

# Restoration of Historical Wall Paintings Using Improved Nearest Neighbour Algorithm

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**Abstract**— Wall painting restoration is the process of restoring old and damaged wall painting which have cracks, fold marks ,dark or white spots etc. back to their original or a near-original state. Restoration wall painting is a process of recover the wall painting which are corrupted by many natural phenomena like unfavourable weather conditions, dust, smoke etc. due to which the wall paintings affected by many problems like cracks. To overcome these limitations a new algorithm that is nearest neighbour algorithm is used that can serve both the tasks of detecting and removing the cracks, so the quality of the wall painting images can be improved. For more improvement in the quality of digital wall painting ,another deformity is considered that is white spots which are detected as well as removed and nearest neighbour algorithm is improved by increasing the contrast and saturation. The nearest neighbour algorithm provide the more accurate result as compared to SIHF algorithm based on parameters that are Peak signal to noise ratio (PSNR) and mean squared error (MSE). The nearest neighbour algorithm gives the more accurate results than the SIHF algorithm as it remove the more number of cracks and white spots.

**Keywords**— Image Restoration, Historical Wall paintings, Nearest Neighbour Algorithm, Cracks.

## I. INTRODUCTION

Wall painting restoration is the process of restoring old and damaged wall painting which have cracks, fold marks ,dark or white spots etc. back to their original or a near-original state. Restoration of old wall paintings which is an esteemed symbol of culture and history. So there is a need to preserve them so that future generations could see and learn from our culture. Throughout history, wall painting as being a human creation shows a culture expression that is extending up from the earliest beginning to present day. Any deterioration or destruction of these wall paintings may cause a great loss to our cultural heritage. During earthquakes, a large number of paintings get destroyed, as before volcanic eruption their painted coat gets collapsed with each other. [16]

Some other unfavourable weather conditions may also cause a great destruction of wall paintings. In dry environment, cracks and non-uniform contraction come in existence due to natural drying i.e. loss of water. Cracks are very frequent in wall paintings that results in poor quality of perceived image. Appearance of painting gets degraded due to the presence of deteriorations like smoke and dust. Due to which colors of paintings may get faint or seems to be black or brown [2]. Color fading is common problem in the old wall painting almost every color has faded to some extents [5]. So there is a need to restore the color of painting which is faded. To enhance the overall quality of the image, there is a need to improve or enhance the color of image. By using the different types of color encoding techniques it can enhance the color of wall painting and remove the local deformities in the wall paintings. The spots at which pixels have lost their color and turned to white values in the old paintings is also the problem in the wall paintings. There are many other problems occurs in the wall

painting like folding lines, scratches which degrade the quality of the wall paintings. So there is a need to recover paintings which are affected by such problems. Restoration is a process of recovering an image that is degraded linear degradation. Paintings such as oil paintings can lose some points on the image to white spots that are very important to be recovered to maintain good overall visibility of the image. A different methodology and technology needed for the conservation and restoration of mural paintings, the specialization focuses on specific procedures used during the conservation and restoration of murals based on multidisciplinary knowledge. Some previous works on wall painting restoration include the following. Giakoumis et al. [1] remove the cracks from the wall painting image. For that purpose top hat transformation were used for the detection of local minima. They remove the brush strokes that are misidentified in wall painting image as cracks through the MRBF neural network. In [8] wall paintings were restored from the fragments that were introduced into the computer system. Restoration was done by matching algorithms.

Pappas, .M, & Pitas, .I presented a paper “Digital color restoration of old paintings” [2]. This paper presented techniques for restoration of color of old wall paintings. The appearance of old wall paintings degraded due to the physical and chemical changes. Wall painting color which was faded through many natural phenomenon and various others factors like dust, smoke etc were restored. Due to this the wall paintings appears black or brown. Chemically, the colored regions of wall paintings were cleaned up and then patches of digital images are digitized. The main aim of this paper was to find out the color from sample images then apply the color transformation on entire image. Image acquisition systems that are scanners and camera devices etc. produce RGB values. Visual appearance of actual wall painting is estimated by using

different techniques without chemical clean up treatments. For this purpose, the five color restoration methods (Mean sample matching, White point transformation, ICP approximation, linear approximation, and RBF approximation) which simulate the actual appearance of wall paintings. Different types of digital restoration techniques were used to recover the actual appearance of old wall paintings, small chemical processing of its surfaces. Simulation was performed on no. of different wall paintings that provided the satisfactory results. In this paper the best results were obtained by white point transformation and linear approximation but all methods have small computational requirements.

In 2001, Nikolaidis .N & Pitas, .I presented a paper “Digital image processing in painting restoration and archiving” [7]. This paper presented 3 applications of digital image processing. First was crack restoration. Second was the restoration of color and third was mosaicing of images which are partial. Linear approximation and the white point transformation methods were used for color restoration of old wall paintings. Linear approximation was used for the effective choice of transformation function. In white point transformation the object under different lighting conditions look different and the dirty samples was obtained easily.

In this database management system was introduced which was helpful for achieving and classification of paintings. This system has user friendly GUI that works on user defined SQL queries. The database can be accessed through SQL queries. Crack detection was done by morphological top- hat transformation. The thresholding operation was used to eliminate cracks from background. Crack filling was done by applying the median filters. A digital achieving system was also described in this paper.

In 2002, Papaodysseus .C, Panagopoulos, .T, Exarhos, .M, Triantafillou, .C, Fragoulis, .D, & Doulas, .C presented a paper “Contour-shape based reconstruction of fragmented, 1600 B.C. wall paintings” [8]. In this paper, author introduced a technique in which the wall painting excavated in fragments then fragments was photographed. The image of fragments introduced to computer then its contours was obtained. After that the fragments contours was compared to proposed technique. The authors define a approach which extract maximum information from the contours of fragmented parts to achieve the estimation of initial image. In this paper, a novel general methodology was introduced for the computer-aided reconstruction of the impressive wall paintings of the Greek island Thera (Santorini), that were painted in the middle of the second millennium B.C. These wall paintings have been excavated in fragments, and as a result, their reconstruction may be a scrupulous and a long process. Therefore, in order to facilitate and expedite this method, a proper system has been developed based on the introduced methodology. According to this technique, every fragment is photographed, its image is introduced to the computer, its contour is obtained, and, later on, all of the fragments contours are compared in a manner proposed herein.

In 2005, Papaodysseus .C, Exarhos .M, Panagopoulos .T, Triantafillou .C, Rousopoulos .G, Pantazi .A & Doulas .C presented a paper “Identification of geometrical shapes in paintings and its application to demonstrate the foundations of geometry in 1650 BC”[9]. The aim of this paper was to introduce a methodology to determine whether a handmade shape fitted into given geometrical prototype. To achieve that,

three mathematical criteria are introduced, two of them being of statistical in nature and another one is based on fuzzy logic. The application of those criteria to the important Late Bronze age wall paintings, the inner walls are decorating which are constructed excavated at Akrotiri, Thera, shows the spirals which are portrayed on images of wall paintings correspond to linear (Archimedes) spirals with exceptional accuracy.

In this paper the methodology was introduced together with a set of original criteria to show the specific shape in a painting that has probably been drawn by using geometrical method. Pattern recognition methods and related criteria were introduced in this paper. It employed thus far only on the tharan wall paintings which can be applied to any painted shape. The main aim of this paper was to determine the geometrical shapes or curves, which adjust a given equation in paintings.

In 2006, Giakoumis .I, Nikolaidis .N & Pitas .I presented a paper “Digital image processing techniques for the detection and removal of cracks in digitized paintings”[11]. In this paper, the authors presented an integrated strategy for crack detection and filling in digitized paintings. An integrated methodology for the detection and removal of cracks on digitized paintings is presented in this paper. The cracks are detected by thresholding the output of the morphological top-hat transform. Afterward, the thin dark brush strokes which have been misidentified as cracks are removed using either a median radial basis function neural network on hue and saturation data or a semi-automatic procedure based on region growing. Finally, crack filling using order statistics filters or controlled anisotropic diffusion is performed. The methodology has been shown to perform very well on digitized paintings suffering from cracks. The methodology has been applied for the virtual restoration of images and was found very effective by restoration experts. However, there are certain aspects of the proposed methodology that can be further improved.

In 2008, Papaodysseus .C, Exarhos .M, Panagopoulos .M, Rousopoulos, .P, Triantafillou, C, & Panagopoulos .T presented a paper “Image and pattern analysis of 1650 BC wall paintings and reconstruction” [16]. In this paper, image segmentation and pattern analysis was used for the reconstruction of wall paintings. They used color image segmentation method to decay many problems which provide the good estimation of initial fragments which were depicted. For reconstruction of wall paintings, pattern matching techniques were used. The wall paintings typically reconstructed from the thousands of fragments which are scattered within excavated sites. In fragments of wall paintings, many depictions are occur which manifests non uniform color decay and cracks. Sometimes extraneous material is also added in fragments of wall paintings. The image segmentation technique is used which provide the good approximation of depiction of fragments. This technique defines the color region and region border of depicted fragments.

In 2008, Pnevmatikakis .E, & Maragos .P presented a paper “An inpainting system for automatic image structure-texture restoration with text removal” [17]. The authors deal with two problems that are inpainting problems and problem of finding text inside digital images. The main focus of this paper was to finding text inside digital images. Inpainting technique is classified as structure inpainting and texture inpainting. Structure painting is basically is used to define main parts of images like boundaries, edges etc. Texture inpainting is only used to define text data printed on the paintings. Inpainting

techniques are used to define the main parts of image and texture inpainting technique is used to finding text inside the image. The morphological algorithm is used to link them. Morphological algorithm captures the pixel that represents the text characters. Hence inpainting region were defined as a output. For this purpose an automatic system is developed for the image restoration and text removal. So there is no need of user interface for image restoration and text removal at all. The main advantage of this system was to select the area which is inpainted manually. The previous inpainting systems were not detected the region manually.

In 2008, Gupta .A, Khandelwal .V & Srivastava .M presented a paper "Image processing methods for the restoration of digitized paintings"[15].Several methods have been proposed for detection and removal of cracks in digitized paintings. Cracks not only deteriorate the quality of painting but also question its authenticity. In this paper, a morphological methodology (MAO) is proposed which is a variant of recently published morphological methods to identify cracks. After detecting cracks, a modified adaptive median filter (MAMF) is used to fill the cracks. The order of the median filter to be applied on crack pixels is computed on the basis of the number of crack pixels in its neighborhood. This methodology of detection and elimination of cracks in digitized paintings is shown to be very effective in preserving the edges also.

In 2009, Rousopoulos .P, Arabadjis .D, Panagopoulos .M , Papaodysseus .C, & Papazoglou .E presented a paper "Determination of the method of drawing of prehistoric wall-paintings via original methods of pattern recognition and image analysis" [18]. In this paper a technique of construction of prehistoric painting was enforced. The approach proposed a algorithm that perform preprocessing of the boundary of the figures showing within the painting, determines the patterns repetitions within the boundary of the represented components, Classification of those repeated patterns into correct geometric prototypes and curve fitting.

In 2011, Naik .P.K., Nitin, N., Janmeja, A., Puri, S., Chawla, K., Bhasin, M., & Jain, K "B-MIPT: a case tool for biomedical image processing and their classification using nearest neighbor and genetic algorithm" [20]. A high rate of expression of Endothelin protein in the placental cell is very much regulated by inhalation of tobacco smoke and leads to placental abnormalities subjected to birth failure. The application developed using Image Processing ,Nearest Neighbour algorithm (NN) and Genetic Algorithms (GA), automates the study of these proteins to assist pathologists and lab technicians in achieving a more efficient and faster diagnosis. The results of the present work demonstrate that the image derived features with GA-NN model appear to be a very fast image identification mechanism providing good results, comparable to some of the current efforts in the literature. We have demonstrated the feasibility of combining GA-NN with image derived features for classification of images into active/passive smokers. Expanding the image derived features, use of merely statistical techniques in conjunction with the extracted parameters and an adequate and low-noise training set, are critical to the success of NN. Apparently, the more specifically an image is to predict, thus the more definite a training set can be assembled, and the higher predicting power the corresponding NN can acquire.

In 2013,Guo, H., Jiang, F., Liu, S., & Zhao, D. presented a paper "Natural images scale invariance and high-fidelity image restoration" [25]. In this paper authors mainly discusses scale invariance at three aspects of essence, representation and application. a natural image always contains the same contents of different scales and dually the same contents of same scale exist throughout scales of the image. GMM based scale invariance model was used into the proposed image restoration algorithm. In this algorithm, natural image scale invariance and nonlocal self similarity were utilized simultaneously. More specifically, multi-scale similar patches were searched, adjusted by GMM and then 3-D transformed. In regularization-based framework, local total variation regularizer and nonlocal adaptive 3-D scale invariant sparse representation regularizer are introduced into the minimization function. Experimental results show that the proposed algorithm achieves more significant performance than the current state-of-the-art schemes.

In 2013, Chompupatipong, N., & Jearanaitanakij, K. presented a paper "Improving the running time of the nearest neighbor algorithm" [24]. Nearest neighbor algorithm is a well-known method, in pattern recognition, for classifying objects based on the nearest examples in the feature space. However, its major drawback is the sequential search operation which calculates the distance between the probing object and the entire set of the training instances. In this paper, authors propose a novel method to accelerate the searching operation in the nearest neighbor algorithm. Our method consists of two main steps; creating the reference table and searching the nearest neighbor. Reference table of the training instances is created once in the initial phase and referred periodically by the searching step. Surprisingly, this reference table can drastically reduce the searching time of the nearest neighbour algorithm on any feature space. The experimental results on five real-world datasets from the UCI repository show a remarkable improvement on the searching time while the accuracy is still preserved.

In 2013, Karianakis, N., & Maragos, P. presented a paper "An integrated system for digital restoration of prehistoric Theran wall paintings" [26]. They implemented an integrated system which restores missing parts of various sizes and shapes that appear in Theran wall paintings. In this, the missing area was stitched by applying the seamless image stitching algorithm and the total variation inpainting was used for area extraction and repair. The non-local inpainting mechanism was used for elimination of minor defects on the retrieved parts. The graph cuts were used for missing area with complicated boundaries. In this paper, the authors proposed an integrated system that restores missing parts of assorted shapes and sizes that seem in Theran wall paintings. At first, a mathematical morphology algorithm was used that additionally incorporates edge information for detecting missing areas.

After studying the various techniques of wall painting restoration, there are many problems in the existing techniques. Making fragments of wall painting is quite a long, time consuming and difficult task. Morphological algorithm detects only the cracks and missing area in the wall painting To overcome these limitations a new algorithm that is nearest neighbour algorithm is used that can serve both the tasks of detecting and removing the cracks. So the quality of the wall painting images can be improved. For more improvement in the quality of digital wall painting ,another deformity is considered

that is white spots which are detected as well as removed and nearest neighbour algorithm is improved by increasing the contrast and saturation.

## II. PROPOSED WORK

- Step 1:** Take the high resolution image of the wall painting to be restored.
- Step 2:** Applying nearest neighbour algorithm for finding out the white spots at local deformities.
  - i) identifying the local deformities like folding lines.
  - ii) identifying the unwanted cracks in the painting.
- Step 3:** Remove cracks and white spots in wall painting images
- Step 4:** Increase the overall contrast and saturation of the image to improve the results of deformity analysis.
- Step 5:** Now adjust to the colours of the neighbours using nearest neighbour algorithm. Thus the restored image is now much better from the deformities.
- Step 6:** Comparison of NN algorithm with existing techniques based on parameters i.e. PSNR and MSE.

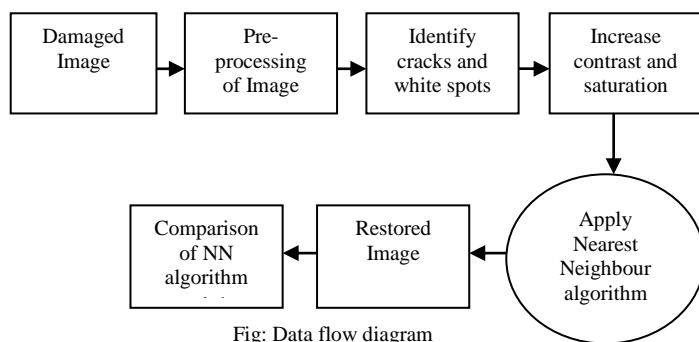


Fig: Data flow diagram

## III. EXPERIMENTAL RESULTS

The experimental is performed on different images of wall paintings. The proposed work is implemented with the help of MATLAB. The results are calculated based on the parameters: MSE and PSNR. Comparative study includes NN and SIHF

algorithm. Fig 1 show the original image which is to be restored. In fig 2 pre-processing of image is done in which the noise is removed from the image. In fig.3 the cracks and white spots are detected separately. The white spots are detected in the image by using the bw function. Find out the spots at which pixels have lost their color and turned to white values in the paintings. The number of cracks and white spots are to be calculated which is presented in the image. The cracks are occurring in the image at the different places. The white spots are occurring in the image at the different places. Fig 6 show Increasing the overall contrast and saturation of the image to improve the results of deformity analysis. By improving the contrast and saturation the deformity analysis can be easily done and easily find out the deformity present in the wall painting images. Adjust the color of nearest neighbour pixel where the cracks and white spots are presented by using the nearest neighbour algorithm. Cracks and white spots are filled by taking the nearest neighbouring pixel values. In fig 8 the histograms show the image before restoration and after. The fig 9 shows the improvement in the nearest neighbour algorithm by increasing the contrast and saturation. The results are better by increasing the contrast and saturation of image. The fig 10 shows the histograms of restored image with increasing the contrast and saturation and restored image without increasing the contrast and saturation. The results are better with increasing the contrast and saturation than without increasing the contrast and saturation. The maximum number of cracks and white spots are removed with increase contrast and saturation than the previous one. The fig.11 shows the comparison between nearest neighbour algorithm and scale invariance high fidelity algorithm. The nearest neighbour algorithm gives the more accurate results than the SIHF algorithm as it remove the large number of cracks and white spots than SIHF algorithm. The fig 12 shows the histograms of wall painting image which is restored by using the nearest neighbour algorithm and SIHF algorithm. It shows the comparison between both algorithms



Fig.1 Original Image



Fig.2 Preprocessed Image



Fig.3 Identification of both white spots and cracks



Fig.4 Identification of white spots



Fig.5 Identification of cracks



Fig.6 Increase contrast and saturation



Fig.7 Restored Image

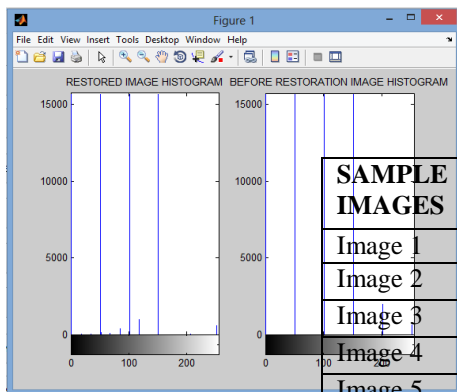


Fig.8 Histograms before and after restoration

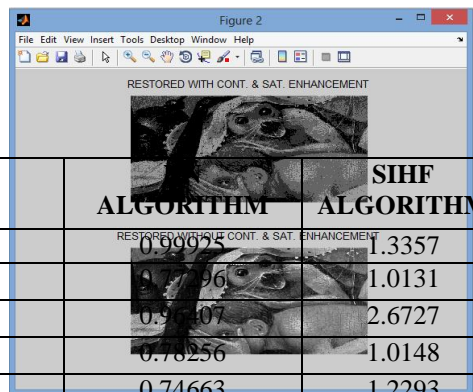


Fig.9 Restoration with and without increase contrast and saturation

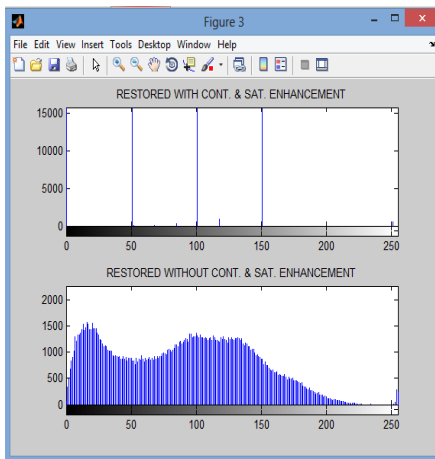


Fig.10 Histograms with and without increase contrast and saturation

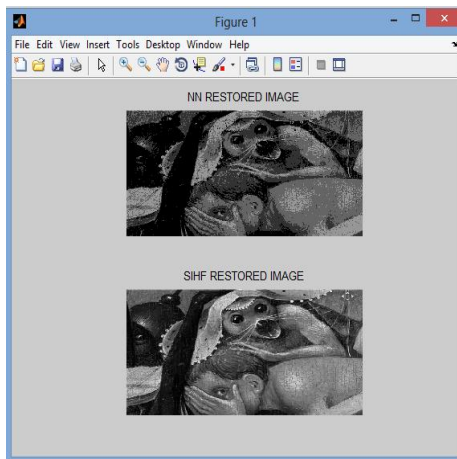


Fig.11 Comparison of NN algorithm with SIHF algorithm

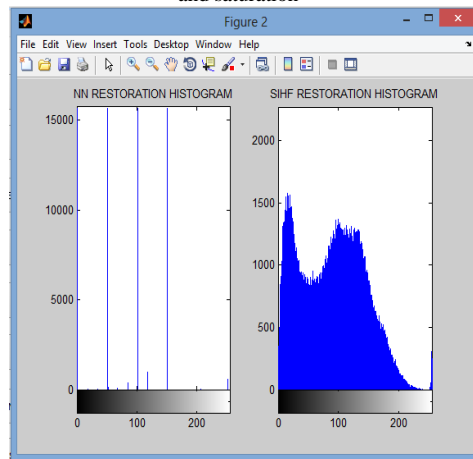


Fig.12 Comparison histograms of NN algorithm with SIHF algorithm

Results in Tabular Form:

Table 1: PSNR values

| SAMPLE IMAGES | NN ALGORITHM | SIHF ALGORITHM |
|---------------|--------------|----------------|
| Image 1       | 20.3866      | 14.715         |
| Image 2       | 37.025       | 16.664         |
| Image 3       | 23.7096      | 9.7535         |
| Image 4       | 32.2297      | 17.2709        |
| Image 5       | 39.5169      | 16.4678        |

Table 2: MSE values

techniques are not able to remove the white spots from the images of wall painting.

To overcome these problems nearest neighbour algorithm is used that helps to remove the cracks and white spots. So the quality of the wall painting images can be improved. For more improvement in the quality of digital wall painting, another deformity is considered that is white spots which are detected as well as removed. Nearest neighbour algorithm is improved by increasing the contrast and saturation. This algorithm significantly removes the white spots and cracks from the images of wall painting.

The comparative study includes the comparison between nearest neighbour algorithm with the scale invariance high-fidelity image restoration (SIHF). Based on comparison, it is concluded that the nearest neighbour algorithm provide the more accurate result as compared to SIHF algorithm based on parameters that are Peak signal to noise ratio (PSNR) and mean squared error (MSE). The nearest neighbour algorithm gives the more accurate results than the SIHF algorithm as it remove the more number of cracks and white spots.

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