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A FRAMEWORK FOR MORPHOLOGICAL OPERATIONS USING COUNTER HARMONIC MEAN

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A B S T R A C T

In this article, we have a tendency to embrace a novel framework for learning morphological operations using counter-harmonic mean. It combines the conception of morphology with convolutional neural networks. Similarly, the elemental morphological operators of dilation and erosion, opening and closing, as well as the more refined top-hat transform, for which we disclose a real-world application from the steel industry, are all subjected to a rigorous experimental validation. Our system learns about the structuring element and the operator's composition via online learning and stochastic gradient descent. It works effectively with massive datasets and in online environments.

1. INTRODUCTION

The close and open, filter with scale-space characteristics and the ability to extract selective functions based on the structuring element, which is obtained by concatenating to elementary operators on the image, specifically dilation, and erosion. Other more complex filters, such as non-Gaussian denoising, picture regularisation, and so on, are created by combining openings and closings (Shaik et al., 2025). Finding the right combination of morphological operators and structural components in realworld applications is a time-consuming and difficult problem with differentiation.

The majority of the options presented, however, do not cover all operators. This is an evident restriction since it makes the creation of complicated filtering pipelines difficult, if not impossible. Moreover, such systems are typically confined to a single application and do not easily extend to other complicated cases. Based on

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earlier work on counter harmonic mean asymptotic morphology, we provide a novel framework for training operator morphological pipelines. By integrating convolutional neural networks, we expand this model to a Morphological Convolutional Neural Network (MCNN) with an advanced type of layer which allows complicated pipelines over several layers.

It builds on past work in deep learning by making all of the field's optimization techniques and conclusions immediately relevant. The model learns numerous operator pipelines, from dilation/erosion through top-hat transform (i.e., the residue of opening/closing) in this section, which focuses on methodological underpinnings (figure 1).

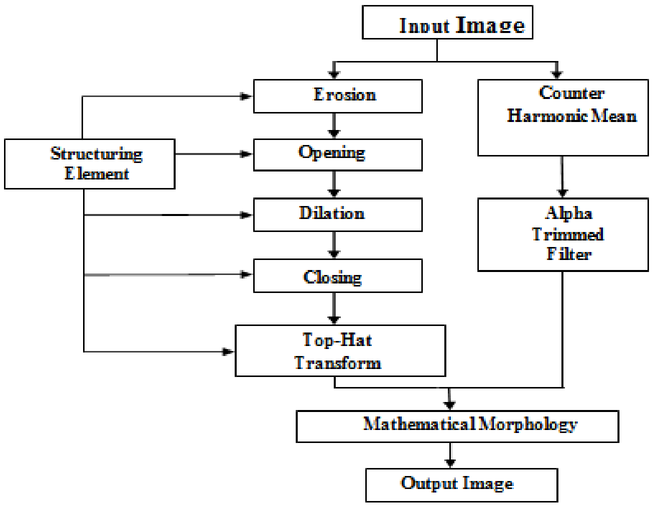

Figure 1. Block Diagram of Morphological Operations

2. LITERATURE SURVEY

In this chapter, Morphology is concerned with the form linked with the structure of an image' object in image processing. Various designs for morphological image processing have been developed in the past, with several research papers published. Some of these morphological investigations are summarised here.

In the paper "Diffusion of the counter-harmonic image by diffusing morphological image" Springer, 2010. Proceedings of Actives 2010, LNCS Vol. 6474, Part I (Angulo, 2010). Several prior publications have studied the relationships between linear and morphological scale spaces. The goal of this study is to identify techniques for expanding diffusion-based techniques to incorporate nonlinear filters with effects that imitate morphological dilatation and erosion. Here, a counter-harmonic mean approach is used. The numerical implementation is thoroughly examined, and the findings are provided to show the behaviour of the several investigated cases: isotropic, nonlinear, and coherence-enhanced diffusion. We also find a common link between Gaussian scale spaces and quadratic structuring functions-based expansion/erosion scale-spaces.

In the paper "A committee of neural network for traffic sign classification. In: International Joint Conference on Neural Networks (Ciresan et al., 2011), The solution that won the preliminary round at the International Joint Conference on Neural Networks is being discussed as part of the phase of the German traffic sign recognition benchmark, which has a better-than human identification rate of 98.98 percent (2011). By further training the nets, we can get a detection rate of 99.15 percent.

In the paper "Pipeline architectures for recursive morphological operations," IEEE Transactions on Image Processing, vol. 4, no. 1, 1995. Researchers incontestable an efficient pipeline methodology for continual morphological procedures. the quality morphological approach is applied to the initial input image directly (Shih et al., 1995). A pulse array style for a algorithmic morphological filter was conjointly conferred during this paper. In recursive morphology, the image scanning technique dictates the ensuing picture.

Although just for 1D structural pieces, it provided a 1D systolic architecture for basic grey scale operation. The architecture leverages chip design for the fundamental component of the array, allowing real-time video processing with only 32 processors working in parallel, 8 bit and 16-bit grey level frames of size 512512 may be generated (Thomas et al., 2015).

In A morphological filter chip using a modified decoding function," IEEE Transactions on Circuits and Systems II: Analog and Digital Signal Processing, vol. 47,2000." The author has changed Shev' style by using a circuit route and a decoder/encoder combine comparator to cut back hardware costs (Ong & Sunwoo, 2005). The feedback loop route reuses partial results to minimise the amount of adder and subtracter units, and therefore the decoder/encoder pair because the number of morphological operations increases, the comparator applies a modified coding operate to reduce gate count and propagation delay.

In "Morphological Filtering for Image Enhancement and Feature detection," in Handbook of Image and Video Processing, Elsevier, 2005". The issues of a morphological image processing application for picture enhancement and feature identification are discussed in paper (Maragos & Pessoa, 1999),. Four major issues were identified: cleansing the picture of various forms of noise or enhancing contrast; recognising the presence and placement of geometric features whose categories are known but not their exact shape; and building effective morphological filters. Morphological filters were also illustrated to be more successful in solving non-linear situations. The selected technique demonstrated that optimal design, as well as scale-space formulation and implementation, may give improved picture enhancement and feature detection.

In paper Multi-sensor image enhanced fusion algorithm based on NSST and top-hat transformation, Opt. - Int. J. Light Electron Opt., vol. 126, no. 23, Dec. 2015. "The multi-scale top-hat rework (MTHT) and no subsampled shear let transform (NSLT) were employed in the investigation (Zhi-she 2015) (NSST) were used to merge artificial Aperture radio detection and ranging (SAR), infrared, and visual light-weight footage. The goal is to boost visual distinction and edges. First, the 3 original pictures were rotten into low frequency sub band coefficients and band pass sub band coefficients exploitation NSST. Secondly, the MTHT calculated the effective features of bright and dark image built on low frequency sub band coefficients (Suman, 2024). The pixel-wise maximum approach was then used to create the visible combined bright and dark areas, with the following fusing combining the low frequency combined coefficients.

In paper "Computationally efficient, one-pass algorithm for morphological filters," Journal of Visual Communication and Image Representation, vol. 22, no. 5, 2011." Dokládal & Dokladalova utilised delay line architecture. In this article, a novel technique for morphological operations employing a flat rectangular structuring element for 2-D data is described, which may be simply extended to n-D pictures. The algorithm utilised in this hardware design has negligible latency, allowing for efficient implementations with strict time limitations (Dokládal & Dokladalova, 2011).

3. DESIGN OF FRAMEWORK FOR MORPHOLOGICAL OPERATIONS

Proposed Method:

GUIs (also known as Graphical User Interfaces or UIs) allow users to operate software programmes using a point-and-click interface, removing the need to learn a language or input instructions. MATLAB applications are standalone MATLAB programs with a graphical user interface that automate a job or calculation. Menus, toolbars, buttons, and sliders are common controls found in the GUI (Angulo, 2011). You may even make your own custom applications, complete with user interfaces, for others to use. For the most part, the fundamentals of effective GUI design are ageless and universal (figure 2).

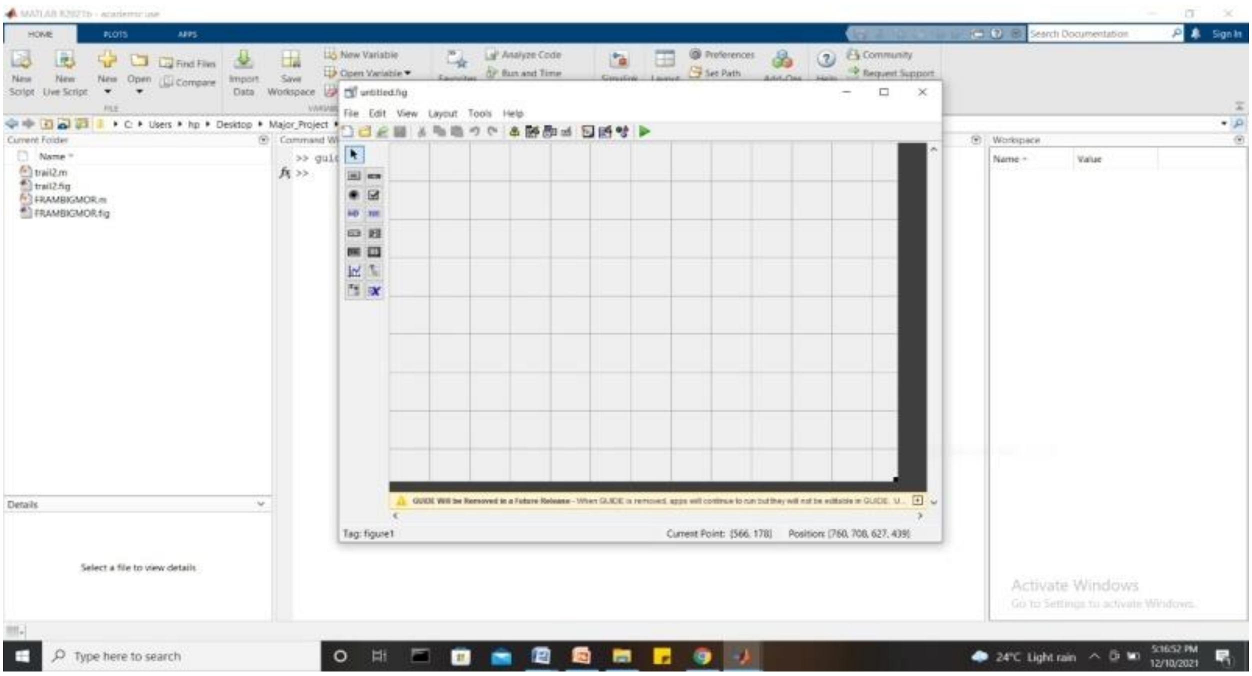

Figure 2. GUI Editor

Make a simple app out of a script:

Use the Live Editor to turn a script into a basic app with interactive controls so that people may play around with your code. Without writing any code, you may add sliders, dropdowns, edit fields, and buttons to your page (Harvey & Porter, 2005). When a value is modified, specify which sections of the script will execute. In order to build simple apps and dashboards, we need to hide the code.

Interactively Create an App:

App Designer is an interactive environment that combines the two core aspects of app development: Layout of visual components and behaviour scripting, it allows you to quickly move between canvas graphic design and code in the MATLAB editor (Singhal et al., 2024).

Others can utilise your app in MATLAB on the desktop or MATLAB Online in a web browser. App Designer apps may be packaged and installed into the MATLAB Apps tab as well. You may convert programmes into independent desktop and online apps with MATLAB Compiler to share with non-MATLAB users. The Guide Tools include, amongst different things, the Property Editor, Call-returned Editor, Alignment Tool, and Menu Editor (Ramu et al., 2024). Figure 2 depicts a blank GUI created with GUIDE.

4. MORPHOLOGICAL AND IMAGE PROCESSING OPERATIONS

Morphological processes approaches consist of erosion, dilation, opening, and closing. To conduct morphological image analysis, these processes are frequently combined. Mathematical morphology defines a number of important operators (Sankranti et al., 2024). Approaches consist of dilation, erosion, closing, and opening. Morphological procedures use structural clues to generate an output image of similar size from an input image. Regardless of its size, the origin is at the center of the structural member. The maximum fundamental morphological operators are dilation and erosion (Kumar et al., 2024); all different morphological operations are primarily based totally on those.

A. Erosion

In a binary picture, erosion diminishes or thins the object. The erosion operator takes fundamental inputs: the photograph to erode and a hard and fast of coordinates called a structuring detail and now and again known as a kernel. This structural detail determines how a lot erosion takes place with inside the brought photograph. Erosion is understood to lessen peaks and widen valleys (Raju S.V.S.R 2023); The ablation of the grey photograph A through the shape detail B is described as follows:

The expression describes the erosion of $\boldsymbol{A}$ by$\boldsymbol{B}$.

$$\boldsymbol{A} \ominus \boldsymbol{B} = \bigcap_{\boldsymbol{b} \in \boldsymbol{B}} \boldsymbol{A}_{-\boldsymbol{b}}$$

B. Dilation

The dilation operation is the act of building detail B in photograph A and transferring it via the photograph in a technique just like convolution. The dilation operator takes inputs: the photograph to be dilated and a set of coordinates referred to as a structuring detail, every now and then called a kernel (Harikrishna et al., 2023). This shape detail determines the precise impact of stretching at the enter photograph. A and B's dilation is a set of all displacement. Breaks and incursions are repaired via dilation. The initial figure is stretched or shrunk through dilation. The following formula can be used to calculate the dilation of A produced by structural member B:

$$\boldsymbol{A} \oplus \boldsymbol{B} = \bigcap_{\boldsymbol{b} \in \boldsymbol{B}} \boldsymbol{A}_{\boldsymbol{b}}$$

C. Opening

Opening the contour item smoothens it, breaking apart slim isthmus and putting off exceptional bumps. An establishing operation is called erosion accompanied via way of means of dilation, each finished with the equal structural element. A picture to be opened and a structural element are the primary two inputs for the opening operator. Grey level opening is just a combination of grey level erosion and grey level dilation. Characterized as, defined as

$$\boldsymbol{A} \circ \boldsymbol{B} = (\boldsymbol{A} \ominus \boldsymbol{B}) \oplus \boldsymbol{B}$$

D. Closing

Closing is the opposite of opening. In short, it is dilation followed by erosion, using the same structural element in both processes. The closure operator takes two inputs: a closed image and a structuring element. Grey level closure is the process of a grey level dilatation followed by grey level erosion.

$$\boldsymbol{A} \cdot \boldsymbol{B} = (\boldsymbol{A} \oplus \boldsymbol{B}) \ominus \boldsymbol{B}$$

E. Top-Hat Transform

Top-hat transform is an operation that extracts small elements and details from given images. Top-hat transforms are used for various image processing tasks such as feature extraction, background equalization, image enhancement and others [13]. The top-hat transformation, (TH) is defined by

TH = Image – Open (Image)

F. Alpha Trimmed Filter

Filter's output → average gray levels of remaining pixels (mn-d) (g_r(s, t)) in the mask after removing the lowest d/2 and the highest d/2 gray levels in S_{xy}.

$0 \leq d \leq (mn-1)$

d = 0 → arithmetic mean filter

d = (mn-1)/2 → median filter

- The alpha trimming filter can be used to solve the problem of multi-type noise (e.g., combination of salt and pepper and Gaussian).

$$\hat{f}(x, y) = \frac{1}{mn - d} \sum_{(s,t)\in S_{xy}} g_r(s, t)$$

G. Counter Harmonic Mean

Reduce the results of salt-and-pepper noise, however we tend to cannot take away salt noise and pepper noise at identical time (figure 3).

M > 0 → eliminate pepper noise (M: order of the filter)

M < 0 → eliminate salt noise

M = 0 → Arithmetic mean filter

M = -1 → harmonic mean filter

$$\hat{f}(x, y) = \frac{\sum_{(s,t)\in S_{xy}} g^{M+1}(s, t)}{\sum_{(s,t)\in S_{xy}} g^{M}(s, t)}$$

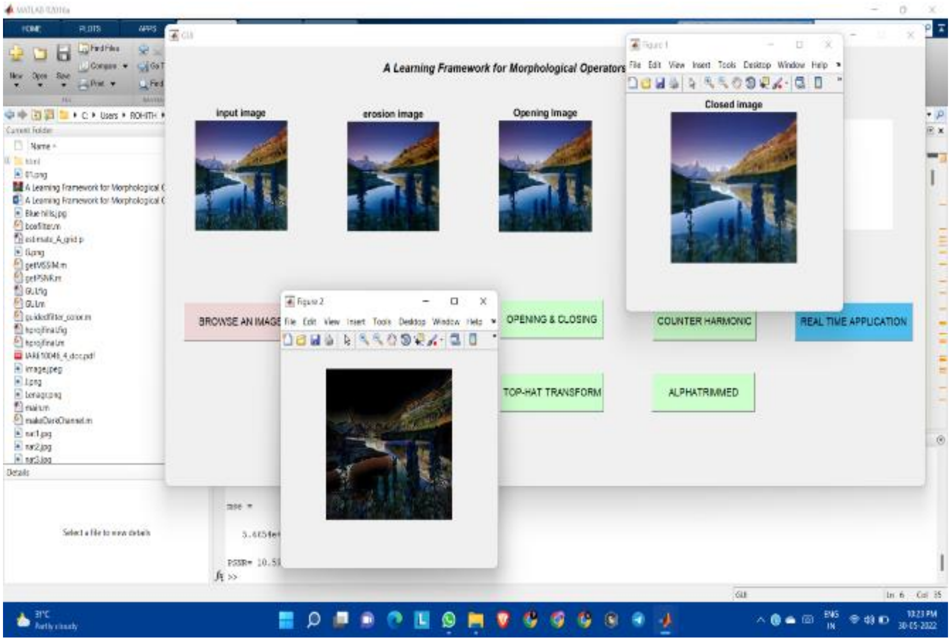

Figure 3. Cannot remove salt noise and pepper noise at the same time

H. Quality Assessment Parameters

For all things and their functionalities, quality is a decisive criterion. Image quality is a central requirement in image-based object recognition. Ground truth is necessary for an accurate assessment of image quality. Image quality is often assessed using comprehensive comparative measurements, such as MSE error and the SNR of the image. In contrast to MSE and PSNR, comprehensive benchmark metrics such as SSIM (Structured Similarity Indexing Method) have recently been developed to perceptually compare measures of structure and feature similarity between restored and original objects (Ramu et al., 2024).

Full-Reference (FR):

The assessment of the quality of a test image in contrast to a reference image is the focus of these techniques.

MSE (Mean Square Error):

An estimator's Mean Squared Deviation is also known as the MSE (MSD). An estimator is a tool for calculating the size of an unknown number of photographs. The MSE, often known as the MSD, is a formula that determines the average square of errors. It's a risk function that considers the expected value of a squared mistake or quadratic loss.

PSNR (Peak Signal to Noise Ratio):

PSNR is utilized to calculate the ratio between the best possible sign electricity and the strength of the distorting noise that has an influence on the illustration quality. PSNR is used to compute the ratio amongst he very best possible sign electricity and the strength of the distorting noise that impacts the illustration first-class (Saberi et al., 2023). The decibel ratio between two photos is calculated.

SSIM (Structure Similarity Index Method):

Method for scheming the Structure Similarity Index (SSIM) The Structural Similarity Index technique could be a version whole} totally on perception. Image deterioration is outlined as an amendment within the perception of structural info during this manner.

I. Convolutional Neural Network

One of the most prevalent types of neural networks used for picture categorization and recognition is convolutional neural networks. Convolutional neural networks are commonly used in applications such as scene labelling, item identification, and facial recognition, to name a few (Bhagyalakshmi et al., 2020).

CNN takes a photo and identifies and processes it into one of numerous categories, like dog, cat, lion, tiger, and so on. A picture is interpreted by the computer as an array of pixels, the size of which is determined by the image's resolution. Depending on the photo resolution, it will show as h * w * d, where h = height, w = width, and d = dimension. A 6 * 6 * 3 matrix array represents an RGB image, whereas a 4 * 4 * 1 matrix array represents a gray scale image.

Each input picture in CNN will go through a series of convolution layers, as well as pooling, fully connected layers, and filters (Also known as kernels). The Soft-max function will then be used to categorize an item with probabilistic values of 0 and 1.

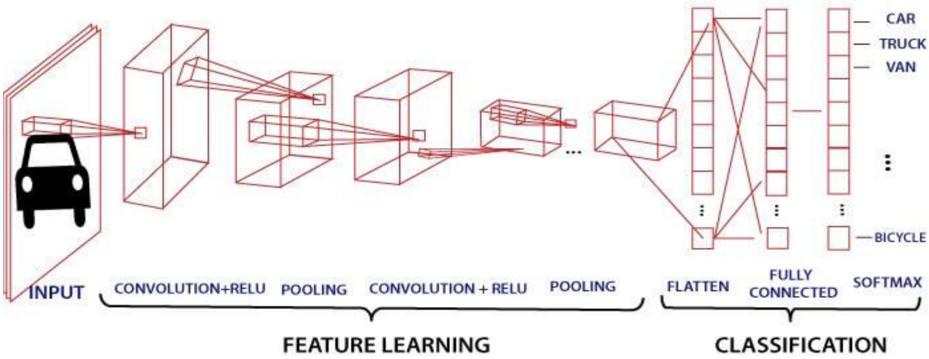

Figure 4. Classification of Convolutional Neural Network

5. RESULTS AND DISCUSSIONS

A FrameWork representing Input and Output images for Morphological Image Processing is presented on figure 5.

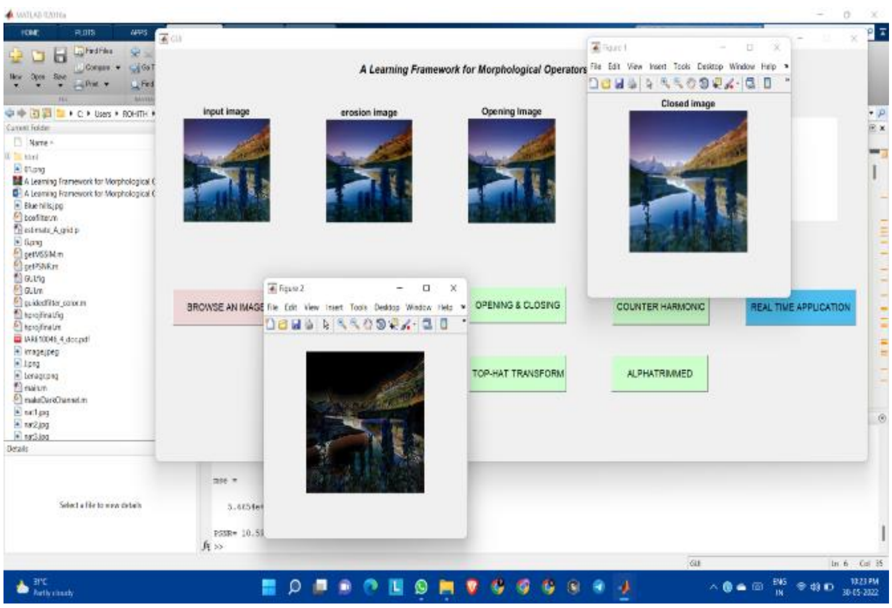

Figure 5. A FrameWork representing Input and Output images for Morphological Image Processing

We used 2018a software for writing the morphological operations, Alpha Trimmed Filter and Counter Harmonic Mean codes. Using Graphical User Interface (GUI), we developed the App in order to learn and execute the operations in the framework on various images (Ettl & Kuijper, 2014). We obtained the required results in MATLAB after constructing and running the scripts.

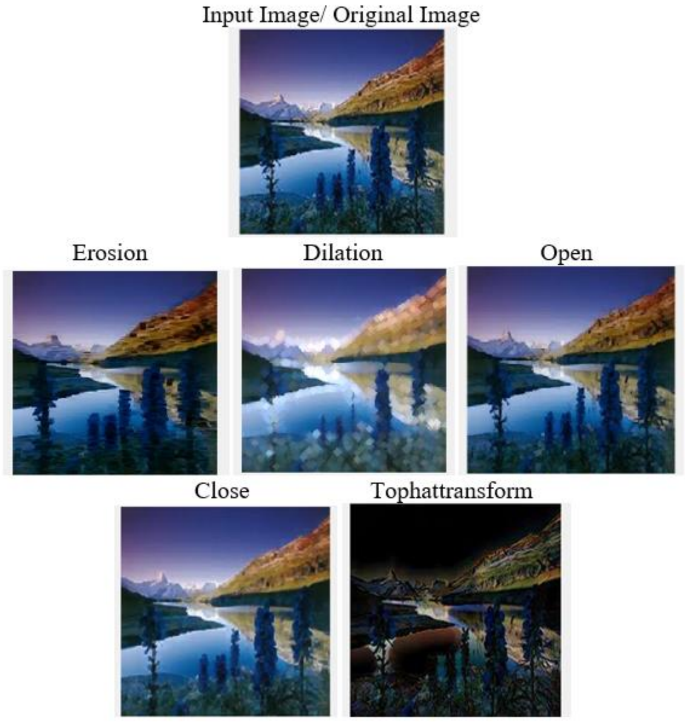

Figure 6. Input and Outputs for Morphological Image Processing

The enter picture is used as an enter for the Morphological picture processing in Figure 6, and the output is exhibited within side the identical picture below. Erosion, dilation, opening, closing, and top-hat transform are some of procedures subjected to the above image (Javeed et al., 2023).

The implementation of the operations in Graphical User Interface (GUI) can also additionally see in Figure 4. Through the Push buttons we can access the operations and implement them accordingly. The enter picture is used as enter for the Morphological picture processing in Figure 7 and Figure 8, which is similar to the previous operations from Figure 5 and the outputs are exhibited in the same image below.

The picture has been subjected to a number of procedures, including Alpha Trimmed Filter and Counter Harmonic Mean (Bhargavi et al., 2023).

The following Figure 7 suggests how the operations are applied in a GUI. We might also additionally get entry to the operations and positioned them into movement the usage of the frenzy buttons.

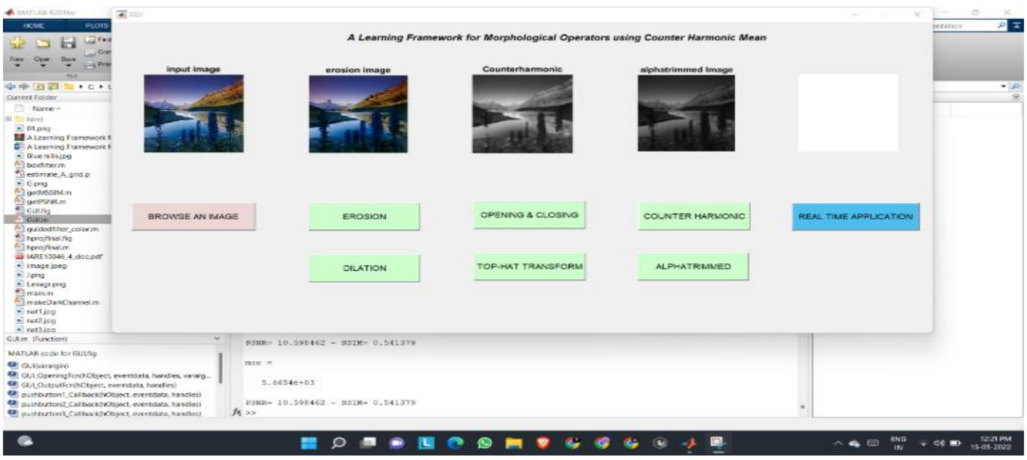

Figure 7. A FrameWork representing Input and Output images for Alpha Trimmed Filter and Counter Harmonic Mean

Filter including Morphological Image Processing

We may see the assessed performance parameters (PSNR, MSE and SSIM) for corresponding adjusted outputs for Erosion, Dilation, Opening, Closing and Top-Hat Transform operations in Figure 9 to take a look at the changed output. Table 1 presents the values of the PSNR, SSIM and MSE quality assessment parameters in two different imaging operations.

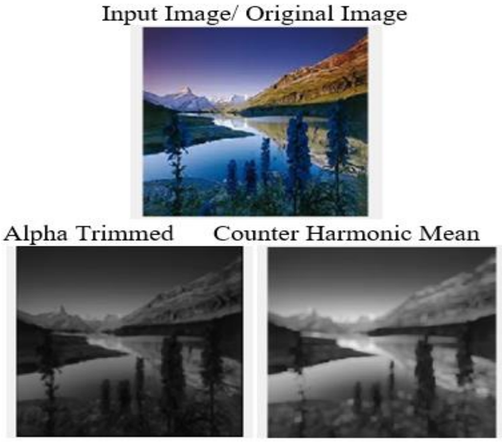

Figure 8. Input and Output Images for Alpha Trimmed Filter and Counter Harmonic Mean Filter

Figure 10. Input Image 2 and Input Image 3

Table 1. Analysis of Image Parameters

For Image 2				
S. No	Operations	MSE	PSNR	SSIM
1	Erosion	41.3099	31.970263	0.910846
2	Dilation	41.3099	0.000000	0.712078
3	Opening	5.3245	40.867979	0.978966
4	Closing	5.3245	0.000000	0.977450
5	Top-Hat Transform	8.6925	5.759703	0.276598
6	Counter Harmonic Mean	8.6925	5.759703	0.276598
7	Alpha Trimmed filter	8.6925	5.759703	0.276598
For Image 3				
S. No	Operations	MSE	PSNR	SSIM
1	Erosion	41.3099	31.970263	0.910846
2	Dilation	41.3099	0.000000	0.712078
3	Opening	5.3245	40.867979	0.978966
4	Closing	5.3245	0.000000	0.977450
5	Top-Hat Transform	8.6925	5.759703	0.276598
6	Counter Harmonic Mean	8.6925	5.759703	0.276598
7	Alpha Trimmed filter	8.6925	5.759703	0.276598

6. CONCLUSION

The use of the counter harmonic mean in morphological operations provides an effective means of processing images, especially in the presence of noise and artifacts. By leveraging the CHM, which is less sensitive to extreme values, we can achieve significant improvements in image clarity and detail preservation.

Future research can explore the integration of CHM with advanced morphological techniques and machine learning approaches, further enhancing its effectiveness and applicability in diverse fields such as medical imaging, remote sensing, and computer vision.

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