Project Report

On

Contrast Enhancement

using

Wallis Filter

This report submitted on completion

Of summer training at DEAL, DRDO

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CERTIFICATE

This is to certify that **Mr. Shikhar Agarwal** (Student ID: 21021833) student of B-Tech IV year, Computer Science and Engineering, Graphic Era University, Dehradun, Uttarakhand has successfully completed his project on **"Contrast Enhancement using Wallis Filter"** at **Defence Electronics Applications Laboratory (DEAL)**, Dehradun, as part of his Industrial Training during the period of 24th June 2024 to 8th August 2024.

The project was undertaken under the guidance and supervision of **Mr. Deepak Kumar Gupta, TO – B** of Application Software Group, DEAL, Dehradun.

He has done an excellent job and was sincere during his training. We wish him the absolute best in all his future ventures in life.

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"No work can be completed successfully without the proper guidance and help of the trainer and other people." This project report is also a manifestation of the invaluable guidance, suggestions, support, and encouragement extended by various people.

I am grateful to my project guide, **Mr. Deepak Kumar Gupta**, **Technical Officer – B**, for his invaluable guidance and support in understanding and visualizing the project. Their regular guidance gave me the direction to work during the project.

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I am thankful to all the other staff members, librarian, and other co-workers for their help in the completion of this project.

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ABSTRACT

Contrast is a crucial factor in any subjective evaluation of image quality. *Contrast Enhancement* aims at a change in visual properties that makes an object distinguishable from other objects and the background. It is especially important to understand the need for image processing and enhancement in today's world. In this concept we just deal with the filtering operation that is performed directly on the image.

In this project, the concept of Wallis filter is used for contrast enhancement. It provides greater detail in shadowed areas and saturated areas simultaneously, and thus to allow a greater number of interest points to be detected. The Wallis filter is adaptive and adjusts pixel brightness values in local areas only, as opposed to a global contrast filter which applies the same level of contrast throughout an entire image. The resulting image contains greater detail in both low- and high-level contrast regions concurrently, ensuring that good local enhancement is achieved throughout the entire image.

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1. Introduction to Image Processing

Image processing involves several techniques to improve the visual quality and usability of digital images. One such technique is contrast enhancement, which is crucial in making images more interpretable and visually appealing. The Wallis filter is a popular method used to enhance the contrast of images. This report explores the principles, implementation, and benefits of using the Wallis filter for contrast enhancement.

1.1. What is a Digital Image?

An image can be described as a two-dimensional function *f (x, y),* where *x* and *y* are spatial coordinates on a plane. The value of f at any given coordinate pair *(x, y)* represents the image's intensity or grey level at that specific location.

A digital image is a representation of a two-dimensional image as a set of numerical values, known as pixels. These pixels are the smallest elements of an image, and each one contains color and intensity information. Digital images can be created by scanning photographs, capturing images with digital cameras, or generating them through software.

1.2. Types of Images

Digital images are of various file formats, with its own characteristics and uses:

- **Joint Photographic Experts Group (JPEG)** is used for compressing images. It uses lossy compression, meaning image quality is sacrificed to reduce file size.
- **Portable Network Graphics (PNG)** is a lossless compression format, which means it retains all image data when compressed.

- **Tagged Image File Format (TIFF)** is a flexible format that supports lossless compression, used in professional photography and publishing.
- **Bitmap (BMP)** is an uncompressed raster format that stores color data for each pixel without any compression.
- **Graphics Interchange Format (GIF)** is a format for images that supports both animated and static images, using lossless compression.
- **RAW** is header less format image, in which we directly stored the image data. A raw image contains grayscale data of the intensity values for each pixel in an image.

1.3 Attributes of an Image

A digital image possesses several key attributes that define its characteristics and how it is represented and processed. Here are the fundamental attributes of a digital image:

- **Contrast:** Contrast in imaging refers to the difference in brightness between light and dark areas in an image. It defines the visual impact and clarity of an image.
- **Dynamic Range**: Dynamic range refers to the range of brightness levels or contrast that can be captured or displayed in the image. Higher dynamic range images can differentiate between subtle variations in brightness, resulting in more detailed and realistic images.
- **Resolution**: It refers to the number of pixels (picture elements) that make up the image. It is typically specified as the number of pixels in width × number of pixels in height (e.g., 1920 × 1080 pixels for Full HD). Higher resolution images contain more detail and can be printed or displayed at larger sizes without loss of quality.
- **Dimensions**: Dimensions specify the physical size of the image in pixels (width × height) or other units such as inches or centimeters when printed or displayed. The dimensions determine the aspect ratio and overall visual appearance of the image.

Understanding these attributes is essential for effectively managing, processing, and sharing digital images across different platforms and applications, ensuring optimal quality and usability in various contexts.

1.4. What is Image Processing?

Image processing is the field of computer science that deals with the manipulation of digital images. It involves applying algorithms to extract information from images, enhance their quality, or create new images.

Image processing involves the following operations:

- **Image Acquisition** is the process of capturing an image, typically using a camera or scanner, to convert it into a digital form that can be processed by a computer.
- **Image Enhancement** involves improving the visual appearance of an image by adjusting contrast, brightness, or removing noise.
- **Image Restoration** reconstructs or recovers an image that has been degraded by factors - noise, blur, or motion, using mathematical and computational techniques.
- **Color image processing** involves manipulating color images and enhancing them by adjusting color balance, saturation, or converting between color spaces.
- **Wavelets and Multi-Resolution Processing** use mathematical functions to analyze different scales or resolutions of an image, aiding in compression and enhancement.
- **Morphological Image Processing** applies operations based on the shape and structure of objects within an image, such as dilation, erosion, opening, and closing.
- **Image Segmentation:** Image segmentation divides an image into meaningful regions or objects, often to simplify analysis or focus on specific areas of interest.

- **Representation and description** involve extracting and representing prominent features of an image in a form suitable for computer processing and analysis, such as edges, contours, and textures.
- **Object recognition** identifies and classifies objects within an image based on their features, enabling applications like face recognition, vehicle detection, and more.

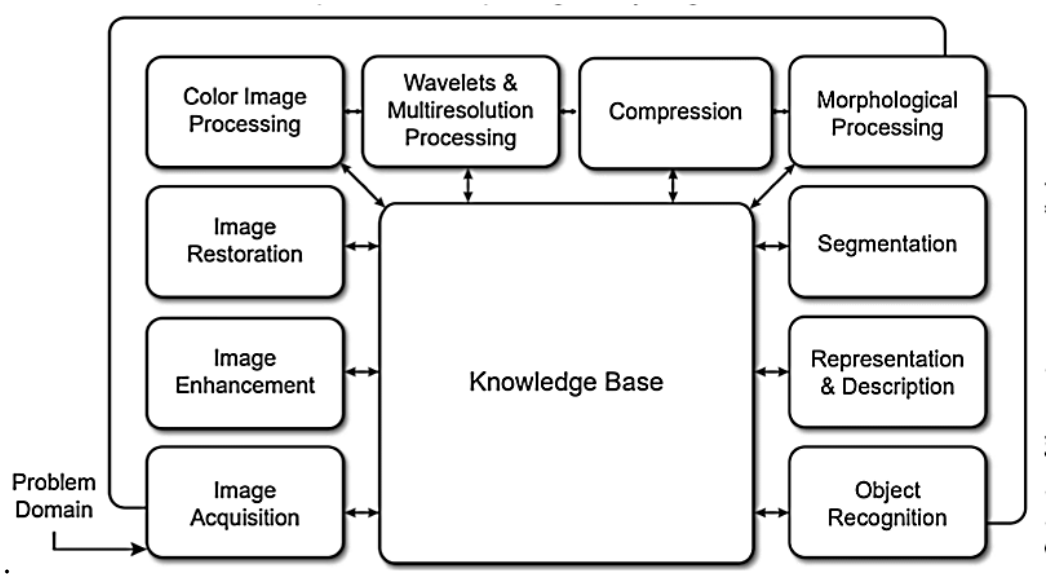


Figure 1. Operations involved in Image Processing

2. Image Filtering

Image Filtering is a technique for modifying or enhancing an image. For example, you can filter an image to emphasize certain features or remove other features. Image processing operations implemented with filtering include smoothing, sharpening, and edge enhancement. Filtering is a neighborhood operation, in which the value of any given pixel in the output image is determined by applying some algorithm to the values of the pixels about the corresponding input pixel. The filtering operation is performed directly on the image.

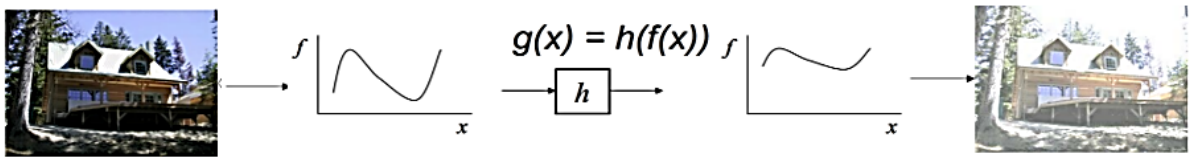


Figure 2 (a). Image Filtering using a Mask (h)

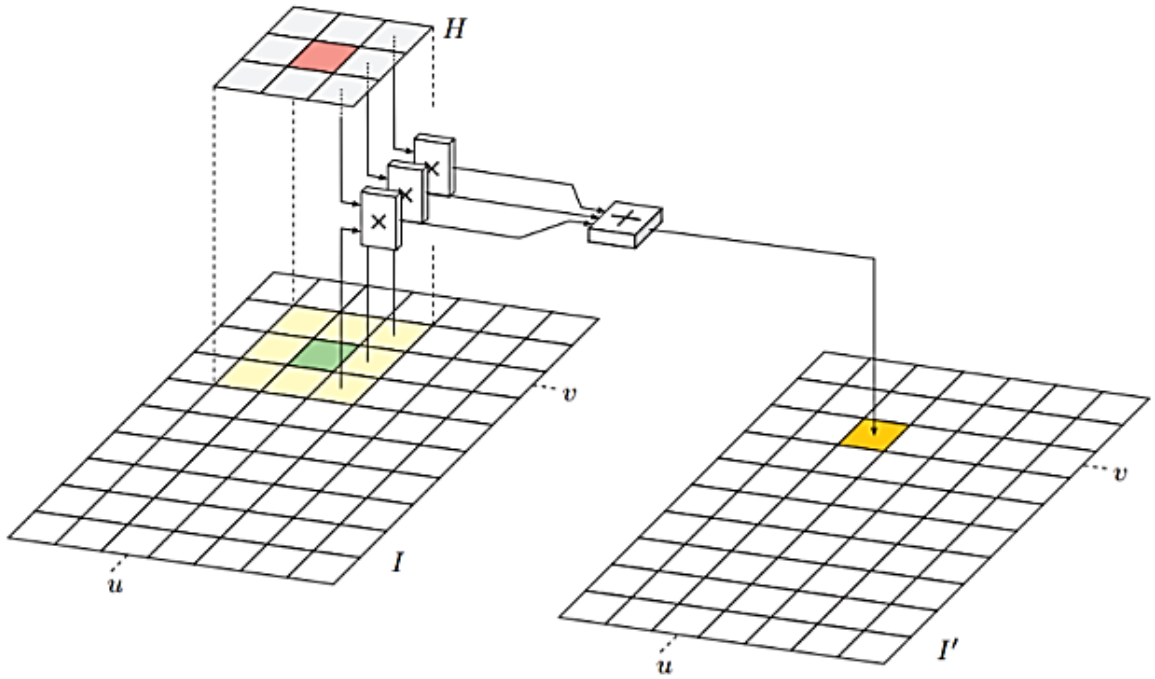


Figure 2 (b). Image Filtering using a Mask (h)

2.1. Uses of Filters

Filters are applied on image for multiple purposes. The two common uses are:

- Filters are used for Blurring and noise reduction.
- Filters are used or edge detection and sharpness.

Figure 3 (a). Original Image

Figure 3 (b). Blur Image

Figure 3 (c). Sharpen Image

3. Contrast Enhancement

Contrast enhancement is a fundamental technique in image processing used to improve the visibility of features within an image. This technique is particularly important in fields such as medical imaging, remote sensing, and digital photography, where the clarity of images can greatly affect analysis and interpretation. This document explores the principles of contrast enhancement, various methods used, and their applications.

Contrast refers to the difference in luminance or colour that makes an object distinguishable from other objects and the background. In images, contrast is crucial because it affects how beautifully details and features can be identified. Low-contrast images can be difficult to interpret because the differences between light and dark regions are not pronounced.

Contrast enhancement techniques aim to adjust the image intensities to span the available range of values fully. This can make the image appear more vivid and improve the discernibility of features.

4. Wallis Filter

An image pre-processing algorithm can be applied to enhance the images for subsequent image processing. The Wallis filter is a sophisticated technique that enhances image contrast by considering the local mean and standard deviation of pixel intensities. It adjusts each pixel's value based on these local statistics, enhancing local contrast while maintaining global consistency.

The Wallis filter provides greater detail in shadowed areas and saturated areas simultaneously, and thus to allow a greater number of interest points to be detected. The Wallis filter is a digital processing function that enhances the contrast levels of an image and it can be applied in order to optimise images for subsequent image matching. The algorithm is adaptive and adjusts pixel brightness values in local areas only, as opposed to a global contrast filter which applies the same level of contrast throughout an entire image. The resulting image contains greater detail in both low- and high-level contrast regions concurrently, ensuring that good local enhancement is achieved throughout the entire image.

The Wallis Filter adjusts brightness values in local areas so that the local mean and standard deviation match user-specified target values. This enhancement produces good local contrast throughout the image, while reducing the overall contrast between bright and dark areas. The algorithm uses an image-partitioning and interpolation scheme to speed processing of the image. The output raster is a user-controlled weighted average of the Wallis filter output and the original image.

The Wallis filter requires the user to input a target mean and standard deviation, and adjusts local areas to match the target values accordingly. A weight value

is used to control to what extent the target values are used and how much of the original image is kept.

The general form of the Wallis filter is given by:

$$i_{wallis}(x,y) = i_{original}(x.y)r_1 + r_0 \qquad \textbf{Equation (1)}$$

where $$r_1 = \frac{cs_{original}}{(cs_{original} + \frac{s_{target}}{c})}$$

and

$$r_0 = bm_{target} + (1 - b - r_1)m_{original}$$

where i_{wallis} and $i_{original}$ are the filtered and the original images, respectively; r_0 and r_1 the additive and multiplicative parameters, respectively; $m_{original}$ and $s_{original}$ the mean and standard deviation of the original images; m_{target} and s_{target} the user-specified target mean and standard deviation values for the filtered output images; c the constant expansion constant; and b, a weight parameter, the brightness forcing constant.

The contrast expansion constant, c, is a general contrast function that may be any value between 0 and 1. Lower values such as 0.1 produce an overall grey image where only the outlines of objects are visible, with very little contrast and detail. Values closer to 1, produce a highly contrasted image with greater detail and distinct black and white areas.

5. Implementation Steps

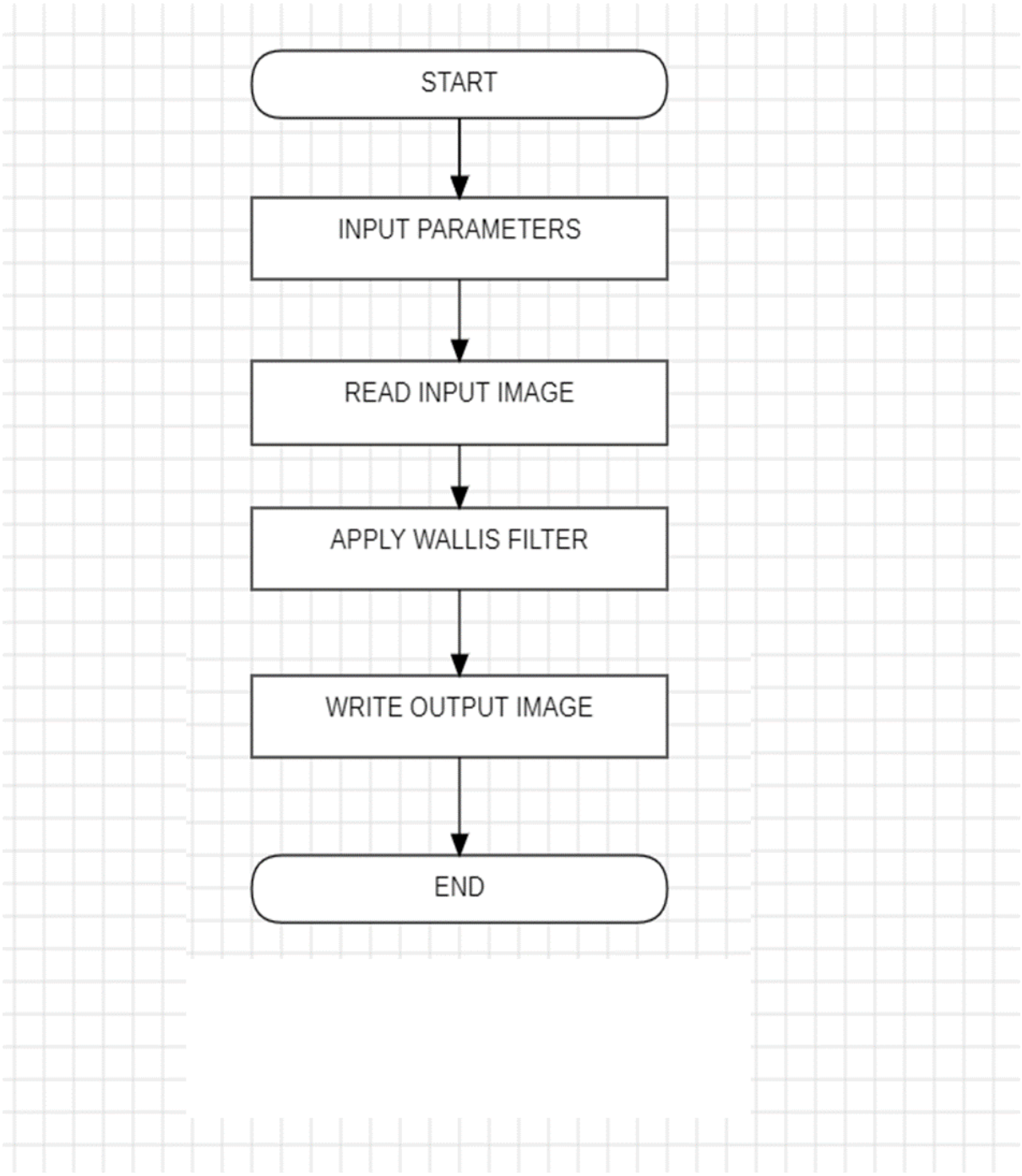
- **Read the Input Image:** Read the input image from the RAW format file.
- **Compute the various Parameters**

a. **Block or Window Size**: Define the size of the local window to medium block of 31x31 pixels is enough to recover the required detail in input image.
b. **Compute mean and standard deviation of each Block**: The original mean and standard deviation of the unfiltered image, $m_{original}$ and $s_{original}$, are calculated for each individual block based on the grey values of the pixels.
c. **Specify Target mean and standard deviation**: that are used to adjust the brightness and the contrast of the input cells respectively. The target mean value is specified by the user and can be any value between 0-255. Higher local mean values than 127 will brighten the image, while an input of less than 127 will create a darker output. The target standard deviation value is set at 60 by default and may be assigned any value within the data range of the image.
d. **Compute the output pixel value:** resulting value is assigned to the central cell in each block.

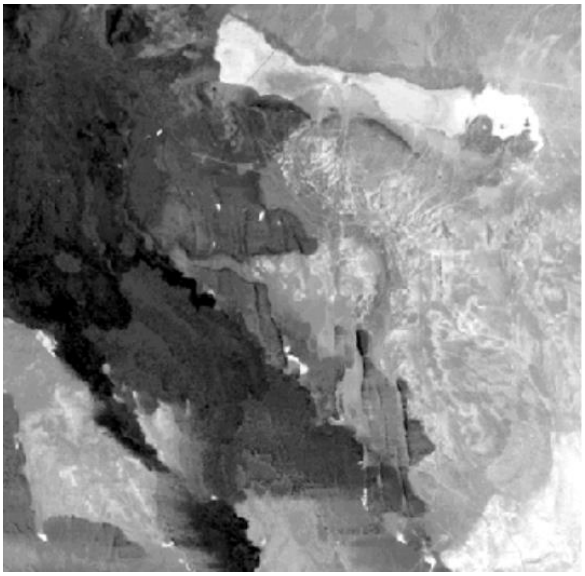
- **Apply Wallis Filter:** The Wallis filter computes each pixel's intensity using the Equation (1) on page no 13. The resulting Wallis filtered image is a weighted combination of the mean and standard deviation of the original image and the target mean and standard deviation values specified by the user's input. The weight is determined by the brightness forcing constant, b, which can take on any value between 0 and 1. A weight value of 1 will generate an output image equal to the Wallis filter target values specified, while a weight of 0 will keep the original pixel values.

  Ensure the new intensity values are within the valid range (e.g., 0 to 255 for 8-bit images). Clip any values that fall outside this range.
- **Save the Output Image:** Save the Wallis filtered image (i.e., enhanced image) to file.

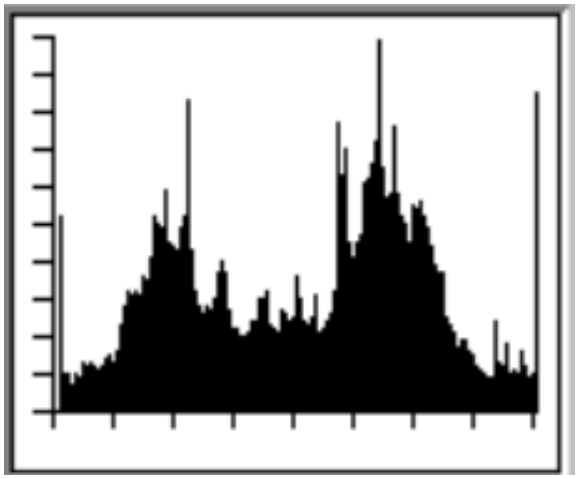
6. Flowchart


START
INPUT PARAMETERS
READ INPUT IMAGE
APPLY WALLIS FILTER
WRITE OUTPUT IMAGE
END

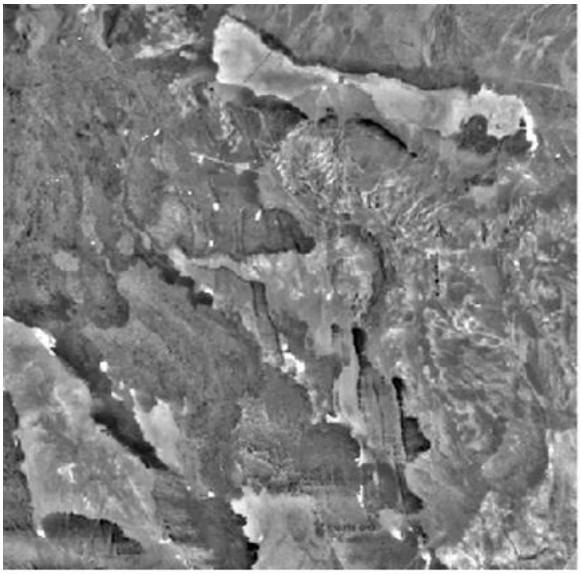
7. Inputs and Outputs



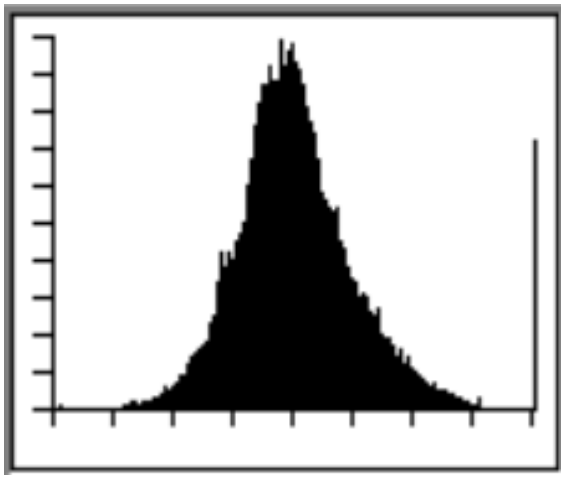
6.1 (a). Input Image



6.1 (b) Histogram of Input image



6.2(a). Output Image by applying Wallis Filter



6.2(b) Histogram of Output image

8. Conclusion and Future Plan

This project on image processing by applying Wallis filter was successfully completed by me. This project alters the image accordingly and provides the output in the specified file (in raw format).

During this project, I have learned filtering or masking that is applied on the image and how they are applied and what changes they can make to our images. If used correctly the output is very fruitful since much information from the enhanced output image.

This project can be further worked upon by implementing several other features like auto enhancement, first order and second order derivative, edge detection etc. And graphical user interface can also be implemented to display the input and out images.

9. References

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[3.] Wallis, R. (1976). *An approach to the space variant restoration and enhancement of images*. In *Proceedings of the Symposium on Current Mathematical Problems in Geodesy*. American Society of Photogrammetry.