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RESEARCH ARTICLE

DIGITAL IMAGE PROCESSING TECHNIQUES FOR THE DETECTION AND REMOVAL OF CRACKS IN DIGITIZED PAINTINGS OR CONCRETE STRUCTURE

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ABSTRACT

This document presents crack detection and removal techniques on digitized paintings. The crack detection technique proposed here can also be used to detect cracks in concrete structures by processing the digitized concrete images. Safety inspection of concrete structures is very important since it is closely related with the structural health and reliability. So, the development of crack detecting systems has been a significant issue. One of the objective of this document is to provide a method to develop an automatic crack detection system that can analyse the concrete surface and detect the cracks efficiently. The crack detection procedure proposed here is based on morphological bottom-hat transformation and finally crack filling is done by applying order static median filter using information of neighbourhood pixels.

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INTRODUCTION

Crack is a line on the surface of something along which it has split without breaking apart. Various types of materials are used for paintings and as well as frames like varnish, paint, glue, canvas, wood, metal, gilding and plaster. Different types of material produces complex structure which can be easily damaged. Painting materials are very sensitive and can be damaged by different surrounding environmental impacts. 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 many paintings, especially old ones, suffer from breaks in the substrate, the paint, or the varnish. These patterns are usually called cracks and fine pattern of dense "cracking" formed on the surface of painting materials is called Craquelure. The main causes of cracks in painting are 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.

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Finally, mechanical cracks result from painting deformations due to external causes, e.g. vibrations and impacts. In the case of paintings on canvas, the canvas slackens as it ages as it cannot endure the long-term stress of stretching. Another area where crack detection is very important is to detect cracks in concrete structure. We can judge the condition of the structural health objectively by acquiring and processing the concrete structure's image. In these structures, the one of the ways in judging the structural health is to examine a crack on the surface of the structure. Since the condition of a concrete structure can be easily and directly identified by inspecting the surface crack, the crack assessment should be done on a regular basis to ensure durability and safety. So many researchers have studied the automated concrete crack detecting method. Concrete structure images are acquired by using CCTV, laser scanner, and microwave. So, by applying the image processing technique to detect crack in concrete structure is our documents another goal.

Restoration of digitized paintings is one of the major concern of our documents. As the appearance of cracks on paintings deteriorates the perceived image quality. So solution for this is to use digital image processing technique to eliminate the cracks on digitized paintings. So this type of image processing for restoration of digitized paintings 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. Now to fill the crack pixels we have to get information from the neighbourhood pixels. So information from neighbourhood pixels are used to interpolate the value to a crack pixel. Crack filling can be obtained by applying different types of order statistic filters such as median filters, max filters, min filters, midpoint filters, trimmed mean filters can be applied.

Related Work

There are multiple previous research works on Crack detection on digitized paintings as well as concrete structure images and crack filling. A brief description of some most recent researches are given here. Yamaguchi and Hashimoto (2010) proposed a fast crack detection method for large-size concrete surface images using percolation-based image processing. The percolation process is based on the physical model of liquid permeation, is started from each pixel. Depending on the shape of the percolated region, the pixel is considered as a crack pixel or not. The process proposed provide good result for detecting cracks but the computation time is very large as percolation process starts from each pixels and huge computation power is also needed. Giakoumis, Nikolaidis and Pitas (2006), proposed a method to detect cracks in digitized paintings. They uses morphological operation on images to detect cracks and the misidentified thin dark strokes are excluded by hue and saturation as well as neural network. Still, many irrelevant objects are misidentified as cracks. They also described different methods for crack filling. Wenyu Zhang, Zhenjiang Zhang, Dapeng Qi, and Yun Liu (2014) proposed automatic crack detection and classification method for subway tunnel safety monitoring system. To eliminate the unnecessary local small valleys, they applied an average image-smoothing filter to pre-process the original gray-scale images. They applied top-hat transformation to detect cracks and they also perform an extensive crack classification. Gavilán, Balcones, Marcos, O Llorca, Sotelo, Parra, Ocaña, Aliseda, Yarza, Amírola (2011) proposed an adaptive Road Crack Detection System by Pavement Classification. A vehicle equipped with line scan cameras is used to store the digital images that will be further processed to identify road cracks. They proposed Non-crack features detection method to mask areas of the images with joints, sealed cracks and white painting that usually generate false positive cracking and provide a seed-based approach to deal with road crack detection combining Multiple Directional Non-Minimum Suppression (MDNMS) with a symmetry check. The system performs well for road crack detection, but is not suitable for cracks in painting. Miss VidyaVinayakKhandare and Prof. Mr. Nitin B. Sambre (2014) proposed a crack detection and removal method in digitized painting. The cracks are identified and detected by Gabor which is an integrated methodology for removal of cracks. First, they filter the selected crack image using 8 differently oriented Gabor filters for the purpose of feature extraction to represent acrack network from sets of local orientation features. They used resultant features for crack filling with median filter and weighted medianfilter. Their methodology has been shown to perform well on digitized paintings suffering fromcracks.

Proposed Method

The total procedure of crack detection and removal consists of several steps which can be combined into three stages

- Image Reading and Pre-processing
- Crack Detection
- Crack
- Filling

Image reading and Pre-processing

Digital image of painting or concrete structure are read from various database. Image read may need some pre-processing. Like if the image is over sharpened then we need apply some averaging filter for smoothing. In most cases images read are lack of proper dynamic range then we need to apply contrast stretching transformation technique to transform low contrasted image to properly contrasted image. Contrast Stretching is a process that expands the range of intensity levels of an image so that it spans the full intensity range of pixel values that the image type concerned allows. This makes crack regions more dark and other regions of the image more bright which helps to separate cracks from whole image.

Crack Detection

For the process of crack detection we can define two major characteristics to identify cracks (1) shape of the cracks are thinner compared to other textual pattern in the image and (2) brightness in the crack regions are dimmer than the background. The method proposed here is based on the previously said two properties. So cracks with same brightness as of the background of the image is very difficult to detect. By the above two properties of crack we can say that cracks have low luminance that is intensity values of the crack pixels are minimum. So crack detection process is applied on the intensity component of the image. A crack detection procedure based on bottom-hat transformation is proposed here. Bottom-hat transformation is morphological image processing which is used to extract image components such as the shape of cracks. The bottom-hat transformation, is based on another morphological operation 'closing' of an image. Thus bottom-hat transform, is defined as the residual of a closing compared to the original signal, i.e.

$$y = f \blacksquare K - f$$

Where $\blacksquare$ denotes morphological closing of the image f and K is the structuring element.

The closing of agrayscale or binary image A by a structuring element B is the erosion of the dilation of that image,

$$A \blacksquare B = (A\ \theta\ B)\ \varphi\ B$$

Where θ and φ denotes dilation and erosion respectively.

The bottom-hat transform returns an image, containing the objects or elements that are smaller than or equal to the structuring element, andare darker than their surroundings. The structuring element plays key role in detecting cracks properly.

Selection of structuring element is based on two parameters:

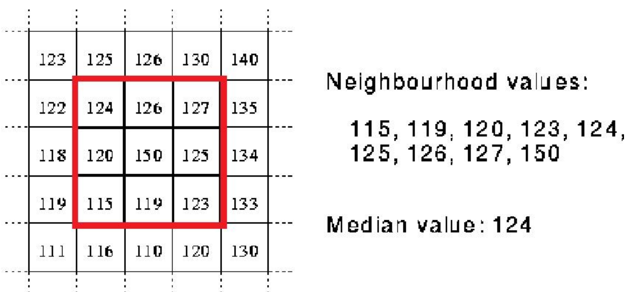
- Type of the structuring element i.e. diamond, disk, line, rectangle, square etc.

- Size of the structuring element e.g. specifying the width of the square type element

The size of the structuring element is chosen such that it can cover the width of the widest crack in the image. The output of the bottom-hat transform is a grayscale image where pixels with higher intensity value is considered as crack pixels. So to separate crack from rest of the image thresholding operation on bottom-hat transformed grayscale image in done. For thresholding operation is done based one the global image threshold level value using Otsu's method which chooses the threshold value to minimize the intra-class variance of the thresholded black and white pixels. After thresholding the binary image produced is considered as mask image that will be used to determineregion of interest (ROI) in crack filling process. The cracks regions in this binary image is white and other locations is black. So to visualize the cracks more prominently we have done complement i.e. negative of the image.

Crack Filling

After detecting the crack and separating cracked regions from original image as mask image, the final task remains crack filling based on the neighbourhood pixels to fill cracks. The crack filling method proposed here is an order statistic filter particularly we can say modified median filter. Results of crack filling is largely depends on neighbourhood window selection. We used rectangular neighbourhood window which is approximately 50% wider than the widest crack in the image to ensure that the filtered output value is non-crack pixel value. Here to get better result we have done some modification to the original median filter. If any pixel has intensity value less than some threshold value then we ignore that pixel or we can use some predefined pixel value for that pixel, predefined pixel value must be greater than threshold value and close to the average pixel value in that neighbourhood window.. This kind of median filter can be considered as modified trimmed median filter. We have trimmed the pixels with intensity values less than 70.This crack filling method is only applied to the pixels which belong to the cracks, the filling procedure does not affect any other useful information of the image except crack pixels that’s why the filtering procedure is a non-destructive process to restore crack images.



Algorithm

Step 1: Read the image and if the image is not grayscale than convert it to grayscale image.

Step 2: Pre-process the grayscale image as necessary like smoothing or contrast stretching.

Step 3: Define the structural element by specifying structural element type and size. In most of the cases square type structural element is beneficial for crack detection and define its size approximately as the size of the widest crack width.

Step 4: Perform the bottom-hat transformation using the defined structural element in step-3.

Step 5: Compute the global image threshold level value using Otsu’s (6) method which chooses the threshold value to minimize the intra-class variance of the thresholded black and white pixels.

Step 6:Convert the bottom-hat transformed image into binary image by thresholding using the threshold level value from step-5.

Step 7:Apply median filter to the cracked regions in the original grayscale image to fill the crack. This is done by using binary image from step-6 as mask for applying filter to the original grayscale image.

Coding

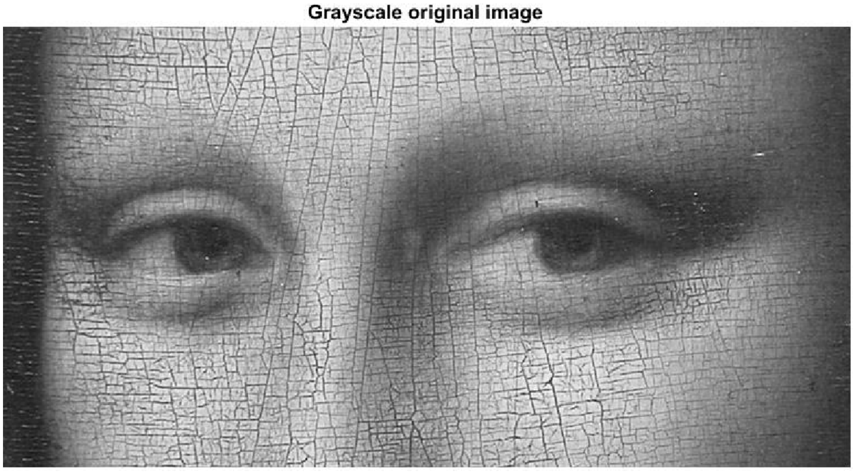
The above crack detection and removal procedure has been implemented in MATLAB and the implementation code is given below.

```
% Crack Detection and Removal from digital images
clc clear

%% load image
a =imread('crackimage.jpg');
figure,imshow(a)
title('Original image')

%% Image adjust
b = imadjust(a,stretchlim(a));
figure,imshow(b)
title('Contrast stretched image')

%% Convert RGB image to gray
o = rgb2gray(a);
figure,imshow(o)
title('RGB to gray original image')
c = rgb2gray(b);
figure,imshow(c)
title('RGB to gray (contrast stretched) ')

%% Image morphological operation
se = strel('square',3);
d = imbothat(c,se);
figure,imshow(d)
title('Bottom-hat transformed image')

%% Thresholding
level = graythresh(d);
%e = im2bw(d, 0.17);
e = im2bw(d, level);
figure,imshow(e)
title('Bottom-hat thresholded image')

%% Negative Image
f=imcomplement(e);
```

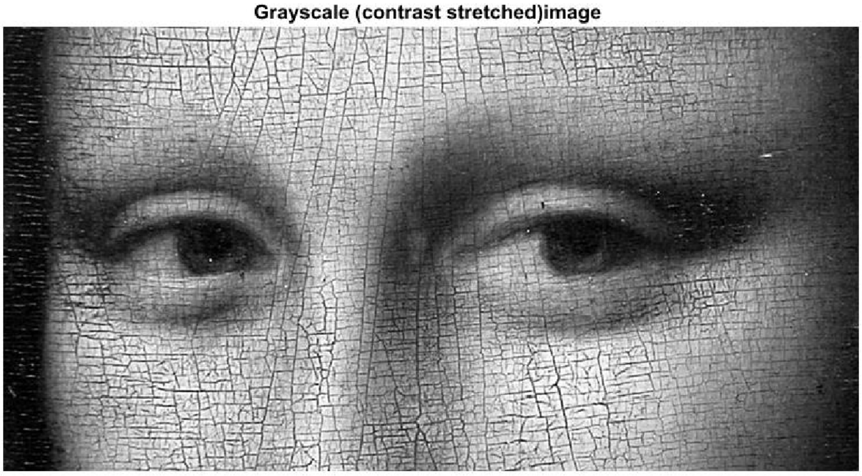
```
figure,imshow(f)
title('Bottom-hat thresholded negative image')

%% Crack Filling
A1 = o;
SE1 = strel('square',2);
mask2 = e;
%PAD THE MATRIX WITH ZEROS ON ALL SIDES
modifyA=zeros(size(A1)+4);
B1=zeros(size(A1));

%COPY THE ORIGINAL IMAGE MATRIX TO THE PADDED MATRIX
for x=1:size(A1,1)
for y=1:size(A1,2)
modifyA(x+2,y+2)=A1(x,y);
end
end

%LET THE WINDOW BE AN ARRAY AND STORE THE NEIGHBOUR VALUES IN THE ARRAY
%SORT AND FIND THE MIDDLE ELEMENT

fori= 1:size(modifyA,1)-4
for j=1:size(modifyA,2)-4
%IF THE PIXEL BELONGS TO CRACK PIXEL
if(mask2(i,j)==1)
window=zeros(25,1);
inc=1;
for x=1:5
for y=1:5
temp = modifyA(i+x-1,j+y-1);
if( temp < 70)
window(inc) = 100;
else
window(inc)=modifyA(i+x-1,j+y-1);
end
inc=inc+1;
end
end
med=sort(window);
%PLACE THE MEDIAN ELEMENT IN THE OUTPUT MATRIX
B1(i,j)=med(13);
Else
%IF THE PIXEL IS NOT BELONGS TO CRACK PIXEL
B1(i,j)=A1(i,j);
end


end
end
%CONVERT THE OUTPUT MATRIX TO 0-255 RANGE IMAGE TYPE
B1=uint8(B1);
figure, imshow(B1);title('Crack filled image');
```

Experimental Results

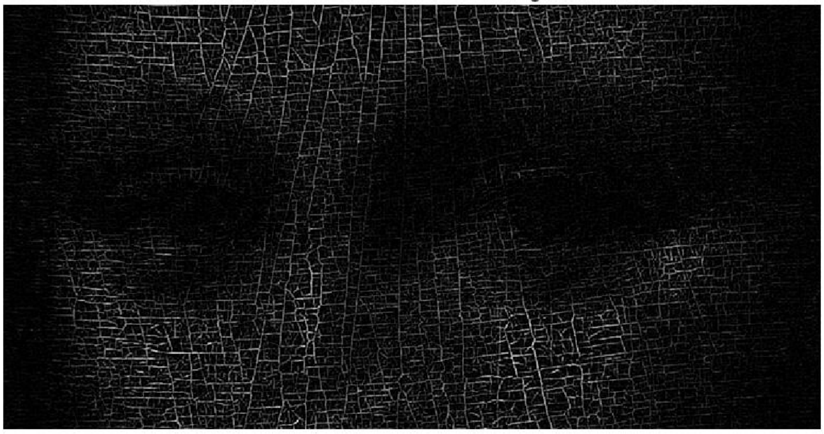
Grayscale original image



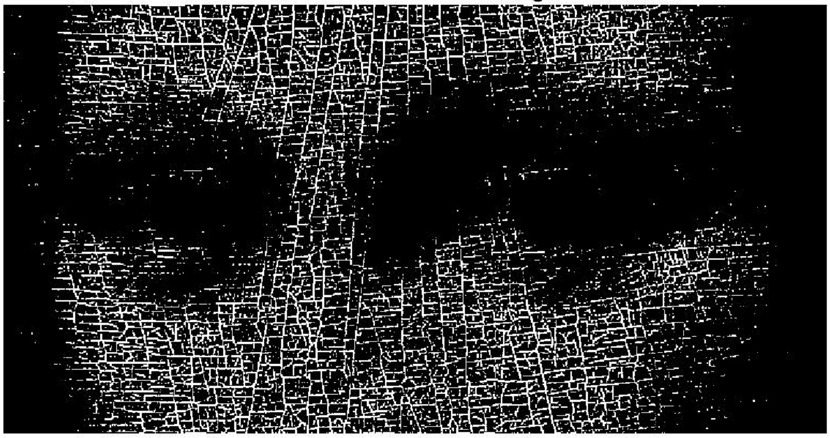
Grayscale (contrast stretched)image



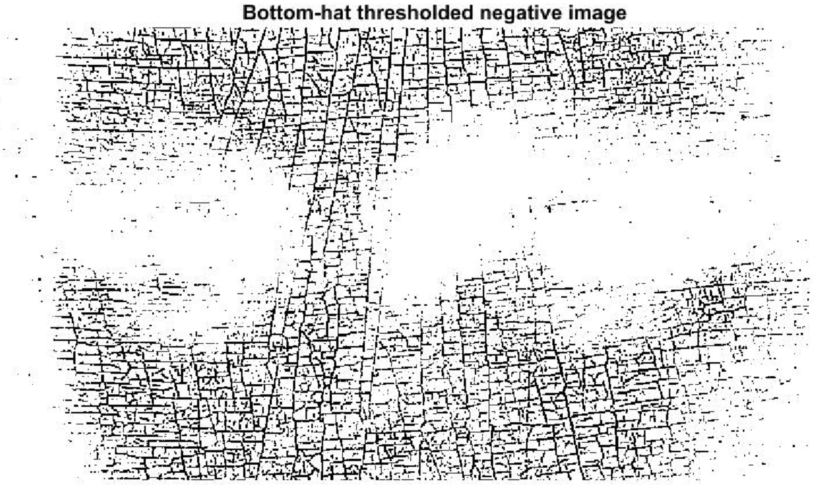
Bottom-hat transformed image



Bottom-hat thresholded image



Bottom-hat thresholded negative image



Crack filled image

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