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DIGITIZED PAINTINGS FOR CRACK DETECTION AND RESTORATION USING MEDIAN FILTER AND THRESHOLD ALGORITHM

Ukpe, Kufre Christopher[1]; Ledisi Giok Kabari[2]

[1]School of Post Graduate Studies, Department of Computer Science, Faculty of Natural and Applied Sciences, Ignatius Ajuru University of Education, Rumuolumeni, Port Harcourt, Rivers State, Nigeria
Email: ukpekaycee123@gmail.com

[2]Department of Computer Science, Faculty of Applied Sciences, Ken Saro-Wiwa Polytechnic, Bori, Rivers State, Nigeria
Email: lediikabs@gmail.com

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ABSTRACT – Due to a variety of factors such as long time storage, dry environment, and volatilization of painting, some cracks and stains may appear on the surface of the oil paintings. These tend to seriously affect the value of the paintings. Image restoration techniques are proving to be of great help in the analysis and documentation of our cultural heritage. Digital image restoration techniques provide a multitude of choices for improving the visual quality of images. In this work, we propose a multi-dimensional median filter and threshold algorithm for detection and removal of cracks in digital images. The work conducts an analysis of multi-dimensional median filter and threshold algorithm for effective restoration of cracks in digitized painting using the Java programming language version 8.0. To demonstrate the usefulness of this technique, cracked images of different resolution are collected for use in testing the efficiency of these models. The results show a remarkable difference between the original and enhanced images. This work is implemented using the Java programming language on Netbeans IDE.

Key Words: Digitized Paintings, Crack Detection and Restoration, Median Filter, Threshold Algorithm.

Introduction

Oil paintings develop a lot of cracks as a result of long time storage, dry environment, volatilization of painting materials, among other factors (Pitas, 2006). In addition, for incompletely preserved measures or some other reasons, stains may appear on the surface of the paintings. These cracks and stains will seriously affect the quality and value of the paintings. Image processing technology can be taken advantage of to detect and repair cracks and stains in digitized painting images (Bovik, 1995). Using this repair method could be used to restore paintings in museums, art galleries or other public places, so that people could see the original features of the damaged paintings (Landstrom et al, 2012).

At present, the use of image processing technology to repair digitized painting images has become a research hotspot in the field of digital image processing, and the repair work mainly includes two phases: crack detection and crack repair or restoration (Jain, 1989). Now, many scholars and researchers propose a number of crack detection and crack repair algorithms, such as region growth algorithm, neural network algorithm, etc. However, these algorithms are generally not applicable to the oil restoration of painting image instead, combination of different repair techniques gradually become a new research trend. In this research, a multi-dimensional median filter and threshold algorithm is proposed for the detection and removal of crack in digital paintings. This work uses the Java programming language and Netbeans IDE on Windows 10.

The paper presents development of a multi-dimensional median filter and threshold algorithm for detection and restoration of cracks in digitized paintings. We provide an efficient algorithm for detection and removal of crack in digitized paintings, efficiently display the cracked region of an image to the user, enhance the capability of a median filter algorithm via dynamic window size and finally provide a means by which damaged images can be restored.

Thresholding transformations (Haralick et al, 1992) are particularly useful for segmentation in which we want to isolate an object of interest from a background. The median filter is a nonlinear digital filtering technique, often used to remove noise (Yang, 2009). Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges of the images while removing noise.

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Crack detection based on region growing algorithm need to determine the seed point location of each crack area artificially (Lufkin, 2005). Although this method can detect the crack area more accurately, it is too cumbersome. And the method based on top-hat transform can quickly detect the crack area, but it has greater possibility of false detection. Therefore, crack detection based on threshold proves to be more efficient. Many image restoration techniques are not memory efficient due to its complexity; an example is the top-hat transform. The 1-D median filter proves practically inefficient to remove noise in an image (Freeman, 2005).

Related Works

Image Enhancement

Image enhancement is basically improving the interpretability or perception of information in images for human viewers and providing "better" input for other automated image processing techniques (Dwijest, 2002). The principal objective of image enhancement is to modify attributes of an image to make it more suitable for a given task and a specific observer. During this process, one or more attributes of the image are modified. The choice of attributes and the way they are modified are specific to a given task (Chanda et al, 2002). Moreover, observer-specific factors, such as the human visual system and the observer's experience, will introduce a great deal of subjectivity into the choice of image enhancement methods.

a. Threshold Image Enhancement Techniques

Thresholding transformations (Haralick et al, 1992) are particularly useful for segmentation in which we want to isolate an object of interest from a background as shown in the figure below;

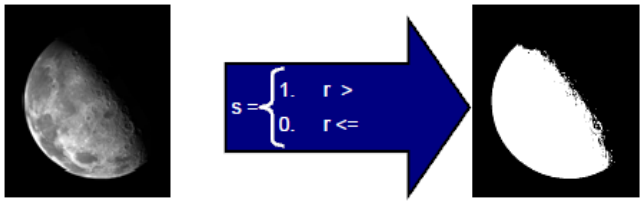

Figure 2: Threshold Method

In this method, each pixel of the input image is compared to a certain threshold value, and a Boolean value (0 or 1) is selected based on the result of the comparison.

b. Median Filtering Technique

In signal processing, it is often desirable to be able to perform some kind of noise reduction on an image or signal. The median filter is a nonlinear digital filtering technique, often used to remove noise (Yang, 2009). Such noise reduction is a typical preprocessing step to improve the results of later processing (for example, edge on an image). Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges of the images while removing noise. Median is a non-linear local filter whose output value is the middle element of a sorted array of pixel values from the filter window. Since median value is robust to outliers, the filter is used for reducing the impulse noise. Now we will describe median filtering with the help of example in which we will place some values for pixels. Example To demonstrate, using a window size of three with one entry immediately preceding and following each entry, a median filter will be applied to the following simple 1D signal: x = [2 80 6 3] So, the median filtered output signal y will be: y[1] = Median[2 2 80] = 2 y[2] = Median[2 80 6] = Median[2 6 80] = 6 y[3] = Median[80 6 3] = Median[3 6 80] = 6 y[4] = Median[6 3 3] = Median[3 3 6] = 3 i.e. y = [2 6 6 3].

In the above example, because there is no entry preceding the first value, the first value is repeated, with the last value, to handle the missing window entries at the boundaries of the signal, but there are other schemes that have different properties that might be preferred in particular circumstances. Avoid processing the boundaries, with or without cropping the signal or image boundary afterwards, fetching entries from other places in the signal. With images for example, entries from the far horizontal or vertical boundary might be selected (Kailas, 1985).

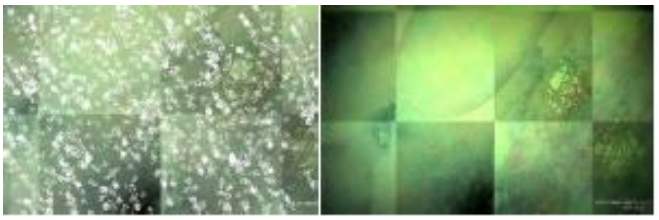

Figure 2: Median Filtering

Methodology

The Proposed Model for the enhancement of digitized paintings for crack detection and restoration using multi-dimensional median filter and threshold algorithm is presented in Figure 3;

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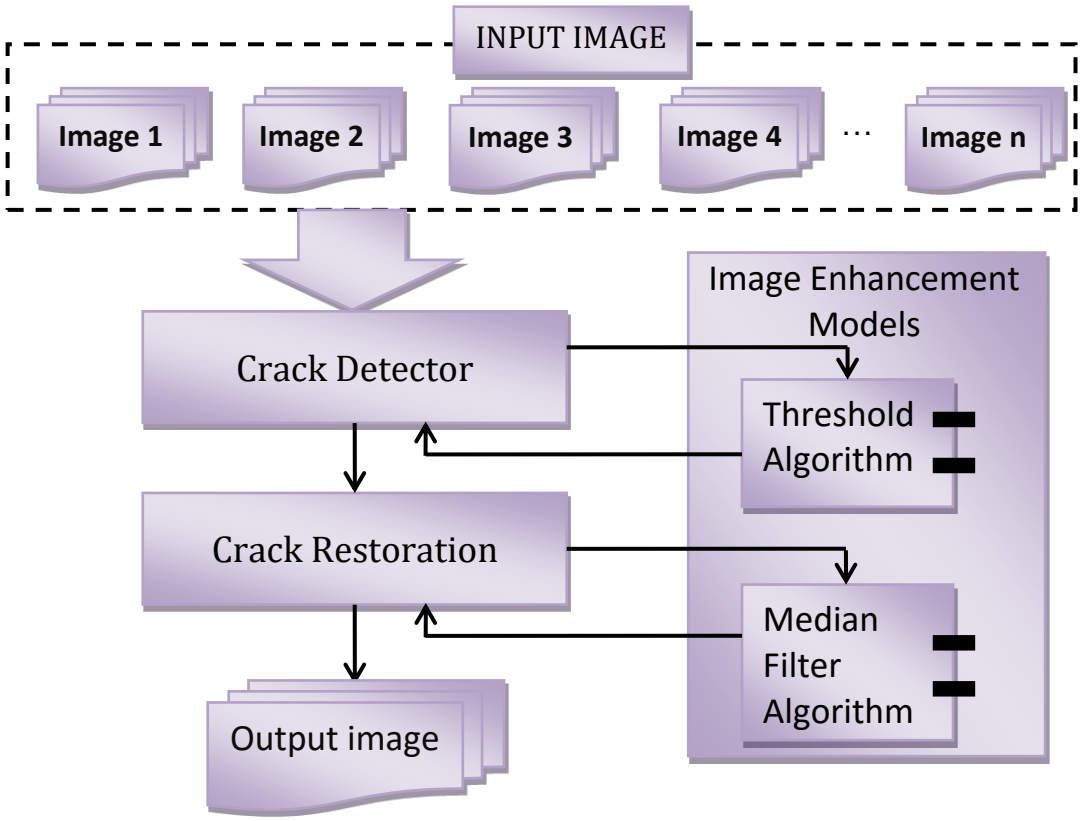

Figure 3: The System Framework

Components of System Architecture

The architecture of multi-dimensional median filter and threshold technique for image crack detection and restoration consist of the following components – Input Image, Crack Detection, Crack Restoration, Output Image, and the Image Enhancement Module (Threshold and Median filter algorithm). These components are described below;

1. **Input Image:** An input image is a PNG (portable network graphic) image file loaded from the file system to the crack detection module as input. This image file is the original cracked digital paintings.
2. **Crack Detection:** The crack detection module accepts the input image; sends the image to the threshold algorithm for processing and detection. The output of detection is sent to the crack restoration module.
3. **Crack Restoration:** This module accepts input image from the crack detection module and sends same to the multi-dimensional median filtering algorithm for crack restoration. The output of this module is a restored image.
4. **Image Enhancement Models:** This module implements the image crack detection and restoration algorithm (threshold algorithm and the multi-dimensional median filter algorithm) using the java programming language.
5. **Output Image:** The output image is the restored image that is stored in the file system using the PNG file format.

Proposed Median Filter Algorithm

The main idea of the median filter is to run through the signal entry by entry, replacing each entry with the median of neighboring entries. The pattern of neighbors is called the "window", which slides, entry by entry, over the entire signal. The window size used in this project is 3x3 since we are considering 2-dimensional median filter.

To demonstrate, using a window size of 3x3 with one entry immediately preceding and following each entry, a median filter will be applied to the following 2D signal:

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Table 1: Image Pixels

23	65	34	12	76	33
65	76	12	46	87	24
92	43	65	18	55	32
19	41	52	70	65	43
53	66	27	37	54	37
71	29	87	35	65	44

Y [1][1] = {23, 65, 34, 65, 76, 12, 92, 43, 65} = 65
Y [1][2] = {65, 34, 12, 76, 12, 46, 43, 65, 18} = 43
Y [1][3] = {34, 12, 76, 12, 46, 87, 65, 18, 55} = 46
Y [1][4] = {12, 76, 33, 46, 87, 24, 18, 55, 32} = 33

Y [2][1] = {65, 76, 12, 92, 43, 65, 19, 41, 52} = 52
Y [2][2] = {76, 12, 46, 43, 65, 18, 41, 52, 70} = 46
Y [2][3] = {12, 46, 87, 65, 18, 55, 52, 70, 65} = 55
Y [2][4] = {46, 87, 24, 18, 55, 32, 70, 65, 43} = 46

Y [3][1] = {92, 43, 65, 19, 41, 52, 53, 66, 27} = 52
Y [3][2] = {43, 65, 18, 41, 52, 70, 66, 27, 37} = 43
Y [3][3] = {65, 18, 55, 52, 70, 65, 27, 37, 54} = 54
Y [3][4] = {18, 55, 32, 70, 65, 43, 37, 54, 37} = 43

Y [4][1] = {19, 41, 52, 53, 66, 27, 71, 27, 87} = 52
Y [4][2] = {41, 52, 70, 66, 27, 37, 29, 87, 35} = 41
Y [4][3] = {52, 70, 65, 27, 37, 54, 87, 35, 65} = 54
Y [4][4] = {70, 65, 43, 37, 54, 37, 35, 65, 44} = 44

The output of the filtering is presented in Table 2;

Table 2: Output Image Pixels

23	65	34	12	76	33
65	65	43	46	33	24
92	52	46	55	46	32
19	52	43	54	43	43
53	52	41	54	44	37
71	29	87	35	65	44

Threshold Technique

This method is used to filter out signals from the image which are suspected to be noise. This model is presented mathematically as;

$$|f(A) - f(x_i)| \leq T$$

$$f(x_i) \in [T_1, T_2]$$

Where f(A) is the average pixel brightness
$f(x_i)$ is the luminance component of i-th pixel in image
T is the threshold condition
And [T1, T2] is the value range.

Data Collection

This research work employs open and free PNG digital images in testing the efficiency of the system. The images are downloaded randomly from the internet. The images used are ones affected by noise. This noise can be classified as salt and pepper noise. The digitized images used are presented in Figure 4.

Figure 4: Test Images

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Results and Discussion

The crack detector form is the main menu of this system. It implements the multi-dimensional median filter and Threshold algorithm for crack detection and restoration in digitized paintings. It provides the user with an opportunity to load an input image into the system using the "load" button at the top-left corner of the form. The loaded image is displayed in an image panel located at the bottom of the load button. Detection takes place when the user clicks on the "Detect" button beside the image panel with a specified threshold in the range of 0-255. After image detection, the "Restore" button is clicked to restore the detected image. A window size is selected for the median filter algorithm to control the quality of restored image. The crack detector form is the main output of this system and is presented in Figure 5;

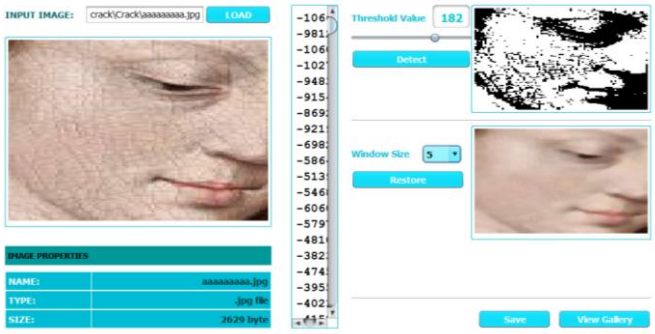

Figure 5: The Crack Detection Form

Figure 6: Crack Detection Form

The output images restored using the threshold and median filter algorithm is presented in Figure 7.

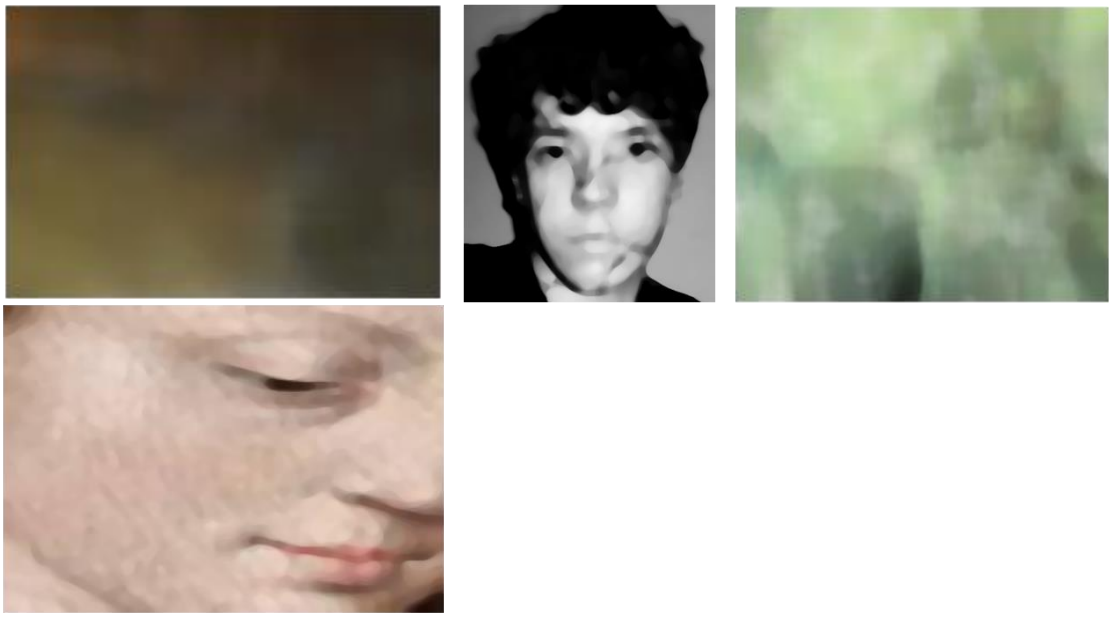

Figure 7: Restored Images

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Conclusion

In this work, a threshold and multi-dimensional median filter algorithm was proposed. The work employed four (4) random digitized paintings for system testing. The crack images collected, was used as an input to both the threshold and multi-dimensional median filter algorithm. Firstly, crack was detected by passing the test images through a threshold algorithm whose output is used by the median filter algorithm. The window size of multi-dimensional median filter algorithm was selected by the user. The higher the window size the better the smoothness of the output image. The final output of this system was presented. The system was implemented in java programming language which makes it a portable software system – it can run on any operating system with a JVM (Java Virtual Machine) installed. The results show that threshold algorithm and multi-dimensional median filter algorithm is a good combination for use in crack detection and restoration

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