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Multi-level Image Enhancement for Text Recognition System using Hybrid Filters

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Abstract: OCR, document scanning, and other uses for the image-based text recognition technology are common. However, the accuracy of recognition is greatly influenced by the quality of the image that was used to capture it. other environmental elements, including as illumination, camera motion, and other sounds, might damage the acquired image. The image quality must be improved as a result before being input into the recognition system. In this research, a multi-level hybrid filter-based image enhancement method is proposed to increase the image quality. The effectiveness of the proposed strategy is done using various indicators, including PSNR, MSE, SC, and NAE. The outcomes show how the suggested method is efficient at enhancing the quality of the acquired image, which can greatly improve the performance of the text recognition system.

Keywords: *Image Enhancement, Text Recognition System, Gurmukhi, Typewritten Text, Filters.*

1. Introduction

Digitalization has become integral to modern-day life as people's dependency on digital content grows. Digital technology has completely changed how we live, work, and communicate, from cell phones to computers, social media to online shopping, and e-learning to medical. Moreover, the method we generate, preserve, and communicate information has changed significantly from the time of the Granths and Vedas until the advent of the digital age [1]. New technologies have increased access to knowledge and further democratized access to information. For the benefit of future generations, knowledge must be kept alive and shared.

India's extensive past has impacted its political, social, and economic environment and diversified and rich cultural legacy. Many significant empires and kingdoms have risen and fallen throughout India's history. India also has many different languages and dialects, and every region has unique traditions and customs [2]. Ancient manuscripts known as The Granths are still studied and cherished today and offer invaluable insights into Indian history, culture, and spirituality. Furthermore, Punjab's language, literature, and customs, a state in northern India, are influenced by its distinctive culture and history. The language of the state, Punjabi, is written using the Gurmukhi script, which has a long history and is also used to write contemporary Punjabi. The Gurmukhi and Punjabi languages have a great deal to do with writings attributed to Sikh gurus and other saints [3]. The rich heritage of Punjabi literature, history, and religion may now be more easily accessed and studied because of the availability of these manuscripts in typewritten form. So, in order to convert this text, Optical character recognition (OCR) software is utilized that scan the typewritten documents and turn the scanned images into machine-readable text [4]. Scanning typewritten documents and turning them into images encounters several difficulties. One of the critical problems is the image quality since typewritten documents can fade or get damaged over time, which makes it challenging for OCR software to recognize the characters effectively. Moreover, factors such as low resolution, blurred or distorted text, uneven illumination, and noise are the reasons for poor image quality [5]. It may result in erroneous or partial text and problems throughout the converting process.

In order to deal with the quality issue, image enhancement techniques were introduced in the text recognition systems. These methods attempt to solve these problems by enhancing the image's quality before OCR software is processed. Several techniques, including contrast enhancement, noise reduction, deskewing, edge enhancement, morphological operation, deblurring, etc., can be utilized based on the requirement of the system.

1.1 Motivation

Employing cutting-edge image enhancement methods may significantly increase the precision and comprehensiveness of typewritten text recognition systems. Even though OCR software has advanced significantly in recent years, recognizing typewritten text can still be difficult because of various problems, such as inconsistent font sizes, uneven spacing, line breaks, and image deterioration. The accuracy and

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comprehensiveness of the generated text may be increased by combining image enhancers, including binarization, skew correction, edge enhancement, and morphological procedures to boost text clarity and minimize noise. Applications for these approaches include the digitalization of old documents, data extraction, and information retrieval. The system needs a robust preprocessing stage to manage the various typewritten documents and training data for the OCR software. The system must also be scalable to manage enormous document volumes and instantly deliver findings.

1.2 Contribution of the paper

This paper mainly contributed to the area of image enhancement for typewritten documents. Further, the contributions of this paper are:

- Multi-level Image Enhancement Approach that not only removes the noise from the image but also improves its quality
- Skew correction is also one contribution of this paper
- Both of the above approaches are designed to enhance the images of Gurmukhi typewritten text data

Furthermore, the following sections of the paper discuss the current state of the art, including image enhancement methods for text recognition systems and other applications. Moreover, the proposed multi-level image enhancement approach will be elaborated, which compares different filters and integrate them to improve the performance. Finally, the experimentation and its analysis will be discussed along with the proof of concept. In the end, this work's conclusion and future scope are defined.

2. Related Work

This section scrutinizes existing image enhancement approaches developed in image processing. Moreover, this section covers only the recently developed or used image enhancement methods in text recognition and other application systems.

First, the methods used or developed for text recognition systems are discussed. Like, Singh and Chaturvedi [6] proposed a system for handwritten character recognition and a Stacked sparse denoising autoencoder network for image and feature enhancement. The other image enhancement approach using OTSU and Gaussian methods was used by Raj et al. [7] to improve the quality of the image sample for Tamil Handwritten Character Recognition System. Further, to deal with the degraded handwritten documents of Arabic and Latin Languages, Jemni et al. [8] presented binarization and ensured the improved visual quality of the sample images. Moreover, researchers added noise removal and enhancement to provide high-quality images. Finally, Abbas et al. [9] proposed an improvement method using Median Filter, Binarization and Skew correction for handwritten documents.

Moreover, the noise removal and image enhancement methods used in other applications, including Naseer [10], proposed a Weiner and regularized filters to enhance the image quality by removing noise for different applications. Similarly, Khmag [11] proposed an adaptive learning GAN for precise Gaussian noise removal. Further, a fuzzy clustering algorithm was proposed to enhance the visual quality of brain MRI images by Hu et al. [12]. Another work for MRI image enhancement is done with Mean Lee Filter techniques [13]. This filter also helps reduce the noise present in the form of distortion and blurring.

Additionally in medical image enhancement, Vimala et al. [14] utilized different methods for image quality enhancement and noise removal. These methods are logarithmic and exponential transforms for contrast enhancement, guided filter, spatial high-pass filtering for clarity improvement, and edge-sensitive transformations for speckle noise removal. Furthermore, for speckle noise reduction from the synthetic aperture radar (SAR) images, a homomorphic filtering-based filter was utilized by Shukla et al. [15]. However, blurring is a possible issue in the motion video system. So, Saravanan and Urkude [16] proposed a blurry ruling technique that identifies and removes noisy pixels.

Table 1: Recently used or developed Noise Removal or Image Enhancement Methods

Paper ref	Year	Method	Purpose	Application
[6]	2023	Stacked sparse denoising autoencoder network	Noise Removal	Handwritten Character Recognition
[7]	2023	Otsu, Gaussian, and Thinning	Noise Removal	Handwritten Character Recognition

[8]	2022	Binarization	Visual Quality Improvement	Handwritten Documents
[9]	2022	Median Filter, Binarization, and Skew Correction	Noise Removal and Visual quality improvement	Handwritten Document Recognition
[10]	2022	Weiner & other blur removal Filter	Noise Removal	Not specific Applications
[12]	2021	Fuzzy Clustering Algorithm	Visual Quality Improvement	Medical Image Processing
[11]	2022	Adaptive Learning GAN	Noise Removal	Not specific Applications
[13]	2023	Hybrid Mean Lee Filter	Noise Removal	Medical Image Processing
[15]	2023	Homomorphic Filtering	Noise Removal	SAR Images
[16]	2023	blurry ruling	Noise Removal	Video Data (Motion)
[14]	2023	Logarithmic and exponential transforms, guided and spatial high-pass filter, and edge-sensitive approach	Noise Removal and Visual quality improvement	Medical Image Processing

The above table provides the methods from the past three years only. Moreover, methods of image enhancements are not limited to the above table. Other image processing applications can use several other methods for image enhancement and noise removal.

3. Proposed Multi-level Image Enhancement

This work proposes a multi-level image enhancement method for the typewritten Gurmukhi text recognition system because typewritten text images might deteriorate due to wear and tear, aging, or storage circumstances [17], resulting in problems like fading or blurred text. Furthermore, the proposed technique can help make these images more transparent and readable by reducing noise, sharpening edges, and boosting contrast. So, this multi-level image enhancement approach worked in four phases: Phase 1 for noise removal, phase 2 for contrast enhancement, phase 3 for image smoothing and Phase 4 for skew correction. The details of these phases are given as follows:

Phase 1- Noise Removal: Images of typewritten text could include noise from outside interferences such as camera shaking, illumination, and image compression. Therefore, eliminating the noise in the samples is the primary goal. The paper suggests using Weiner, Gaussian, and anisotropic filters to accomplish this aim. A frequency-domain filter called the Weiner filter can significantly reduce noise while maintaining visual features [18]. The spatial-domain filter, known as the Gaussian filter, may blur pictures and lessen noise [19]. Finally, a diffusion-based anisotropic filter may selectively blur pictures while keeping their edges [20]. After this, the proposed work suggests three hybrid filters, as shown in Figure 1. that incorporate the advantages of each filter. These hybrid filters reduce noise while retaining the images' texture, borders, and delicate features. The work uses these filters to increase the quality of the sample images and the OCR results' precision for typewritten text recognition systems [21][22]

Phase 2-Contrast Enhancement: Some of the collected samples of typewritten text could also have low contrast in addition to noise, making it challenging to distinguish the text accurately. In order to alter the contrast of the samples and enhance the quality of the images, the work suggests using contrast enhancement techniques. By altering the intensity values of the pixels, contrast enhancement increases the visibility of details in an image. The accuracy of OCR results can be increased by using this approach to increase the contrast of the image and make the text more visible, for which an Adaptive histogram equalization method is used [21]. The contrast of the sample may be altered locally via adaptive histogram equalization, which enhances text visibility and lowers OCR mistake rates. It effectively increases the contrast of the image of typewritten text by breaking it into tiny, overlapping parts and equating the histogram of each sector independently. Due to its computational effectiveness and real-time applicability, this methodology is frequently employed, making it a helpful improvement method for typewritten text recognition systems [23][24].

Phase 3- Image Smoothing: The samples showed a sharpening effect when the noise was removed, and the contrast was adjusted. Smoothing is necessary to deal with the inaccuracies in the OCR output. The samples in this investigation were smoothed using bilateral, median, and average filters. The median filter efficiently lessens the impact of outliers or isolated noise pixels by replacing each pixel in the picture with the median of the surrounding pixels. Conversely, the average filter smoothes out the image and reduces noise by replacing each pixel with the average value of its neighbors. Bilateral filters can maintain edges while lowering noise by accounting for the pixel intensity variations between adjacent pixels [22]. To increase the efficacy of this phase, hybrid filters were created by mixing several filter types. These soothing strategies effectively regulated the sharpening impact, producing more precise recognition outcomes. The system's performance was enhanced using hybrid filters, demonstrating the significance of integrating several image-enhancing methods for the best outcomes in typewritten text recognition systems [25][26].

Phase 4- Skew Correction: Skew correction comes next in the typewritten text recognition process after the smoothing phase. Skew correction is used to fix any rotational flaws in the text image which might impair the identification system's accuracy. The result of the prior stage, a smoothed picture, is first binarized in this phase to produce a binary image of the text using the OTSU method [23]. After the image has been binarized, the necessary rotational angle is calculated by analyzing the probability distribution of the histogram bins [24]. The bins' frequency, the image's entropy, and the angle that generates the maximum likelihood of correctly detecting the text are all considered while determining the angle. Finally, the image is rotated by the proper amount, and the skew correction is applied when the rotation angle has been established. This procedure ensures that the text is straight and properly aligned, increasing the recognition system's precision. By putting this step into place, the typewritten text recognition system is better equipped to recognize and decipher text images effectively and with few mistakes [27][28].

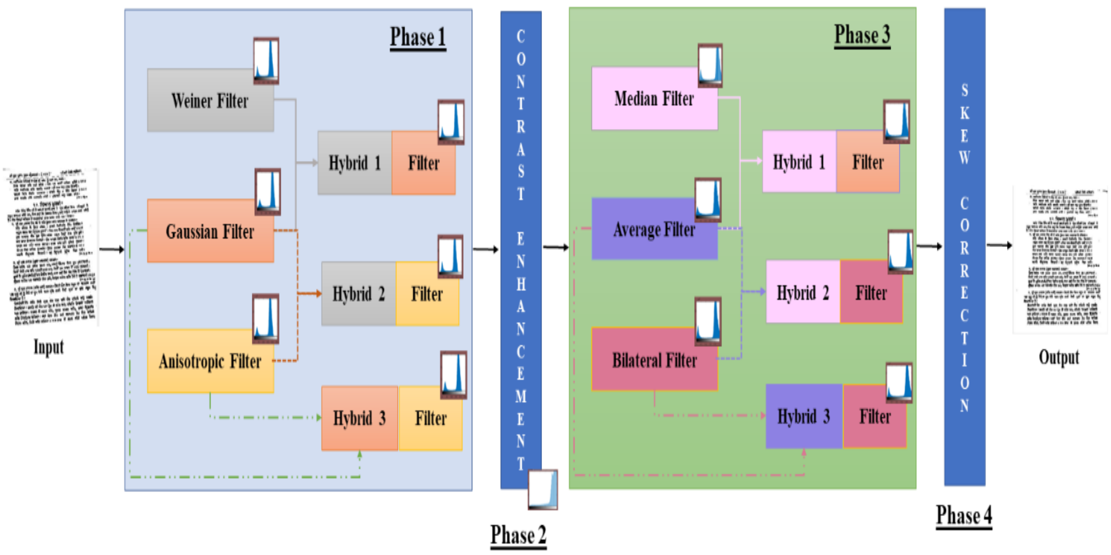


Fig. 1: Proposed Multi-level Image Enhancement Approach

The above figure presents different phases of this proposed approach that utilized the combination of different and hybrid filters to find the best method for image enhancement. The following table defines different combinations of filters and methods based on that.

Table 2: Methods in Multi-level Image Enhancement

Method Name	*Phase 1 Method*	*Phase 2 Method*	*Phase 3 Method*	*Phase 4 Method*
M1	Weiner	Contrast-Enhancement	Median	Skew Correction
M2	Weiner	Contrast-Enhancement	Average	Skew Correction
M3	Weiner	Contrast-Enhancement	Bilateral	Skew Correction
M4	Gaussian	Contrast-Enhancement	Median	Skew Correction
M5	Gaussian	Contrast-Enhancement	Average	Skew Correction
M6	Gaussian	Contrast-Enhancement	Bilateral	Skew Correction
M7	Anisotropic	Contrast-Enhancement	Median	Skew Correction
M8	Anisotropic	Contrast-Enhancement	Average	Skew Correction
M9	Anisotropic	Contrast-Enhancement	Bilateral	Skew Correction
M10	Hybrid 1	Contrast-Enhancement	Hybrid 1	Skew Correction
M11	Hybrid 1	Contrast-Enhancement	Hybrid 2	Skew Correction
M12	Hybrid 1	Contrast-Enhancement	Hybrid 3	Skew Correction
M13	Hybrid 2	Contrast-Enhancement	Hybrid 1	Skew Correction
M14	Hybrid 2	Contrast-Enhancement	Hybrid 2	Skew Correction
M15	Hybrid 2	Contrast-Enhancement	Hybrid 3	Skew Correction
M16	Hybrid 3	Contrast-Enhancement	Hybrid 1	Skew Correction
M17	Hybrid 3	Contrast-Enhancement	Hybrid 2	Skew Correction
M18	Hybrid 3	Contrast-Enhancement	Hybrid 3	Skew Correction

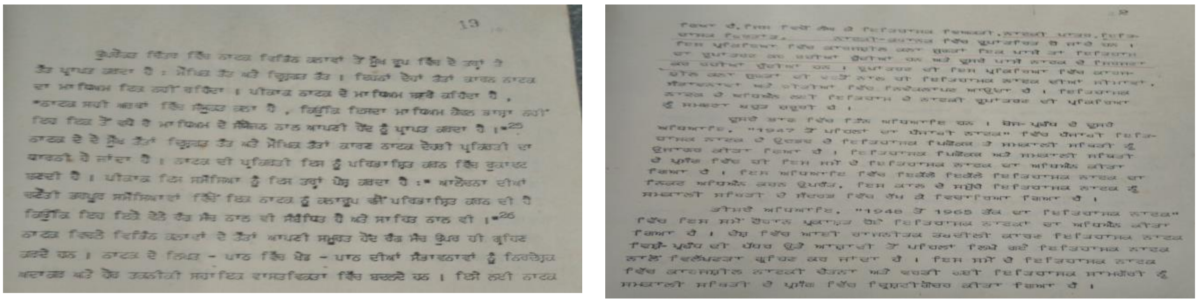
The suggested image enhancement technique for typewritten text recognition systems includes several strategies listed in the table. The approaches are divided into three categories according to how they are applied in the approach's first, second, third, and fourth phases. For reducing noise from the typewritten text pictures in Phase 1, techniques such as Weiner, Gaussian, and anisotropic filters were employed. Phase 2 involves using a contrast enhancement approach, while Phase 3 involves smoothing utilizing median, average, and bilateral filters. Hybrid filters, which combine the filters mentioned above and are employed in Phase 3, are also listed in the table. Hybrid 1, Hybrid 2, and Hybrid 3 are the names of the hybrid filters. Moreover, phase 4 performs the skew correction. The table provides simple access to the many filter combinations utilized in each approach.

4. Experimentation and Result Analysis

This section of the paper provides the proof of the concept for different filters and their combination for the objective of image enhancement. For the experimentation, the dataset of Gurmukhi typewritten text documents is used and description of the dataset is also discussed in the next sub-sections. Moreover, the implementation of this work is done with MATLAB simulator, so the results of the multi-level image enhancement approach is evaluated using different filters. These details with the outcomes are discussed in the next sub-sections.

4.1 Dataset details

For this work, a dataset is prepared from various Gurmukhi typewritten theses, stories, poetry, novel, and religious books. The dataset samples are prepared using a smartphone camera: firstly, these images were captured in JPG format with 72 dpi, and then unnecessary objects were removed by cropping these images. This dataset comprises full document images, which are further utilized for processing. In this paper, the main work is to provide an image enhancement approach to deal with the issues of the collected dataset. As the dataset is collected using a smartphone camera, several issues were introduced. For instance the following figure presents the blurred and the samole having low contrast and are not very clear for the recognition of text based systems.



(a) Blurring (b) Contrast

Fig 2. Quality Issues in database

4.2 Results Analysis

The quality of the image sample is analyzed based on different factors from which this paper computes Peak Signal-to-Noise Ratio (PSNR), Mean Squared Error (MSE), Structural Content (SC), and Normalized Absolute Error (NAE). A commonly used statistic called PSNR calculates the difference between the maximum power of a signal and the power of corrupting noise. greater PSNR values denote greater picture quality, and are frequently used to assess the quality of reconstructed images. Structural Content, often known as SC, is the term used to describe how material is arranged and presented in a written work. Structural Similarity Index (SSIM), a statistic used to assess how similar two pictures are, can be referred to as SC in the context of image processing. The last statistic is the Normalised Absolute Error (NAE), which measures the average absolute difference between the raw and processed pictures, normalised by the highest pixel value. When determining the quality of images whose maximum pixel value is unknown, this statistic is helpful. So, to evaluate these metrics, 200 samples are used with mostly samples having quality reduces due to lighting and camera motion and the average performance of the different filters of multi-level image enhancement approach are given in table below:

Table 3: Performance Analysis

Methods	**Parameters**			
	PSNR	**MSE**	**SC**	**NAE**
M1	17.5223	0.2158	0.697525	0.203376
M2	17.6121	0.412261	0.70341	0.199784
M3	3.79913	8.15573	45272.7	0.995363
M4	17.451	0.041431	0.692013	0.205107
M5	17.5287	0.493862	0.697339	0.202782
M6	3.79931	8.15786	44923.3	0.99533
M7	17.3292	0.339843	0.688539	0.208813
M8	17.479	0.320028	0.69493	0.204105
M9	3.7994	8.15415	44711.6	0.995321
M10	17.6834	0.614535	0.708299	0.199889
M11	3.79896	8.1602	45632.2	0.995382
M12	3.79878	8.1831	46018.7	0.995385
M13	17.6956	0.415328	0.705604	0.199165
M14	3.79906	8.15605	45413.9	0.995371
M15	3.79886	8.17936	45850.5	0.995375

M16	17.3554	0.497475	0.694213	0.206911
M17	3.7994	8.15784	44.66.4	0.995323
M18	3.79921	8.18119	45102.8	0.995327

The results of measuring several filters in multi-level image enhancement (M1–M18) using various quality metrics (PSNR, MSE, SC, and NAE) are shown in the table above. These parameters were used to assess how well each image processing technique worked and which technique created the best-looking photographs. Peak Signal-to-Noise Ratio, or PSNR, is an indicator of picture quality that contrasts the strongest potential signal with the strength of the noise that is distorting the signal. An improved image quality is indicated by a greater PSNR value. The PSNR values in this table range from 3.79913 to 17.6956 for each technique, with M13 providing the highest PSNR value at 17.6956. The average squared difference between the original picture and the processed image is measured by the MSE, or Mean Squared Error. A higher-quality image has a lower MSE value. The MSE values in this table range from 0.041431 to 8.1831 for each method, with M4 providing the lowest MSE value of 0.041431. The SC, or Structural Similarity Index, compares the brightness, contrast, and structure of two pictures to determine how similar they are to one another. An improved image quality is indicated by a higher SC score. The SC values in this table vary from 0.688539 to 0.708299 for each technique, with M10 providing the highest SC value at 0.708299. The NAE, or Normalised Absolute Error, quantifies the highest pixel value normalised by the average absolute difference between the original and processed pictures. A higher-quality image has a lower NAE value. The NAE values in this table vary from 0.199165 to 0.995385 for each technique, with M13 providing the lowest NAE value at 0.199165.

We can observe from the data presented in this table that certain strategies outperform others in terms of several quality measures. For instance, M13 creates high-quality pictures across various metrics, as seen by the fact that it has the lowest MSE and NAE values and the greatest PSNR value. M3, on the other hand, generates pictures of inferior quality as seen by its extremely high MSE and NAE values as well as its extremely low PSNR value. These metrics can be used to compare the performance of various algorithms or approaches or to decide which image processing technique is optimal for a certain application.

5. Conclusion

The multi-level image improvement technique that is being advocated is intended to enhance the readability and transparency of images by lowering noise, enhancing contrast, and sharpening edges. Noise reduction, contrast enhancement, picture smoothing, and skew correction are the four steps of the method. Weiner, Gaussian, and anisotropic filters are employed to reduce noise from the picture in Phase 1. By using adaptive histogram equalisation, contrast enhancement is accomplished in Phase 2. Three separate filters—bilateral, median, and average—are used in phase three to smooth the images. To correct any distortion brought on by the image's rotation, skew correction is lastly applied in Phase 4. In order to improve the quality of typewritten Gurmukhi text pictures and make them better suited for text recognition systems, the suggested multi-level image enhancement approach provides a comprehensive solution. The several processes combine to handle a variety of picture quality concerns, producing clear, crisp, and readable images. The effectiveness and efficiency of typewritten Gurmukhi text recognition systems may be greatly increased by using this technique.

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