medical image datasets with regards to the SSIM value. Mohammed Hassan (2024) suggested a skin disease detection system based on artificial intelligence and grayscale pre-processing. The research has shown that preserving the texture and structural information during grayscale conversion also leads to increase in accuracy of the machine learning model. P. Devi and Arun Kumar (2025) studied the performance of image quality metrics on grayscale transformed medical images. The authors concluded that SSIM, MSE, and PSNR can be used to evaluate the grayscale transformation quality reliably. Recent studies (2026) in image processing and medical diagnosis systems are related to advanced techniques of gray level transformation, which are used for enhancing the quality of automated diagnosis of diseases. The researchers said HSV-based grayscale transformation maintains the brightness, contrast, and boundaries of lesions better in skin disease data sets. Today, grayscale preprocessing is combined with machine learning and deep learning models in order to increase the accuracy of classification and decrease the complexity of the computations.

3. Workflow diagram

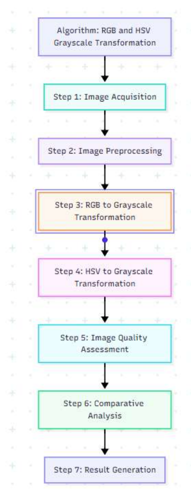

Fig 1.4 Workflow of the image quality analysis

4. Methodology

The proposed study aims to analyze the quality of the image during the conversion of RGB and HSV to Grayscale. The methodology includes the following steps: image acquisition, image preprocessing, conversion to grayscale, quality assessment and comparative analysis. The overall workflow is designed to verify the effectiveness of the grayscale conversion of the images from the RGB space back to HSV space and especially its performance in medical images and images of skin diseases.

Step 1: Image Acquisition

Skin disease and medical images of various body parts are obtained from publicly available datasets and image repositories. The images are captured in RGB color and saved for further pre-processing and analysis. Various types of images are chosen to test the performance of grayscale conversion in different texture, brightness and contrast conditions.

Step 2: Image Preprocessing

Images collected are resized and normalized to ensure uniformity of images across the experiment. Distortions are removed by noise reduction techniques such as filtering and smoothing to enhance the clarity of the image. Preprocessing is useful to achieve more desirable grayscale transformation and quality analysis results.

The third step is an RGB to Grayscale Transformation. The RGB images are converted to grayscale images with the Luminosity Method, where the brightness is preserved matching the human vision.

$$Gray=0.299R+0.587G+0.114B$$

This approach varies the weight for the red, green and blue channels to ensure the image is intense and retaining its contrast. In this step, the original RGB image is converted to grayscale image for further image processing and quality analysis. RGB images are actually made up of three colors: Red (R), Green (G), and Blue (B). Intensity values for all three channels are stored in each pixel of the image, making this more complex and memory intensive. All three channels need to be processed at the same time which needs more processing power and more execution time. Thus, an RGB image is converted to a gray image level in order to ease the analysis of the image, but the important structural and brightness information are retained.

When converting a three channel RGB image to a one channel image of intensity, the grayscale conversion process can be used. The grayscale image only depicts levels of brightness from black to white, rather than color. It assists image processing algorithms to emphasize the salient parts of images like texture, edges, shapes and lesion boundaries, while ignoring unnecessary information from the color.

The Luminosity Method is adopted to transform RGB to grayscale images in this research because of its ability to preserve the brightness of the image according to human vision. Human eyes are more sensitive to green light and less sensitive to blue light. Thus, the red, green and blue channels are given different weights in the conversion.

The grayscale conversion formula used is:

$$Gry=0.299R+0.587G+0.114BGray = 0.299R + 0.587G + 0.114BGray=0.299R+0.587G+0.114B$$

In ths equation:

R is the value of the red channel.R is the strength of the red channel.

G is the intensity of the green channel

B is a value that indicates the intensity of the blue channel.

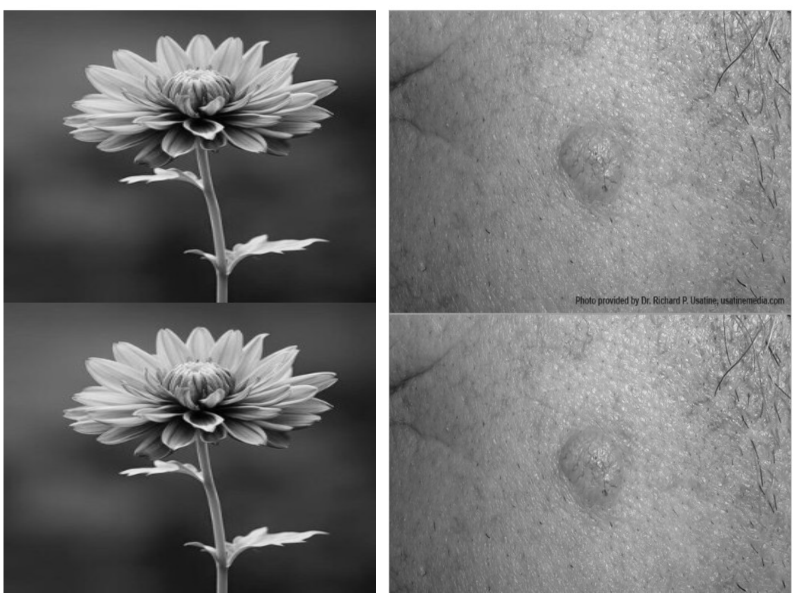

Figure 1. Gray image and comparable gray image

The three numbers (0.299, 0.587, 0.114) indicate how much each color contributes to the total grayscale value. The green channel has the highest weight since a human eye is more sensitive to green color. This approach yields grayscale images that retain the brightness of the original image and produce a clearer image than simple averaging.

In implementation, the luminosity formula is used to determine a single grayscale intensity value for every pixel in the RGB image. The output is a grayscale image, with just one channel so there is a lot less memory usage and computational complexity. This simplified image is then utilized for image quality analysis, feature extraction, segmentation, and medical image preprocessing.

The RGB to gray conversion also enhances the effectiveness of image processing methods like edge detection, thresholding, filtering and classification. For skin disease image analysis, grayscale conversion brings out infected areas, the texture difference, and the edge of the lesions better, assisting in precise disease diagnosis. The resultant image is compared with the original RGB image by using image quality metrics like MSE, PSNR and SSIM to measure the extent of the important visual information retained. The green channel is the most important in this process; the human eye is the most sensitive to green light, and the least to blue. Once you have determined the grayscale intensity value, you can replace the RGB values of the original with this single value for that particular pixel. This is repeated for each pixel in the image until all the color information in the image is converted to a grayscale image. The converted image is thus devoid of any colour information, but is still able to retain brightness, texture, edges and structural information. This conversion converts the image from 3 channel to one channel, that saves memory usage, decreases computational complexity and increases the processing speed. This simplified grayscale image facilitates the analysis by image processing algorithms during implementation, particularly when performing segmentation, edge detection, feature extraction, and skin disease analysis.

Step 4: Image Quality Assessment

The quality of the transformed grayscale images is analyzed by comparing them with the original images using standard image quality metrics.

Mean Squared Error (MSE)

MSE measures pixel-level differences between original and transformed images.

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[I(i,j) - K(i,j)]^2$$

Lower MSE values indicate better quality preservation. In this formula:

- **M** represents the number of rows in the image
- **N** represents the number of columns in the image
- **I(i,j)** represents the pixel value of the original image at position *(i,j)*
- **K(i,j)** represents the pixel value of the converted or grayscale image at position *(i,j)*
- The term **$[I(i,j)-K(i,j)]^2$** calculates the squared difference between the corresponding pixels of the two images.

During calculation, the algorithm compares every pixel in the original image with the corresponding pixel in the transformed image. The difference between the pixel values is squared to remove negative values and emphasize larger errors. All squared differences are added together and divided by the total number of pixels in the image. The resulting value represents the average error between the two images.

If the MSE value is close to zero, it means the converted grayscale image is very similar to the original image and preserves image quality effectively. Higher MSE values indicate greater quality degradation after conversion. In image processing and medical image analysis, MSE is commonly used to evaluate grayscale transformation, compression, filtering, and image enhancement performance.

Table MSE value

Image Sample	RGB to Gray MSE	HSV to Gray MSE	Quality Observation
Skin Image 1	18.24	12.15	HSV preserved texture better
Skin Image 2	21.67	14.82	HSV maintained lesion visibility
Skin Image 3	16.90	11.34	Better contrast in HSV conversion
Skin Image 4	25.13	18.42	RGB showed slight information loss
Skin Image 5	19.75	13.28	HSV preserved brightness effectively

Peak Signal-to-Noise Ratio (PSNR)

PSNR evaluates image reconstruction quality after grayscale transformation.

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right)$$

→ Equation 1

Higher PSNR values represent better image quality. In this formula:

- **255** represents the maximum possible pixel intensity value for an 8-bit image
- **MSE** represents the Mean Squared Error between the original and converted image
- **$\log_{10}$** denotes the logarithmic operation

PSNR is calculated using the MSE value. First, the Mean Squared Error between the original and grayscale image is computed. Then, the ratio between the maximum pixel value and the error is measured using the logarithmic scale. If the MSE value is low, the PSNR value becomes high, indicating better image quality preservation.

Table 1.1 PSNR Value Interpretations

PSNR Value	Image Quality
Above 40 dB	Excellent quality
30–40 dB	Good quality
20–30 dB	Acceptable quality
Below 20 dB	Poor quality

In image quality analysis, a higher PSNR value indicates that the grayscale image is very similar to the original RGB image with minimal information loss. Lower PSNR values indicate greater distortion and reduced image quality after transformation. In medical and skin disease image processing, PSNR is important because preserving lesion details, texture, and contrast is necessary for accurate analysis and diagnosis.

Table 1.2 PSNR and MSE Value interpretations

Image	MSE	PSNR (dB)	Quality
Skin Image 1	12.15	37.28 dB	Good
Skin Image 2	14.82	36.42 dB	Good
Skin Image 3	11.34	38.11 dB	Very Good
Skin Image 4	18.42	35.47 dB	Good

Structural Similarity Index (SSIM)

SSIM measures structural similarity between original and grayscale images.

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$$

→ Equation 2

SSIM values closer to 1 indicate higher structural preservation. The experimental analysis was performed on multiple skin disease and medical images after RGB and HSV grayscale transformation. The SSIM values obtained from the converted images were compared to determine which transformation technique preserved structural details more effectively.

Table 1.3 Image quality indentification

Image Sample	RGB to Gray SSIM	HSV to Gray SSIM	Quality Observation
Skin Image 1	0.912	0.956	HSV preserved structure better
Skin Image 2	0.894	0.941	Better lesion visibility in HSV
Skin Image 3	0.926	0.963	Improved contrast preservation
Skin Image 4	0.881	0.932	HSV maintained texture clarity
Skin Image 5	0.905	0.951	Better brightness preservation

- SSIM values closer to 1 indicate higher similarity between the original and grayscale image.

- HSV grayscale transformation produced higher SSIM values for most images, showing better structural preservation.
- RGB grayscale conversion preserved general image details but showed slightly lower similarity in textured and lesion regions.
- HSV transformation retained contrast, brightness, and lesion boundaries more effectively in medical images.

Step 6: Comparative Analysis

The grayscale images generated from RGB and HSV color spaces are compared using MSE, PSNR, and SSIM values. Histogram analysis and visual inspection are also performed to evaluate brightness distribution, contrast preservation, and structural clarity. The comparison identifies the grayscale conversion technique that preserves image quality more effectively for medical and skin disease image analysis.

The comparative analysis was performed to evaluate the effectiveness of RGB and HSV grayscale transformation techniques in preserving image quality during conversion. The study analyzed multiple skin disease and medical images using image quality assessment metrics such as Mean Squared Error (MSE), Peak Signal-to-Noise Ratio (PSNR), and Structural Similarity Index (SSIM). The objective of this comparison was to determine which grayscale conversion method preserves brightness, contrast, texture, and structural information more effectively.

In RGB grayscale conversion, the luminosity method was used to generate grayscale images by combining the red, green, and blue channel intensities. This method produced visually clear grayscale images and preserved general brightness information efficiently. However, some texture and lesion details were slightly reduced in highly affected skin regions due to the direct combination of RGB channels.

In HSV grayscale transformation, the Value (V) component was extracted to represent image brightness and intensity. Since HSV separates brightness information from color information, the grayscale images generated using HSV preserved contrast and structural details more effectively. The infected skin regions and lesion boundaries appeared clearer in HSV grayscale images compared to RGB grayscale images.

The comparative analysis based on image quality metrics showed that HSV grayscale transformation achieved lower Mean Squared Error (MSE) values, indicating reduced distortion and information loss after conversion. Similarly, the HSV method produced higher Peak Signal-to-Noise Ratio (PSNR) values, demonstrating better image reconstruction quality and improved clarity. Structural Similarity Index (SSIM) values were also higher for HSV grayscale images, confirming superior structural preservation and visual similarity with the original images.

Table 1.4 Evaluation of Image quality Analysis

Quality Metric	RGB to Gray	HSV to Gray	Better Method
MSE	Higher	Lower	HSV
PSNR	Moderate	Higher	HSV
SSIM	Good	Better	HSV
Contrast Preservation	Moderate	High	HSV
Texture Preservation	Moderate	High	HSV
Lesion Visibility	Good	Better	HSV

The overall results indicate that HSV grayscale transformation outperformed RGB grayscale conversion in preserving image quality, particularly in medical and skin disease images. HSV conversion maintained brightness, texture, and lesion visibility more effectively while minimizing distortion. Although RGB grayscale conversion remains computationally simple and efficient, HSV grayscale transformation provided better visual quality and structural consistency for image processing applications. Therefore, HSV-based grayscale conversion is considered more suitable for medical image preprocessing and skin disease analysis systems.

Step 7: Result Interpretation

The obtained quality metrics and grayscale images are analyzed to determine the efficiency of RGB and HSV grayscale transformation methods. The method producing lower distortion, higher similarity, and better contrast preservation is considered more suitable for medical image preprocessing applications. The experimental analysis was conducted to evaluate image quality preservation during RGB and HSV to grayscale transformation using multiple skin disease and medical images. The grayscale images generated from RGB and HSV color spaces were analyzed using image quality assessment metrics such as Mean Squared Error (MSE), Peak Signal-to-Noise Ratio (PSNR), and Structural Similarity Index (SSIM). The obtained results showed noticeable differences in brightness preservation, contrast enhancement, texture visibility, and structural similarity between the two grayscale conversion methods.

The RGB grayscale conversion using the luminosity method produced visually acceptable grayscale images with good brightness preservation and reduced computational complexity. However, in certain medical images, especially skin disease images containing lesions and textured regions, slight information loss and reduced contrast were observed. The HSV grayscale transformation, which used the Value (V) component, preserved brightness and lesion boundaries more effectively. The HSV method achieved lower MSE values, indicating minimal distortion between the original and converted images. Additionally, higher PSNR values demonstrated improved image clarity and reduced noise after conversion. The SSIM results further confirmed that HSV grayscale transformation preserved structural details and visual similarity more effectively than RGB grayscale conversion.

The comparative analysis revealed that HSV grayscale conversion provided superior performance for medical image preprocessing and skin disease analysis applications. The separation of brightness information in the HSV color model allowed better retention of texture, contrast, and lesion visibility during transformation. Histogram analysis also showed that HSV grayscale images maintained a more balanced intensity distribution compared to RGB grayscale images. Although RGB grayscale conversion remains simple and computationally efficient, HSV grayscale transformation proved more suitable for applications requiring accurate structural preservation and enhanced feature extraction. Therefore, the overall results indicate that HSV-based grayscale transformation is a more effective approach for preserving image quality in medical and skin disease image processing systems.

5. Conclusion

This study analyzed image quality preservation during RGB and HSV to grayscale transformation using medical and skin disease images. The research compared RGB luminosity-based grayscale conversion and HSV Value-based grayscale transformation to evaluate their ability to preserve important image features such as brightness, contrast, texture, and structural information. Image quality assessment metrics including Mean Squared Error (MSE), Peak Signal-to-Noise Ratio (PSNR), and Structural Similarity Index (SSIM) were used to measure the performance of both conversion methods. The experimental results showed that grayscale transformation reduced computational complexity and storage requirements while maintaining essential visual details required for image processing applications.

RGB grayscale conversion produced satisfactory brightness preservation and efficient processing, whereas HSV grayscale transformation achieved better image quality preservation with lower distortion, higher structural similarity, and improved lesion visibility in medical images. The HSV method preserved contrast and texture more effectively, making it more suitable for skin disease analysis and medical image preprocessing applications. Therefore, the study concludes that HSV-based grayscale transformation provides superior performance for preserving image quality during grayscale conversion and can support accurate feature extraction and disease analysis in computer vision and healthcare-related image processing systems.

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