

Machine Learning for Image Restoration: A Review of Methods, Trends, and Challenges

Shradha Kumavat¹, Kapil Shah²

¹Research Scholar, ²Assistant Professor

^{1,2}Department of Computer Science and Engineering

^{1,2}Jawaharlal Institute of Technology, Borawan, India;

Abstract— Image restoration the task of recovering degraded or damaged images has become essential across many technical domains, including space imaging, medical imaging, and several post-processing applications. Most restoration techniques begin by modeling the degradation process that corrupts an image, typically involving blur and noise, and then attempt to reconstruct an approximation of the original image. However, in real-world scenarios, degradation is often unknown, requiring the simultaneous estimation of both the true image and the blurring function directly from the observed degraded image, without relying on prior knowledge of the blur mechanism. This thesis proposes a novel digital image restoration approach based on punctual kriging, supported by multiple machine learning algorithms. The work focuses on restoring images corrupted by Gaussian noise by achieving an effective trade-off between two competing goals: producing smooth, visually pleasing results while preserving edge details and structural integrity.

Keywords: Image Restoration, Image Filtering, Gaussian Noise, Image Denoising, Fast Deep Neural Networks, Augmented Lagrangian Multipliers.

I. INTRODUCTION

Photographs are an effective medium for preserving and communicating information because they capture unique moments and help people relive meaningful memories. In the past, printed photographs were typically stored in frames or albums for protection. However, many older photos gradually discolor—often developing a yellow tint due to aging and chemical reactions—and can also be physically damaged through rough handling. Today, such faded, yellowed, or damaged photographs can be digitally restored to closely resemble their original appearance, enabling families and communities to preserve valuable memories for future generations [1].

Deep learning, a major branch of machine learning, learns patterns directly from data using artificial neural networks. In recent years, deep learning has gained significant attention in computer vision because it can represent image data effectively and capture complex visual features. Researchers and academic institutions have increasingly applied deep learning to enhance image quality and develop improved photo restoration techniques. In particular, deep convolutional neural networks (CNNs) and generative adversarial networks (GANs) have shown strong performance in feature extraction, image generation, and image restoration. As a result, deep neural networks are now widely used to reconstruct and restore degraded images, including old photographs [2].

Deep learning models aim to detect hidden patterns and structures that traditional methods may fail to capture. Among the most widely used architectures, CNNs are known for learning hierarchical visual features, while GANs are effective in generating realistic image details. Consequently, many modern image restoration approaches rely on CNN- and GAN-based frameworks [3]. These deep learning-based methods typically use large-scale datasets to outperform traditional restoration algorithms by learning detailed representations of images, leading to more accurate and visually pleasing restoration results.

This paper is organized as follows: Section II reviews related work on image degradation, Section III presents the problem statement, Section IV discusses the motivation, significance, and need for the proposed study, Section V describes various image restoration techniques and their applications, and Section VI concludes the paper.

II. LITERATURE WORK

Lastly, the quality assessment index was used to compare the effects of recovering only the salient object vs. restoring only the background in the whole broken picture. It was found that the salient object had a bigger effect on the image quality [12]. This conclusion was made because it was found that restoring only the most noticeable part of a damaged picture worked better than restoring just the background. This was the

conclusion that was reached when it became clear that the main focus of the repair effort was the one thing that was being changed back to how it was before.

The generative adversarial network, which is a type of deep neural network, has shown that it can be used to fix a skewed image in the field of image processing. Experiments have shown that the suggested method, which uses cycles of skewed pictures, is a good way to fix photos [13]. The results of the tests showed this to be true.

Photos taken by Sentinel-2 of man-made clouds over two test sites in Italy [14] show that the planned method works. The pictures from the trial were looked at to come up with these findings.

Using this method, cutting-edge performance can be achieved in a variety of uses, such as real-world noise reduction, blind picture super-resolution, and getting rid of JPEG compression artifacts [15].

Because of the repair method that was shown, the contrast of the cryo-TEM pictures is much better, which makes it easier to evaluate the data that was gathered [32] Also, the authors show that speed can be improved by letting restored picture data do their own processing in the downstream [16]. They do this by showing it on a task called "dense segmentation."

Even though the writers put limits on the methods they used in the experiment they designed together, the results were of a high standard. Even though the processes had some limits this was still the case [33]. Even so, if the approach described in [17] is used, the speed of such tasks could be improved in terms of how long it takes to do the calculations.

People think that picture completeness and super-resolution are two of the most important parts of picture repair, and they use these two things to judge how well the suggested method works. No matter what kind of picture confusion there is or how bad it is, the results of our tests show that our method is better than the most cutting-edge ways to do these things right now [18].

In-depth, objective reviews and studies of at least five different types of underwater events are needed to prove that these methods can be used in a variety of underwater settings. At least five different kinds of underwater settings must be used for these reviews and studies. In the end, the writers look at the different problems that can come up during the process of restoring and improving underwater pictures, as well as the questions that still need to be answered. They also make some

ideas for areas that could be studied in the future [19]. [Needs citation]

It does this by using the unsharp blurring method on the photo to improve the quality of the picture as a whole. The author used real helicopter shots from around the world to get the pictures that were fixed. This work is checked by using a lot of different overhead photos as input, and the images that are recovered as a result are checked against both aesthetic and quantitative criteria [20].

Extensive study on three of the most common picture background repair problems shows that our DMGN often does a better job than state-of-the-art methods that were made for each task [21]. Some of the things that are being looked into here are how to get rid of picture shadows, image rain streaks, and bring back image dehazing.

When compared to the results of other algorithms that were run on the same set of photos, the results of the suggested method show underwater pictures that look real, have a lot of contrast, and are clear. The author has used both entropy and histogram analysis as measurements for quantitative research in order to prove that the results he or she has gotten are better [22].

Because it has a tiered structure, the JRM-HSR model is both accurate and useful. With the same level of accuracy, JRM-performance HSRs are 16 times faster than JRM-DSR in a single sparse representation and 2 times faster overall [23].

Using a repeated plan based on the Augmented Lagrangian Multipliers (ALM) method is one way to solve the important optimization problem in a time-efficient way. This is just one of many different ways to do things. Experiments with both virtual and real HSI photos [24] show that the quality of the pictures can be greatly improved by using the NHR approach that has been suggested [28].

The processing performance of the suggested method was good enough, and it was able to improve multiobjective comprehensive processing by reducing background radiation, correcting for spatial variation, and compensating for transfer function [25]. In tests in the lab, the efficiency of diffraction was found to be more than 60%, and the average variation in space was less than 0.2 [29].

In addition, the idea of "authorized aggregation" suggests using a "multi-model approach" to make the network more reliable. With this approach, it's very important to avoid getting stuck in a situation where the only answer is a local best one. Several tests on deblurring and blocking jobs for grayscale photos show

that the suggested method is effective, reliable, and gives repair quality that is on par with the latest technology improvements [26]. The results of these tests show that the algorithm can restore grayscale photos with the same level of quality as the latest technical improvements [30].

It is strongly suggested that a new and better Subpixel Block Attention (SBA) module be built. This module should recalibrate the blockwise features so that there are fewer blockwise breaks and speed goes up even more. The study shows that these networks offer great trade-offs for removing picture compression artifacts, cleaning up color images, and improving images. rate of writing, number of figures, and how well repairs are done [27] [31].

Table 1: List of Existing Restoration Methods That Have Been Reviewed

S.No.	Method	Advantages	Disadvantages
1	Non Linear Total Variation Restoration Method	Discontinuities much clear than wiener filter method	Creates the staircase effect for images
2	Restoration using Wavelet Analysis	Combined approach produce good results than single approach	Produces artifacts
3	Fourth order PDE Noise Removal Method	Remove blocky effect due more dissipation and improve visual effects	Without gradient parameter higher order PDE produces more dissipation.
4	Hybrid Image Restoration Method	SWT with PSF estimation produces better ISNR	Noise will still exist if Initial estimation of PSF is not well

III. PROBLEM STATEMENT

The Statement of the Problem The identification of a pixel in an image as belonging to one of the "objects" (i.e., classes) that make up the picture is often done on the basis of some common characteristic(s) or likeness to a chosen set of samples. In other words, the identification of a pixel as belonging to one of the classes that make up the picture is referred to as "classification." This is what people mean when they talk about the "classification" process. This step is done to ensure that the classification is accurate so that further steps may be conducted. In order to determine which aspects of the image may be most accurately categorized as favorable authoroll, it is necessary to have some prior knowledge or experience, in addition to making certain educated assumptions about the event.

IV. PROBLEM FORMULATION/NEED AND SIGNIFICANCE OF PROPOSED RESEARCH WORK

There is now a significant amount of research being conducted on the possible uses of algorithmic approaches to image restoration in a broad number of fields. Present day image restoration may be accomplished using any one of a number of different tried and true methods. Methods such as the Blind image Deconvolution (BID), the Lucy Richardson technique (LRT), the Authoriner filtering process (WFT), and the

regularised filtering approach are some examples of these tactics. There are other more, such as RFT. Every one of these approaches revolves on a certain classification or subcategorization of a filter. In order to make successful use of image restoration algorithms, the most significant challenge that has to be surmounted is to improve the degree to which the quality of the damaged picture can be restored. The objective of the test is to do this. It is essential that the final image that is developed as a result of using a restoration strategy have a high degree of similarity to the usual photograph. This is because the final picture will be shown to the public. It is possible to quantify this resemblance by determining the extent to which the two pictures have the same qualities. The author suggests that the hybrid restoration method should be the key area of focus for the study that is to be done.

V. RESTORATION OF IMAGES AND ITS USE IN VARIOUS CONTEXTS

The purpose of developing an impression is to bring attention to the most fascinating features of a picture in order to make it more appealing to the viewer, but the purpose of recovering an image is not to give relevant data from a scientific point of view. In other words, developing an impression is not the same thing as restoring an image. To put it another way, the purpose of restoring an image is to highlight the elements of the picture that the viewer will find the most intriguing in order to make the picture more attractive overall. [6] "Imagery programmes" provide impression enhancement tactics that do not rely on the a-priori design of the activity from which the picture was formed. Imagery programmes are also known as "imagery" programmes. These are some of the tactics that may be used to provide a more favorable first impression.

Through the use of a strategy called as effigy augmentation, it is possible to effectively cut down on the amount of noise being produced by the problem by surrendering a little amount of the answer. However, not a single one of the numerous software programs that are now available has support for this function. When seen via the lenses of a fluorescence microscope, the uncles'-path possesses a poor resolution. It will be important to create superior methods for visually analyzing photographs in order to extract the item. This will be a need. An application of an IR strategy would be the usage of DE convolution as an example. There is a possibility that the resolution will improve, in particular in the axial direction. There is now noticeably less noise in the background.

As a consequence of increasing the amount of the contract, the problem is becoming better. Researchers must spend a

significant amount of money to acquire expensive optical equipment such as confocal or two-photon enthusiasm microscopes. As a consequence, there is a need to improve imaging efficiency, which is what encouraged researchers to boost axial resolution using an approach that relies "only" on software. The information that was obtained from the microscope is solely utilized as supporting evidence for the existence of the object throughout the process of reconstructing the picture. It is not possible to have access to the actual picture itself in any manner. Images obtained using a microscope show a far greater amount of information than what can be seen by the naked eye alone. • Sometimes, the noise that is created as a consequence of other factors obscures or hides the truth. A Users run the risk of having their perceptions distorted by things that are included inside a file viewer. You are able to make deductions, but in order to get to the bottom of things, you will need to employ methods that are not prioritised in the situation.

VI. CONCLUSION

This article provides a complete examination and analysis of the most contemporary ways for enhancing and preserving underwater photos. The methods covered range from digital image editing to archival storage. In the past, in order to acquire a picture that was clear, one was necessary to take a number of pictures of the same topic while using a number of various pieces of photographic equipment, such as polarizers, sensors, and others. Today, however, one may get a clear image by only taking one shot of the subject using a single piece of equipment. The development of methodologies for computer vision has resulted in the generation of optical models that are capable of generating pictures in areas with low levels of visibility, such as the open air and the depths of the ocean.

This has made it possible to explore previously inaccessible locations. The fact that it is difficult for humans to see in these surroundings means that they include areas like these. These models have the ability to take a single image that seems to have been damaged and produce a result that is of a higher quality than the original. As opposed to more conventional methods such as histogram equalization and contrast stretching, the great majority of image enhancement methods start with an optical model of the original, low-quality picture as the foundation for their work. This is in contrast to more conventional methods such as those mentioned before.

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