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Crack Filling of Art by using Image Processing: A Review

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Abstract: The conservation of Art especially the old paintings has been a matter of concern. Numerous methodologies using Digital Image Processing have been proposed regarding the fixation of the cracks. This has been done so as to provide clues to art historians, and the general public on how the painting would look like in its initial state, i.e., without the cracks. In this paper, a brief Literature Survey has been made so as to analyze different methodologies that have been used for the detection as well as for the crack filling. This article discusses a number of modern techniques used for the analysis of works of art.

Keywords: Craquelure, thresholding, top-hat transform, Median Filter.

I. INTRODUCTION

In today's world, where everyday there is new advancement in the field of technology as well as new ideas are continuously evolving the advancement in the digitally equipped environment. Storage and retrieval of digital information is now possible at phenomenal speed, almost unimaginable just a decade ago. Information may contain pictorial data such as images or video sequences, as well as synthetic illustrations, diagrams, charts or computer aided graphics. Following a revolutionary trend, museums and art galleries are beginning to digitize their collections, not just to make them publicly available on the web, but also for internal use within the museums' or galleries' own environment. Digitizing the collection means providing a faster and more efficient way of recording what is available, thus giving a new dimension to methods of information retrieval within the environment itself. Instead of storing the information in a traditional manner, the ability to store it digitally opened the path for further manipulation of the technology, where digital preservation and restoration can play their part. Many paintings and artifacts were created centuries ago and are in need of preservation and restoration, to make sure that their physical appearance is maintained. Manual recording and detection of aging seem less efficient, given the increasing number of collections and electronic based approaches seems to be the best choice. Different types of materials are used for paintings and frames.

For this use varnish, paint, glue, canvas, wood, metal, gilding and plaster. When both are used then it produces complex structure which can be easily damaged if knocked or dropped. Materials are damaged by different surrounding materials and they are also sensitive too. When there are changes in the heat and humidity then it changes appearance of images. Also when there is a change in environmental conditions then they also produce changes in the paintings and frames. Light and dirt also produce change in images [1]. Many paintings, especially old ones, suffer from breaks in the substrate, the paint, or the varnish. These patterns are usually called cracks or craquelure. These are produces due to no. of reasons like aging, drying, and mechanical factors. Age cracks can result from non-uniform contraction in the canvas or wood-panel support of the painting, which stresses the layers of the painting. Drying cracks are usually caused by the evaporation of volatile paint components and the consequent shrinkage of the paint. Finally, mechanical cracks result from painting deformations due to external causes, e.g. vibrations and impacts. So appearance of image get decreases image quality get reduces. The appearance of cracks on paintings deteriorates the perceived image quality [2]. So solution for this one can use digital image processing technique can be used in this process. Image processing techniques have recently been applied to analysis, preservation and restoration of artwork. Old paintings are cultural assets for country which can be preserved by computer aided analysis and processing. Digital image processing techniques used to detect and eliminate the cracks on digitized paintings. So this type of processing images are used in museum, provide clues to art historians, and the general public on how the painting would look like in its initial state, i.e., without the cracks. Furthermore, it can be used as a non-destructive tool for the planning of the actual restoration.

II. CRAQUELURE

Craquelure is the fine pattern of dense "cracking" formed on the surface of materials, either as part of the process of ageing or of their original formation or production. The term is most often used to refer to tempera or oil paintings, where it is a sign of age that is also sometimes induced in forgeries, and ceramics, where it is often deliberate, and usually called "crackle". It can also develop in old ivory carvings, and painted miniatures on an ivory backing are prone to craquelure. Craquelure represents the unique crack formations on paintings that is related to the materials and methods employed by the artist Paintings from a particular geographical area tend to exhibit similar trends in their craquelure patterns.

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Fig.1 Example of an Art with cracks

III. LITERATURE SURVEY

F. Abas and K. Martinez [2] explained the crack enhancement and detection of the digital paintings. He focuses on Content-based image retrieval (CBIR) and analysis of the art. For the detection of the cracks he has used close top-hat operator which is a good tool to enhance cracks. After doing high feature extraction of the crack patterns he further implemented the whole algorithm in C programming language.

I. Giakoumis, I. Pitas [3] explained that the detection of cracks are done by thresholding the output of the morphological top-hat transform, whereas the thin dark brush strokes which have been misidentified as cracks are removed using either a median radial basis function neural network or a semi-automatic procedure based on region growing. Crack filling is done using order statistics filters or controlled anisotropic diffusion.

El-Youssef, Mouhanned [19] proposed the development of a framework for the geographical analysis of craquelure patterns in his literature. His work seeks to expand on these results with the intention of increasing the accuracy rate in the classification of craquelure to their corresponding geographical origins. For the extraction of the craquelure patterns he has compared the three different thresholding methods that have been attempted and tested in his thesis. The thresholding techniques he tested were Global thresholding, segmented thresholding and offset thresholding. Out of these three techniques the offset method was deemed to be the most accurate technique .The feature extraction phase is arguably the most important phase in his thesis. The features extracted dictate how accurate the classification of the samples will be.

Vidya Vinayak Khandare, Nitin B. Sambre [20] explained that the cracks are identified and detected by Gabor which is an integrated methodology for removal of cracks. From the results shown in their thesis, it is shown that even hair size cracks are detected by this Gabor filter. Gabor filter has a good potential as far as detecting cracks are concerned since it provides the ability for scale-specific and multi-orientation detection. The detected cracks were filled with weighted median filter.

Abhilekh Gupta, Vineet Khandelwal, Abhinav Gupta, M. C. Srivastava [21] proposed crack detection model employing a bottom-hat transform followed by thresholding and MAO. A global thresholding technique, operating directly on the BHT histogram, is used to produce the binary image. They have employed a new filter MAMF (Modified Adaptive Median Filter) to fill in the thick and thin cracks.

Guillermo Sapiro [22] suggested an Image In painting technique to fix the damage of the arts. Applications of image in painting range from the removal of an object from a scene to the retouching of a damaged painting or photograph. The basic goal is to produce a modified image in which the in painted region is merged into the image so seamlessly that a typical viewer is not aware that any modification has occurred. G Schirripa Spagnolo, F Somma [23] explained the cracks are detected by thresholding the output of the morphological top-hat transform. Afterwards, the thin dark brush strokes which have been misidentified as cracks are removed using automatic procedure. Finally, crack filling using texture synthesis algorithms.

IV. METHODOLOGY

A methodology for the restoration of cracks on digitized paintings, which adapts and integrates a number of image processing and analysis tools is proposed in this paper. The methodology is an extension of the crack removal framework. The technique consists of the following stages:

- crack detection;
- Separation of the thin dark brush strokes, which have been
- misidentified as cracks;
- crack filling (interpolation).

A certain degree of user interaction, most notably in the crack-detection stage, is required for optimal results. User interaction is rather unavoidable since the large variations observed in the typology of cracks would lead any fully automatic algorithm to failure. However, all processing steps can be executed in real time, and, thus, the user can instantly observe the effect of parameter tuning on the image under study and select in an intuitive way the values that achieve the optimal visual result. Needless to say, only subjective optimality criteria can be used in this case since no ground truth data are available. The opinion of restoration experts that inspected the virtually restored images was very positive.

The approach used for crack detection & filling is mentioned below:

1) The digital image will be acquired from various databases.
2) Then image will be pre-processed to remove noise & adjust brightness.
3) Crack detection will be done.
4) Crack filling will be done.
5) After filling crack we will get the restored image.

A. Crack detection

Crack-like pattern detection, also known in some literature as ridge-valley structure extraction, has been a matter of high concern among researchers mostly for its useful contribution to a variety of applications. In most cases,

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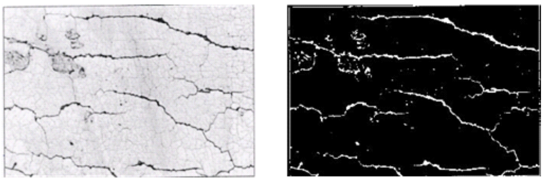
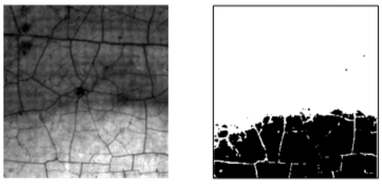
cracks can be considered as being local minima with rather elongated structure [3]. In [4] cracks are identified by taking into account the fact that they have considerably darker grey levels compared to the background and are characterized by a uniform grey level. From a local point of view they also have a strong orientation tendency.

In [5] Varley assumes that crack patterns in paintings can be segmented by just thresholding the image by a certain manually-selected threshold level. Although the assumption is true, unfortunately the outcome is not quite encouraging if such method is applied. As shown in Figure.2, thresholding does not always work. Factors such as inconsistent illumination, noisy presence and low contrast add to the difficulty of obtaining a fairly accurate detection.



(a) Sample image 1 and the result of manual thresholding



(b) Sample image 2 and the result of manual thresholding

Fig.2 Threshold applied on 2 sample crack images.

1. Common Line Detectors

A line segment on an image can be characterized as an elongated rectangular region having gray-level bounded on both its longer sides by homogeneous regions of a different gray-level. For a typical painting crack, gray-levels of the side level have higher values than the centre elongated region containing the dark line. The width along the same line segment may also vary. A general line detector should be able to detect lines in a range of widths. Among early work on line detection is done by Vanderbrug who suggested a semi-linear line detector created by a step edge on either side of the line [6]. He also developed an algorithm which is originally designed for road detection in satellite images [7]. The method is based on the response of the image to different masks, allowing to estimate the local variations of the gray-levels. This algorithm which is also employed by Muller uses 14 masks. Good results are reported if the image is not too affected by noise. However, in the presence of noise, these techniques do not perform well. These techniques are also seen to be very poor in terms flexibility in order to cope with the unpredictable nature of crack patterns.

2. Mathematical Morphology

Mathematical morphology is a part of digital image processing that concerns with image Filtering and geometric analysis by structuring elements. Originally, the theory and application of mathematical morphology was developed for binary images. Its main protagonists were Matheron [8] and Serra [9]. Afterwards, the theory was extended to gray-scale images by Sternberg [10] and later by Haralick, Stenberg and Zhuang [11, 12]. Since those early days, morphological operations and techniques have been applied from low-level, to intermediate, to high-level vision problems.

These operations are mainly used for noise reduction and feature detection, with the objective that noise be reduced as much as possible without eliminating essential features. Dilation and erosion are the two fundamental operations that define the algebra of mathematical morphology. These two operations can be implemented in different combinations in order to obtain more sophisticated operations.

Similar to the binary case, dilations and erosions are the basic operations that define the algebra of gray-scale morphology. They are combined to produce the gray-scale opening and closing operations which are very useful and effective set of operations for various computer vision applications.

The top-hat transform generates a grayscale output image where pixels with a large grey value are potential crack or crack-like elements. Therefore, a thresholding operation on is required to separate cracks from the rest of the image. The threshold can be chosen by a trial and error procedure, i.e., by inspecting its effect on the resulting crack map. The low computational complexity of the thresholding operation enables the user to view the crack-detection results in real time while changing the threshold value, e.g., by moving a slider.

This fact makes interactive threshold selection very effective and intuitive. Alternatively, threshold selection can be done by inspecting the histogram of for a lobe close to the maximum intensity value (which will most probably correspond to crack or crack-like pixels), and assigning it a value that separates this lobe from the rest of the intensities. The result of the thresholding is a binary image marking the possible crack locations.

Instead of this global thersholding technique, more complex thresholding schemes, which use a spatially varying threshold can be used. Obviously, as the threshold value increases the number of image pixels that are identified as cracks decreases.

Thus, certain cracks, especially in dark image areas where the local minimum condition may not be satisfied, can remain undetected. In principle, it is more preferable to select the threshold so that some cracks remain undetected than to choose a threshold that would result in the detection of all cracks but will also falsely identify as cracks, and subsequently modify, other image structures.

The thresholded (binary) output of the top-hat transform on the luminance component of an image containing cracks (Fig. 3) can be seen in Fig. 4.

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Fig.3 Original painting

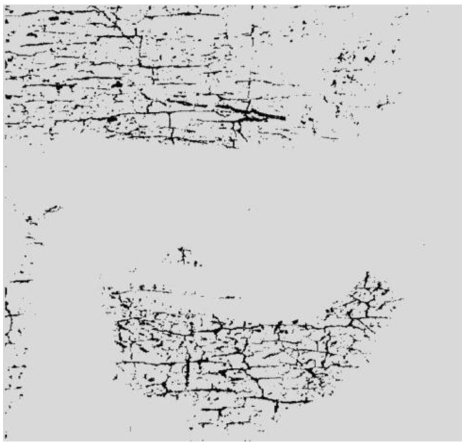

Fig.4 Thresholded output of the top-hat transform

3. Automatic Thresholding

Thresholding is one of the simplest and most widely used image segmentation techniques. The goal of thresholding is to segment an image into regions of interest and to remove all other regions deemed inessential. The simplest thresholding methods use a single threshold in order to isolate objects of interest. In many cases however, especially in the case of crack images, no single threshold provides an excellent segmentation result over the entire image. In such cases, variable and multilevel threshold techniques based on various statistical measures are used. In our research we consider two most commonly used automatic threshold selection methods, namely the Otsu's technique and the simple image statistic technique.

4. Crack Thinning

For the later stages, it is more convenient and less time consuming to work with one-pixel wide cracks rather than those of variable width. Although width is seen as an important element to characterize a crack pattern [1], we ignore it for the time being to concentrate on other characteristics.

We thin the crack patterns using the hit-and-miss algorithm [9]. To make sure the cracks have been thinned to one-pixel wide, we perform 10 iterations. A hit-and-miss cleaning algorithm is then applied to remove isolated pixels. A “thinned" and “cleaned" image is the final outcome of the crack detection process, which will be the input to the next stage.

B. Crack filling

After identifying cracks the final task is to restore the image using local image information (i.e., information from neighboring pixels) to fill the cracks. Two methods utilizing median filter and weighted median filter are proposed for this purpose.

The performance of the crack filling methods presented below was judged by visual inspection of the results. An effective way to interpolate the cracks is to apply filter in their neighborhood. All filters are selectively applied on the cracks, i.e., the center of the filter window traverses only the crack pixels.

If the filter window is sufficiently large, the crack pixels within the window will be outliers and will be rejected. Thus, the crack pixel will be assigned the value of one of the neighboring non crack pixels. The following filters can be used for this purpose.

1. Median filter

A Median filter is a non-linear digital filter which is able to preserve sharp signal changes and is very effective in removing impulse noise. While linear filters have no ability to remove this type of noise without affecting the distinguishing characteristics of the signal. Median filter is applied on a 2-D mask of size NxN, where N is an odd number.

For implementing the median filter, the pixels in the chosen mask need to be sorted in the ascending order then center pixel of the mask is replaced by the median pixel value from the sorted list. Figure.6 illustrates the procedure. For the 3x3 mask with center pixel intensity of 49, the neighborhood pixels are sorted in the ascending order of their intensities.

The center pixel intensity is replaced by the median value of the sorted list, which in this case is 38. Example of median filter using 3X3 neighborhood

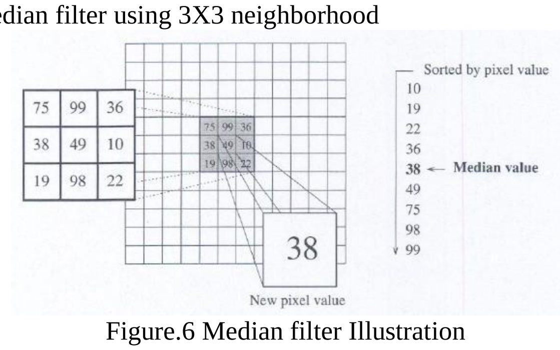

Figure.6 Median filter Illustration

2. Weighted median filter

The weighted median (WM) filter was first introduced as a generalization of the standard median filter, where a nonnegative integer weight is assigned to each position in the filter window. As shown in Fig.7, the structure of a WM filter is quite similar to that of a linear FIR filter.

For real-valued signals, WM filters can be defined in two different but equivalent ways. The first definition can be used in the common case of positive integer weights.

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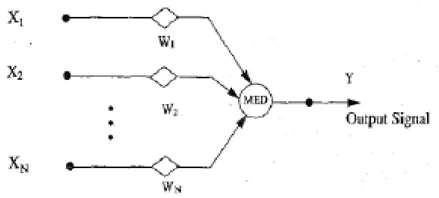

Figure.7 Weighted median filter

V. CONCLUSION

Various methodologies have been discussed in this article for the detection as well as filling of cracks in paintings. The implementation of a good content-based retrieval system tuned for craquelure analysis is a highly challenging task. Realization of such objective depends on how well the computer vision modules can perform their jobs. Various papers have been surveyed regarding Detection of cracks in Art as well as reviewed them here. The main focus of Literature Review is to study various methods from which the craquelure patterns can be detected as well as methods to fix this deterioration of the Art. Further, there is a lot of scope for the detection as well as filling of cracks. The accuracy can be increased which would be our future goal.

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