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DEFECTS DETECTION ON WIND TURBINE BLADE SURFACES BY UNMANNED IMAGE ANALYSIS

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ABSTRACT
The Wind turbine blades are the source of power and the core technology of wind generators. After long periods of time or in some extreme conditions, cracks or damage can occur on the surface of the blades leads to incalculable losses. To find the wind turbine cracks from real images of blades image analysis performed to detect surface defects. The real images were recorded by using the unmanned vehicle with HD camera to detect the surface cracks on the wind turbine blades. These field images are processed by using algorithms and the image processing analytical tools were used to detect the surface cracks on the wind turbine blades. In this work Python Open CV2 software was applied to detect the surface cracks on wind turbine blades and was observed in gray color. By the studies on edge image analysis found a crack like dots and also designated the gel coat cracks. The cracks are visible at damaged surfaces and were distributed through the blade upon the time. Further internal damage of the wind turbine blades considered as one of the manufacturing defects as well mechanical damage of the structure. It basically getting crack at tailing edges. The results of edge image surface analysis revealed that the damaged inside the surface dots caused for surface deep cracks. The algorithm threshold images, gradient images and histogram analysis also revealed the hidden cracks on the blade were detected. Hence the digital image processing and algorithms are very much helpful for the detection of these cracks which will save the inestimable costs by detecting these defects at early stages.

I. INTRODUCTION

A wind turbine blade is key components for energy conversion in a wind power generation system. It is possible for cracks to occur on the blade surface because of working under poor conditions, due to long running times and fatigue damage will accumulate until the blade breaks during the operation, which leads to incalculable losses or damage. Therefore, accurate monitoring of the blade surface condition is required before crack growth is a prerequisite and is necessary for wind power generation systems [1]. Presently there are many blade structures analytical methods are available. Image processing methods are applied mainly in order to increase the quality of image processing and to detect the defects on wind turbine blade surfaces. Digital image processing is a technique that can be applied to verify of different fields such as diagnostic of image processing analysis, it is used for wind turbine blade defects detection on real images.

The digital image processing is very attractive and it gives the more information about the images (pictorial information) and other hand for human

analysis and finally deal with the image data for computer storage drive [2]. Unmanned aerial vehicles or Drones are used in order to collect the picture at various applications. This discipline of image processing is being stepped forward nowadays and extended to numerous fields of technology and engineering [2]. The drone-based approach enables low-cost and frequent inspections, high-resolution optical image acquisition, and minimal human intervention, thereby allowing predictive maintenance at lower costs [3]. The simple concept of image processing analysis is indicate to the processing of the virtual image, putting off the noise and any sort of irregularities seen in a photo using a virtual computer. The noises are in deferent way or irregular shapes may additionally creep into the image both for the duration of its formation or during transformation. For mathematical evaluation easily, the image can be described as two-dimensional function such as (x, y), which is x and y are spatial (aircraft) coordinates in practical, the amplitude of any pair of coordinates, for example (x, y) is referred to as the depth or grey degree of the photograph at that co-ordinate point. When x, y, and intensity values of discrete portions, It is very vital that virtual picture is confident of a finite quantity of factors. Here the image analysis was processed by image pre-processing, image enhancement and image fragmentation techniques.

II. MATERIAL AND METHODS

The real images were recorded by using the unmanned vehicle with HD camera to detect the [4] surface cracks on the wind turbine blades.

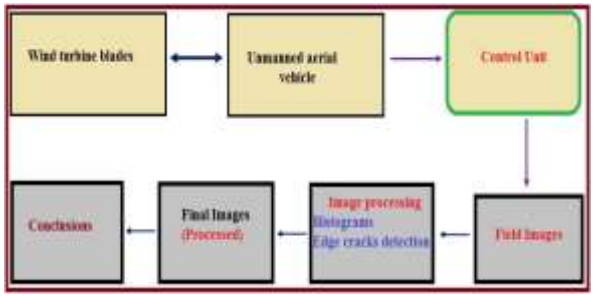

Fig. 1. Line diagram of Image processing Algorithm

These field images are processed by using algorithm; the image processing analysis methods to detect the surface cracks on the wind turbine blades were applied. In this work Python OpenCV2 software applied to detect the surface cracks on wind turbine blades and was observed in gray color. The line diagram of the work performed was given in figure 1.

The Analysis is the main part of wind turbine blades diagnostics in order to find or detect the blade cracks. No one knows when the cracks appear on the wind turbine blade surface. It is essential to avoid the failure during the wind turbine operation. For this reason, blade inspection is very important and the constant maintenance is required. Image processing and analysis were done with use of openCV software (Open source Computer Vision Library). Basically from the images the edge detection method, can find the surface cracks and edge cracks.

III. RESULTS

A. Analysis of wind turbine blades

The processing analysis was carried out by the canny edge detection and histogram methods. The edge detection algorithm and multi-stage algorithm techniques were used. To detect the intensity gradient of the photo and smooth photos also it can be filtered with the Sobal Kernel at both directions, lateral and longitudinal direction. To find the first formula at longitudinal direction (G_x) and the second one is the lateral direction (G_y).The formula is expressed as (1).

$$Edge-gradient\,(G)=\sqrt{G_x^2+G_y^2} \quad (1)$$

$$Angle(\theta)=\tan^{-1}\left(\frac{G_y}{G_x}\right) \quad (2)$$

B. Canny edge detection for analysis of the image

For Image processing analysis is methods to analyze the image properties, the work is mainly focused on edge detection algorithm technique and it is also can be used a multi-stage algorithms. Figure 2 showed that different type's points, first point A are representing an edge (in lateral direction). The gradient orientation is normal to the edge. Both the points B and C is at gradient orientation. Once inspecting point A with help of point B and point C, to find its structures a regional best (fig. 2) if it is

follow the next operation if any case it will be damage.

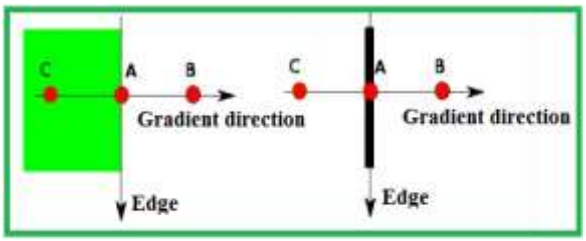

Fig. 2. Line diagram of Image processing Algorithm

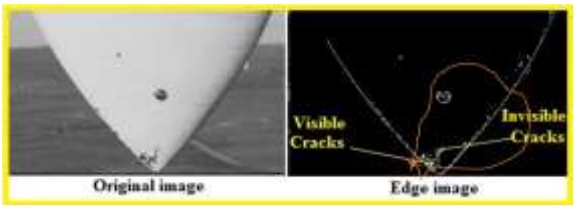

Fig. 3. Comparision of invisible Cracks are edge image after image processing analysis (Algorithm of canny edge detection in OpenCV software)

From the figure 3, image showed that visible cracks have clearly appeared, but even we can observe that how the cracks are distributed many places like dots as well edge structure also damaged. Wind turbine blade was totally damaged at the surface as seen in figure 3, after analysis results can find the internal damage of the wind turbine blades.

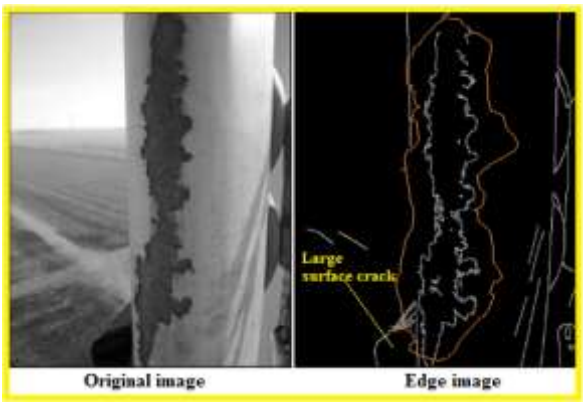

Fig. 4. Comparison of large surface crack and internal structure damaged in edge image (Algorithm of canny edge detection in OpenCV software)

This is also one of the manufacturing defects as well mechanical damage of the structure. It basically getting crack at tailing edges. Above results edge image (fig. 4), surface was totally damaged as well as we can see inside the surface dots are visible which is called surface deep cracks.

C. Histogram

Histogram is one of the most important information, which give are an overall idea about the intensity distribution of the image. It is represented as a graph or plot. For example in plot with pixel values (range from 0 to 255, but not always) in the X-axis represent the tone variation and Y-axis represents the total number of pixels in that particular tone.

1. *Algorithm of histogram in openCV software*

From above the image shows that cleared visibility of the cracks, sometime images were does have clear visibility as well as darkness and low brightness, from this point of view with the histogram image processing and analysis method, one can find the intensity distribution of the image pixel at x,y plot. The result of the images is divided into the number of pixels range from 0 to 256 at x-axis and y-axis 0 to18000 (fig.5b & d).

2. *Algorithm of equalization histogram in openCV software*

Consider an image that pixel values are confined to some specific range of the values only. For example, the bright images have pixels confined to high value. But good images have pixels from all regions of the image. Histogram Equalization is to improve the contrast of the image. The main difference between the histogram and equalized histogram is that even if an image was a darker image instead of a brighter one we used, after equalization, we will get almost the same image as we got as result (fig. 5).

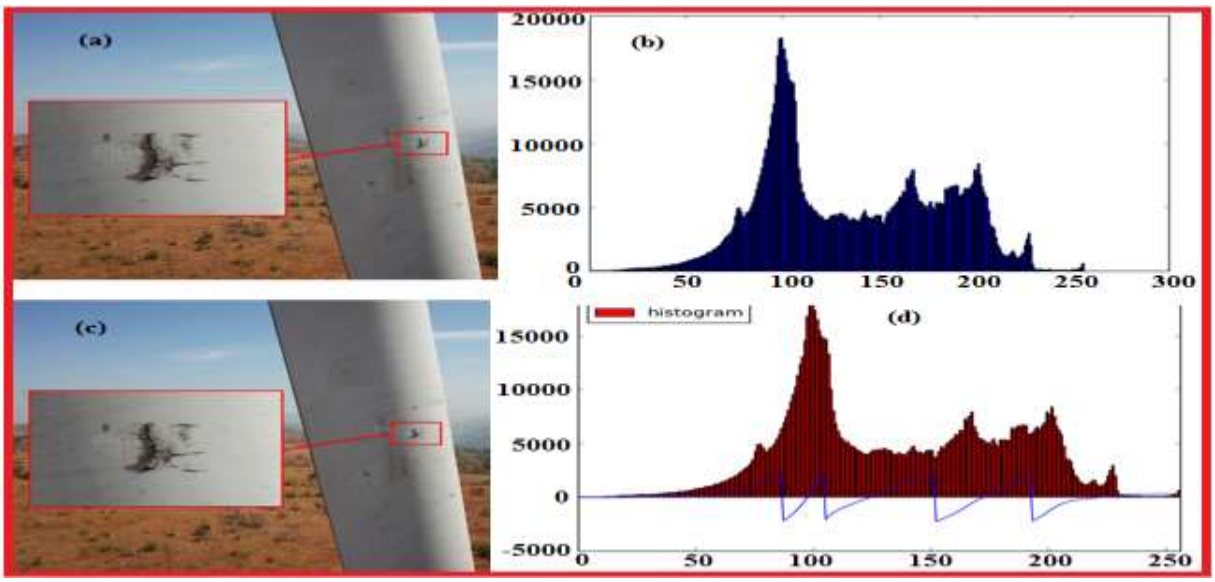

Fig. 5. Algarithmic equalization of histogram through Open CV software

D. Image Thresholding

Thresholding consists of dividing pixels into two or more classes loading on the outlet of a pixel value is the greater than a threshold value. It is assigned one value is white and the second value is blocked presented same code. The first argument is the source image. This should be grey scale. The second one is threshold value which is used to classify the pixel value. Algorithm of Thresholding of OpenCV software for wind turbine blade cracks. From the figure 6 the image was processed and analysed by threshold method, resulting of the original image which is gray scale is converted in five deferent types of images during analysis, here be find the images, first one is block image value assigned, how the images was converted in to background in block colour (image Binary). The second image also assigned white value, after same like the first one how changes background same like second image but in white (Binary_Inv). Finally results of the above images after analysis performed in openCV, observe the crack location on wind turbine blade in figure 6.

E. Smoothing Images

As for one-dimensional signals, images also can be filtered with various low-pass filters (LPF) and high pass filter (HPF),etc. image filtering process LPF is to help in removing noise and blurring the image. Another one which is HPF filter help in finding edges in an images [5]. Open CV provides a function, CV. filter2D(), to convolve a kernel with an image. Here, the average filter on an image was A 5x5 averaging filter kernel can be defined as equation (3) [5].

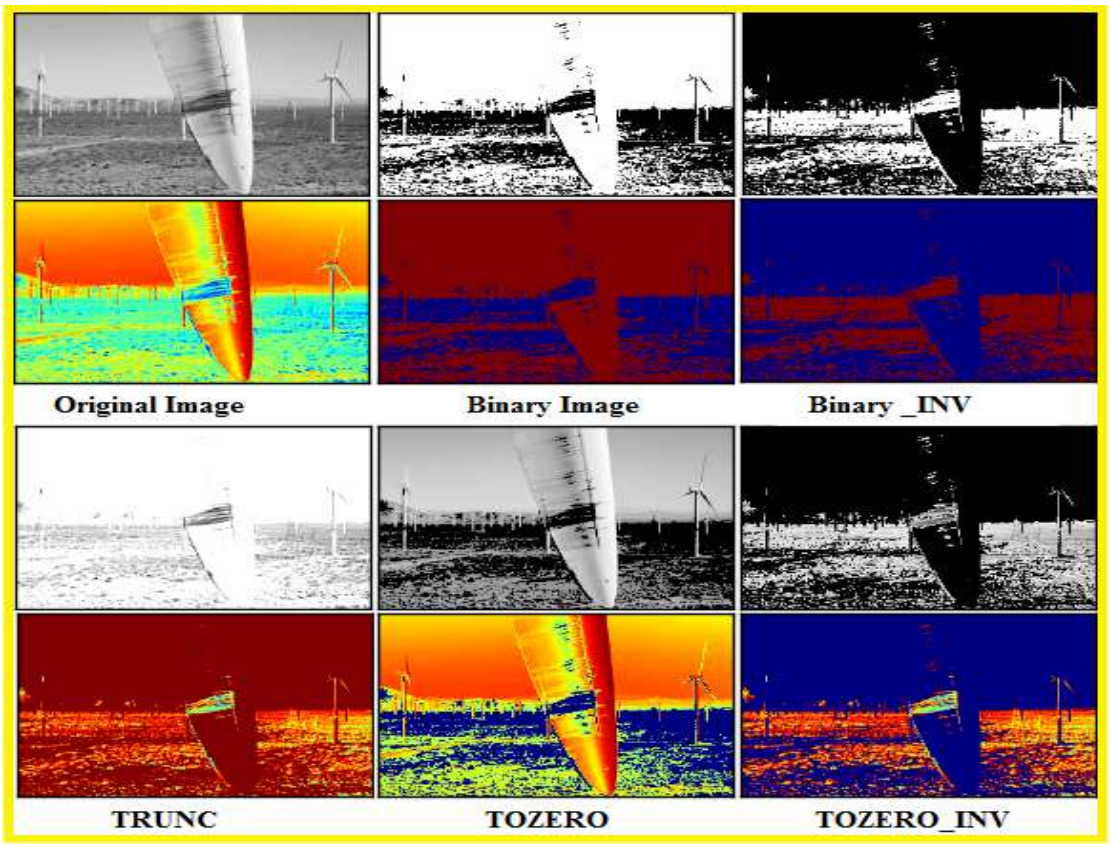

Fig. 6. Algorithm of thresholding in OpenCV software application of wind turbine blade

$$K = \frac{1}{25}\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix} \quad \text{--- (3)}$$

Filtering with the above kernel results in the following being performed, for each pixel, a 5x5 window is centred on this pixel, all pixels falling within this window are summed up and the result is then divided by 25. This equates to computing the average of the pixel values inside that window. This operation is performed for all the pixels in the image to produce the output filtered image [5].

1. Algorithm of blurred and smoothing image in OpenCV software: Blurred images (fig. 7a) also converted into original images with using openCV, this is main advantages for image analysis. The below (fig. 7a) blurred image how it will converted in to original image, which was very clear and good pixels after the image processing analysis results (fig. 7c). Even we cannot see in blurred images, but original images shows clear surface cracks on the tailing edge of the wind turbine blade. Image smoothing is also one of the techniques to justify the image quality as well clear visibility and algorithm of smoothing images shown in figure 7b. From above averaging image was not cleared, after results the original image looking clear visibility. This is an advantages application of smoothing during image processing analysis we can easily modify the image.

Fig. 7. Wind turbine blade smoothing image results

F. Image Gradients

Image gradient is a directional change in the intensity or colour in an image and gradient of the image is one of the fundamental building blocks in image processing. Sobel and Scharr Derivatives, Sobel operation is a joint Gaussian smoothing plus differentiation operation. So it is more resistant to noise. Second one is Laplacian Derivatives it calculates the laplacian of the image given by the relation. Where each derivative is found using the Sobel derivatives. If ksize=1, then following kernel used for filtering equation (4).

$$\ker nel = \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix} \quad \text{---------} \quad (4)$$

1. Algorithm of gradient image in OpenCV software: Gradient images also one of the techniques for detect the outer surface of the wind turbine blade cracks with the use of openCV image processing analysis here we can find the below algorithm. Above original image was resulting in deferent types images like as we can see laplacian, Sobel x and Soble Y, from the Sobal Y images, was showing the cracks depth and crack distribution entire the blade surface (fig. 8).

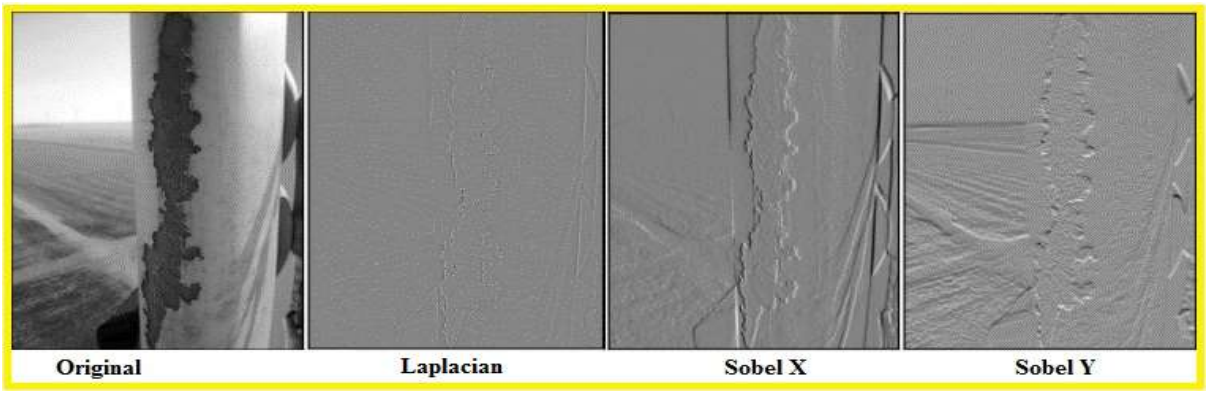

Fig. 8. Wind turbine blade Gradient image results

IV. DISCUSSION

The final image processing analysis carried out by OpenCV software. Deferent types of image process and analysis methods performed with deferent images, comparison and analysis of archived results in figure 8. As one can see above, the original image of wind turbine blade, which is the surface, was damaged due to bonding (manufacture defect). From this image, as one can find, only the outer surface of the wind turbine blade cracks (fig. 3). When we can apply Analysis in OpenCV software for Image processing analysis would show the invisible defects like edge detects or internal damage of structure. In figure 8 original image, which were we performed on the OpenCV. From figure 3 original images are showing crack at the surface of the wind turbine blade but we cannot see the inner part of the structure, where the blade was damaged. Now looking into the second image (Edge image) in that cracks are showing dates as well edges of the wind turbine blade also damaged. Edge detection method is very important in image processing analysis. Easily we can find the full details of images properties. The different types figures of wind turbine blades with cracks and images after analysis results also presented. From figure 4 original images after image processing analysis result with comparison shown below. Figure 4 images shows that visible crack but one location only, after image processing analysis, internal cracks or damage of the structure was cleared shown in edge images. Both the images are showing cracks but some hidden cracks are not visible in original images. The similar work also performed using drone as unmanned vehicle for the inspection of wind turbine blades [6].

The wind turbine blade image analysis was performed and finally comparison and results are shown in below. From the above original image shows that clear visibility of the crack, in other hand we cont find the internal damage of the blade. After resulting edge images shows that internal cracks and

crack distribution area also showing. The main advantage of image processing analysis is detecting the defects in wind turbine blade [7] surfaces. The damages were found on the turbine blades hence additional non-destructive evaluation techniques can be used to characterize the damage.

V. CONCLUSION

Digital image processing is always an interesting field and it will give pictorial information for human interpretation and processing of image data for storage. Image processing is an analyzed mainly in order to increase the quality of image processing and to detect the defects on wind turbine blade surfaces. Digital image processing is a technique that can be applied in verify of different fields such as diagnostics in order to detect the wind turbine blade defects at real images. The OpenCV software applied to the Image processing analysis, which gives pictorial information from the images. The results are supportive and understand the image information by analyze the computer vision system. However, OpenCV is given more information about the images processing analysis, Image processing methods like canny edge, histogram and threshould. This all methods are useful to detect the cracks in wind turbine blade.

By the studies on edge image analysis found a crack like dots and also designated the gel coat cracks. The cracks also visible at damaged surfaces and were distributed through the blade upon the time. Further internal damage of the wind turbine blades considered as one of the manufacturing defects as well mechanical damage of the structure. It basically getting crack at tailing edges. The results of edge image surface analysis revealed damaged as well as inside the surface dots caused for surface deep cracks. The algorithm threshold images gradient images and histogram analysis also revealed the hidden cracks on the blade was detected. Possibility of the image processing analysis is very faster when compared to non-destructive methods. Hence the digital image processing and algorithms are very much helpful for the detection of these cracks which will save the inestimable costs by detecting these defects at early stages.

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