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REMOVAL OF CRACKS FROM DIGITIZED PAINTINGS BY VIRTUAL RESTORATION USING USER INTERVENTION BASED DETECTION

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Abstract: *An user intervention based advanced technique for the detection and elimination of cracks in digitized paintings and images is proposed in this paper. Usually cracks degrade the quality of painting as well as authenticity of painting becomes questionable. In the proposed method the cracks are detected by thresholding the result of the morphological top-hat transform. Further, misidentified cracks are detected either by involving user intervention or by using a semi-automatic procedure based on region growing technique. Finally, crack interpolation also called crack filling is performed using order statistics filters so as to restore the cracked image. The true positive rate and false positive rate are used to evaluate the performance of the proposed technique. We collected 2000 paintings & images classified as cracked and uncracked online digital art database for experimental purpose. The result shows achievement of true positive rate of about 98.3% at the rate of 0.1 false positive per image. This is because of providing user intervention during module called identifying mis-identified cracks.*

Keywords: *User intervention, Digital painting, Cracks, misidentified cracks, top-hat transform, interpolation.*

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INTRODUCTION

Retaining old paintings, old scripts, is a problem with immense importance, as cracks, mishandling, and age humiliate the visual quality. Cracks are the breaks mainly influenced by ageing, drying and mechanical factors [1]. Age cracks usually result from inconsistent contraction in the canvas or may be improper wood-panel support of the painting, which eventually stresses the layers of the painting. Drying cracks are usually observed when the components of paint get evaporated consequently resulting in the shrinkageof the paint. Further, mechanical cracks are outcome of warping due to external causes, such as vibrations and crash. Old photographic prints often suffer from the presence of cracks due to inappropriate handling. Due to mechanical stress and strain, the external photosensitive suspension can splinter, revealing the underlying white paper support; the paper in turncan suffer damage from dampness and humid air and from polluting agents and changing its colour to the yellowish hue.Department of information technology, art and culture,Archaeology, Heritage, Monuments, Painting are working forgathering the damaged paintings, pictures in order to restorethe quality of precious paintings. However this process is timeconsuming, and tedious, and needs to be performed byqualified personnel. Though this approach may restore thequality of paintings and images, it is susceptible to damages asstated earlier. Hence, there exists significant demand fordigitally restoring the visual quality of paintings. The result ofthis shall be proved to be a useful guide.Several techniques have been reported in the literature forthe automatic restoration of damaged paintings; the mostrecent approaches are texture synthesis and impainting. Manyliteratures have been reported for automatic detection ofcracks without user intervention. However, we feel there isnecessity of user intervention, since some image features mayresemble like cracks. Crack identification is a delicate andimportant step. It plays a vital role in the elimination ofcracks. Common steps observed in most of the reportedliterature include:

- Crack Identification
- Separating dark brush strokes which can been misidentifiedas cracks
- Crack filling (Interpolation)

Normally cracks starts from one side (usually left) in theframe of the photograph to another side (usually right) andtend to lie either along straight lines or inclined lines. Acertain level of user intervention, especially in the misidentifiedcrack detection stage, is required for best possibleresults. User intervention is quite inevitable since the largedisparity observed in the morphology of cracks would leadany reported fully automatic algorithm to failure. In fact, allprocessing steps can be executed in real time and thus the usercan instantly observe the effect of parameter correction on theimage under study and select in an instinctive way the

valuesthat achieve the best possible visual result. It is worth to saythat only subjective correction criterion shall be used in thiscase since we don't have ground data. Further, performanceshall be evaluated by calculating the sensitivity and specificityof proposed technique through true positive and false positiverate, The Receiver Operating Characteristics (ROC) curvesprovide a visual tool for examining the tradeoffs between theability of a technique to correctly identify positive cases andthe number of negative cases that are incorrectly classified.This paper depicts the following sections: Section IIpresents the comparative study of reported literatures; SectionIII shows the proposed methodology along with theclassification of cracks; Section IV highlights the results andperformance evaluation; A Conclusion section (section V)concludes the paper.

II. EXISTING METHODOLOGY

In order to understand the existing methodologies and scopefor improvement for the problem of 'detection and removal ofcracks from digitized paintings' we surveyed recent papers.The Table 1.presents the comparative study of literatures. It isobserved that in most of the literature, morphological top hattransform is used for crack detection followed by Semiautomatic procedure based on region growing is used foridentifying mis-identified cracks & finally order statisticsfilter is used for filling the crack. This study contributed us indesigning the better methodology.

Sl.No	Paper Title & Author	Crack Detection	Mis-Identified Cracks	User intervention	Crack Filling
1.	Sachin V. Solanki etal.**Year:** 2009	Top Hat Transform followedby thresholding.	Semi Automaticprocedure based onregion growing.	No	Order Statistics Filter
2.	PrateekshaChoukseyetal.**Year:** 2011	Top-hat transform followedby thresholding operation.	Median radial basisfunction (MRBF)neuralnetwork on hue andsaturation data	No	Orderstatistics filters suchas median filter
4.	B. Cornelis et al. **Year:** 2012	Oriented elongated filters, Multiscale Top-hat, K-SVD along with pre and post processing	Semi-supervised clustering based post processing. & Patch-based technique	No	Patch based technique

5.	G SchirripaSpagnolo et al. **Year:** 2010	Top-hat transform followed bythresholding operation.	Median radial basis functions (MRBF) neural network	No	Texture synthesis algorithm
6.	B.Santhi et al. **Year:** 2012	Canny gray scale morphological processing,	Butterworth Filters	No	Noise removal from original image
7.	Pranob K Charles et al. **Year:** 2006	Thresholding the output of the morphological top-hat and bottom-hat transforms.	-NIL-	No	Order statistics filters
9.	Shilpa et al. **Year:** 2012	Patch based approach Top Hat approach & Thresholding	Region growing algorithm	No	order statistics filtering & anisotropic diffusion Image inpainting techniques
10.	Abhilekh Gupta et al. **Year:** 2008	Bottom Hat Transform followed by Thresholding before applying to MAO (Morphlogical Area Opening) for obtaining Crack Map.	Optimized Bottom Hat Operator	No	Modified Adaptive Median Filter (MAMF). Fills crack by local information.

Table 1: Survey on identification and removal of cracks from digitized paintings

From the above Table.1 it is learnt that most of the techniques have attempted automatic identification of cracks, with top hattransform followed by thresholding for crack detection stage. Eithersemi automatic or automatic methods are used for identification of mis-identified cracks. Order statistic filterslike median filters is quite commonly used for crack filling.

III. PROPOSED METHODOLOGY

The Figure 1 presents the system model. Most of the process is same as commonly observed in literatures, except the novel step where user intervention at detection of misidentified cracks is incorporated until best possible result is observed. Crack detection is carried out by top-hat-transform followed by thresholding. This results in binary image where only cracks are highlighted. After the top-hat transform certain areas may exist where brush strokes have almost the same thickness and luminance features as cracks. The top-hat transform might misclassify these dark brush strokes as cracks. It is very important to deselect the mis-identified cracks is crucial and important step in the success of detection system.

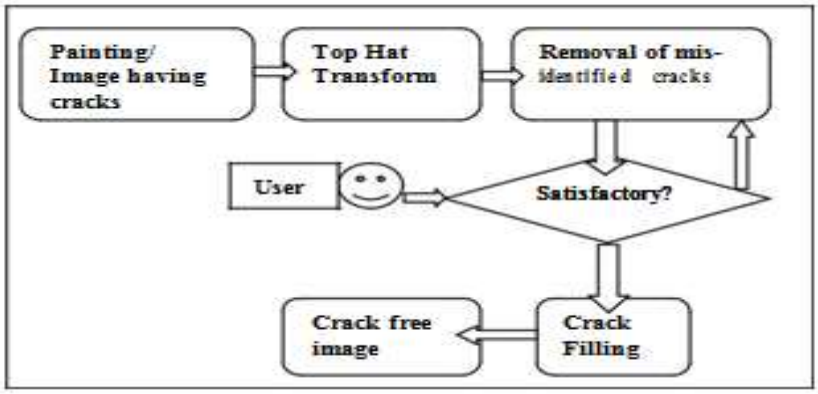

Figure 1: Proposed methodology for crack identification and correction

A. IDENTFICATION F CRACKS

A. Classification of cracks

A simple classification approach was developed, taking into account four categories of classifications namely class A, class B, class C, class D. Experiments are performed based on these 4 categories of images.

Class A: In this category the images are classified based on thickness of cracks. This class contains images under three sub categories thin cracked (A1), Medium cracked (A2) and Thick cracked (A3).

Class B: In this category the images are classified based on No of cracks. This class contains images under three subcategories less cracked (B1), Medium cracked (B2) and highly cracked (B3).

Class C: In this category the images are classified based on Connectivity of cracks. This class contains images under two sub categories less connected (C1) and highly connected (C2).

Class D: This class contains images in which cracks are created for experiment purpose manually created cracks are classified under manual cracks (D1).The categorization was done manually by examining the depth of the crack present in the image.

B. Experimental Setup

Matlab Version 7.0 is used to implement the system. Cost of the proposed work depends on the cost of Matlab softwaretool. To assess the effectiveness, the response time of the system for crack removal is analyzed. Images classified into different categories are considered for further processing. Theexperiments are carried out on Intel Core 2 Duo processorT6600 (2 MB L2 cache, 2.2 GHz, 800 MHz RAM: 3GBDDR3, Windows Operating system, and with Working VB.NET platform.

IV.RESULTS AND DISCUSSIONS

The proposed technique is tested by using image dataset from various online databases such as Historic Pittsburgh Image Database by University of Pittsburgh's Digital Research Library [12], Web Gallery Art [13], and Indian PaintingsArchive [14]. The Sensitivity and specificity are the performance evaluation parameter. Most of the reported literatures use subjective evaluation by image restorationexperts. Hence comparison of proposed method with othermethods by quantitative measures couldn't be carried out.

A. The ROC Method

The most suitable evaluation method for crack detectionmethod is the Receiver Operating Characteristic method. InROC analysis, encapsulates all information contained inthe confusion matrix, because FN is complementof TP and TN is complement of FP. The values recorded arethe False Positive rate (FP) and the True Positive rate (TP),defined in terms of the confusion matrix as:

$$FP = \frac{fp}{(fp \quad tn)} \qquad (1)$$

$$TP = \frac{tp}{(tpfn)} \qquad (2)$$

In this formula, FP is the number of false positives; TP isthe number of true positives. Each (FP, TP) pair is plotted as apoint in ROC space. This proposed technique is tested usingclassified dataset as mentioned in section B of III. Thefollowing Table 2 shows the records.

METHOD	TP	FN	TN	FP	TP rate	FP rate	SE	SP
Class A-A1	220	30	230	20	0.88	0.08	88	92
Class A-A2	232	18	231	19	0.928	0.076	92.8	92.4
Class A-A3	235	15	238	12	0.94	0.048	94	95.2
Class B-B1	242	8	245	5	0.968	0.02	96.8	98
Class B-B2	245	5	241	9	**0.98**	0.036	**98**	96.4
Class B-B3	243	7	243	7	0.972	0.028	97.2	97.2
Class C-C1	215	35	219	31	**0.86**	0.124	**86**	87.6
Class C-C2	218	32	221	29	0.872	0.116	87.2	88.4
Class D	245	5	247	3	0.98	0.012	98	98.8

Table 2. Sensitivity and specificity of proposed method for

True Positive: Presence of crack is correctly detected

False Positive: Absence of crack incorrectly identified asPresent

True Negative: Absence of crack is correctly detected as notpresent

False Negative: Presence of crack is incorrectly identified asnot present

From the Table.2 above following things are analyzed. Theaverage sensitivity and specificity chart for all four classes is asshown in the below figure.2

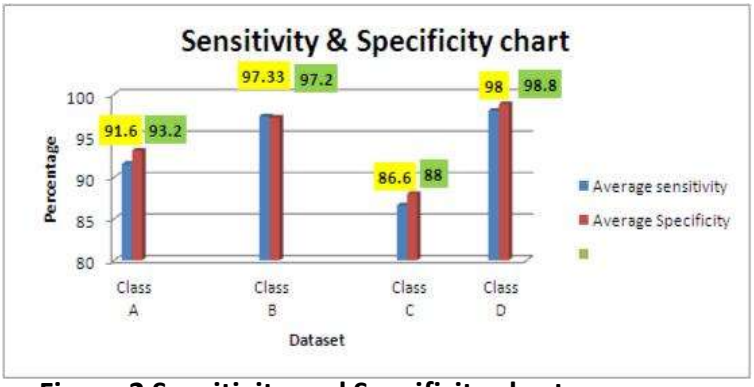

Figure 2 Sensitivity and Specificity chart

From the Table.2 as well as Figure.2 it is observed thathighest TP rate achieved is 98 for class B and lowest TP rateof 86 for class C. The ROC graph of proposed methodologyfor differently classified dataset is shown in the figure 3.

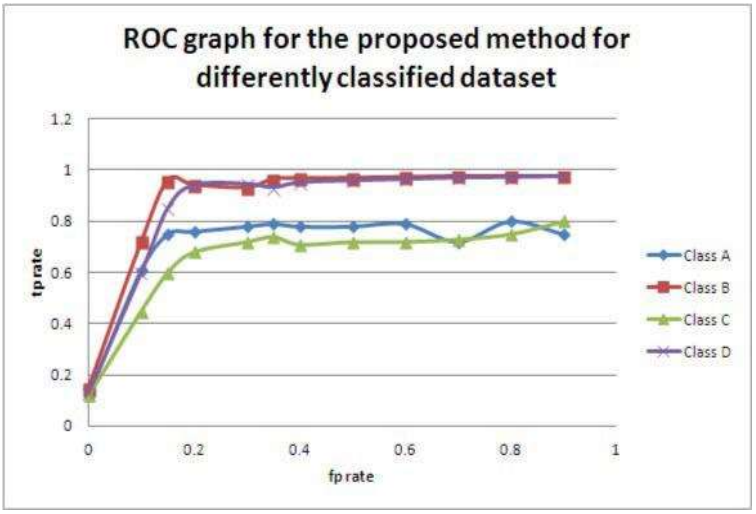

Figure 3 ROC graph for proposed method for differently classified dataset

From the above shown graph it is very clear that proposed technique resulted in better performance for datasets belonging to group B and D, while very poor for group C. For group A the performance was medium. The snapshots shown in figure 4 depict the intermediate results generated at various stages during the process of crack detection and removal.

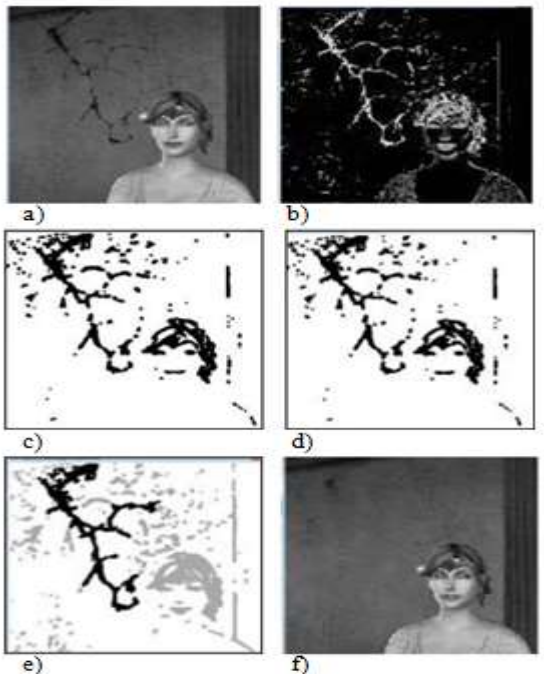

Figure 4: Results of Crack Removal Process

a) Original cracked image b) Eroded Image c) Dilated image d) Top Hat transform result
e) Misidentified crack removal f) Final Interpolated image

V. CONCLUSIONS

In this paper, a novel method by incorporating userintervention during identification of mis-identified crack ispresented. Process begins with crack identification, which isbased on top hat transform. User intervention and crackseparation based on region growing algorithm is used for removal of mis-identified cracks. Further crack interpolationis done using order statistics filter based on mean, trimmedmean filter algorithm. Various categories of images are usedfor evaluating the performance. It is found that providing userintervention during identifying misidentified cracks modulegives better results for all the categories. The experiments alsoshows improved visual quality for the combined mean andtrimmed mean filters at interpolation module. Theincorporation of user intervention has resulted in true positiverate of up to 0.98 at the rate of 0.036 false positive rate. Thesensitivity as well as specificity is also considerably better.Hence, the proposed technique gives better results.

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