Abstract — In car industry, both accuracy and efficiency are equally crucial at the production line to supply high demands of wiper blades in car industry. Since the current production line is mostly employed using manpower, defect detection of car wiper arm remains a huge impact in the quality control process. However, the consistency and the accuracy of identifying defects are still not up to optimum state as the current defect detection method still heavily relies on human vision. To date, the defect detection of car wipers using machine vision has not been extensively implemented in the current car wipers industry. Hence in this paper, we proposed a very first machine vision method to identify defects on car wiper arm. We implemented Gabor filter to detect different kind of defects on wiper arm, such as scratch, bump, and orange skin. The proposed automated defect detection system for car wiper arm has achieved impressive detection accuracy with 81% within a short average processing time of 3.47 seconds.

Keywords — Car Wiper Arm, Defect Detection, Edge Detection, Gabor Filter, Surface Detection

I. INTRODUCTION

Windscreen wiper is a device to wipe off rain, and impurities from a windshield or rear window of a vehicle which operated either electrically or pneumatically. Almost all motor vehicles such as cars, trucks, train and even aircraft, are equipped with windscreen wipers as it is a legal requirement for any on road vehicles. Most vehicles use either two synchronized radial type arms or pantograph arm(s) with adjustable speeds.[1]

Wiper arm defect detection is one of the crucial steps in quality control (QC) where it usually takes place in the final stage of production line before packaging. Conventionally, the inspection is performed manually by human operators using human naked eye with bare hands; where the process is time consuming, at the same time lack of accuracy or precision. Moreover, human operators might overlook the defect units. Fig. 1 shows defect such as scratches, bump, orange skin and dent that are frequently occurred on the body of the car wiper arm. To date, computer vision based defect detection from wipers has not been extensively implemented in this domain. Hence, the main contribution of this paper is to investigate the possibility of applying a suitable defect detection method thus developing an automated defect detection system to search the defects on wiper blade arms using computer vision approach.

In this work, we first obtain those images of car wiper arm using an industrial camera. Then, preprocessing will be applied to enhance the image, where image grayscale and Black Tophat Filter is used in this stage. After that, the pre-processed images of car wiper arm will be segmented using K-Means clustering, followed by defect detection process using Gabor Filter to identify the defects on car wiper arm. Lastly, Morphological Filtering and Contours is applied to extract the defects.

In this paper, previous work will be discussed in Section II, while system design will be described in Section III. In Section IV, the experimental result will be shown followed by a series of discussion with justification and lastly both conclusion and future recommendation is shown in Section V.

II. PRIOR WORK

Texture and Edge detection methods have been widely implemented for defect detection in various production line products such as fabric, tile-set, mobile phone screen glass and others. Nonetheless, to date no work has been done on wiper blade defect identification. Hence in this section, we study different texture and edge based approaches proposed to identify defect in different domains based on previous work. Texture detection is a process where the location of collection pixels in a textured image with extraordinary difference in their intensity values as compared to the background texture is determined. As for Edge detection, it is crucial as the edges of images contain meaningful features with significant information. [4]

G. M. Atiqur Rahaman et al. [5] proposed an automatic defect detection and classification technique for detecting defects on ceramic tiles using Sobel edge detection method. The average defect accuracy for all kinds of defects is at 93% which is more accurate than other methods such as novel conjoint spatial-spatial frequency representation of texture, wigner distribution and laplacian filter. In terms of computational time, the proposed method take a shorter time as compared to the existing defect detection method.
However, the proposed method fails to detect light surface defects such as glaze and scratch faults. In [6], Valavanis et al. proposed Sauvola Local Thresholding method to detect and identify discontinuities in the weld images that may be considered as false defects. However, the proposed method requires high computation time per image.

On the other hand, Jian Chuanxia et al. [7] developed an improved fuzzy c-means cluster (IFCM) to detect defects on mobile phone screen glass. The proposed approach consists of registration, defect detection and segmentation, where 94% in sensitivity and 97.33% in specificity is achieved. Furthermore, approximate 1.6601 seconds is taken using this method. However, precise parameters definition must be performed in order for the proposed system to work properly.

In [8], Yuxiang Yang et al. detected surface defects of film capacitors using computer vision approach. The vision inspection system have implemented Nonsubsampled Contourlet Transform (NSCT) based algorithm which has achieved outstanding performance over other methods in term of accuracy and processing time. The proposed vision inspection system achieved high accuracy of 98.7% which takes only 0.1 sec of processing time per capacitor.

In [9], V.Asha proposed a defect detection algorithm using machine vision to detect defects on the surface of patterned textures. The proposed algorithm has implemented both Ward’s hierarchical clustering and Canny edge detection to detect defective part and it has achieved high accuracy of 100%, 85.9% and 97.6% for average precision, recall and accuracy precision respectively. The result obtained is based on 2136 periodic blocks of various pattern texture surfaces during the testing stage. On top of that, the proposed algorithm has not gone through any training stage thus indicates that the proposed algorithm can be easily implement in the current fabric industry.

In [10], Lucia Bissi et al. performed automatic texture defect detection in uniform and structured fabrics by integrating symmetric Gabor filter bank and Principal Component Analysis (PCA). As for the performance measurement, images of the TILDA Textile Texture Database are compared against ground-truth results annotated by human operator. As a result, the proposed defect detection system outperforms the previous defect detection method, thus achieving a high accuracy of 98.8% with just 0.20% to 0.37% of false alarm rate and misaccuracy of 5% for heavily structured yarns.

In [3], a pavement crack detection method was developed by M. Salman et al. using the Gabor filter. As compared with Local Binary Pattern technique, Bi-Directional Empirical Mode Decomposition (BEMD) and Forward Differential Wavelet transform, Gabor filter is proven to be a better approach to detect pavement crack in different direction, where the results of 95% cracks accuracy is obtained using this approach.

In [11], with the primary goal of developing an automated fabric defect detection and classification system, Junfeng Jing, et al. has proposed to implement Gabor Filter for defect detection and both LBP and Tamura method for defect classification. Gabor filter is implemented to detect the defective part and segmentation has been performed to extract defects from original image for the following classification process. With the implementation of Gabor Filter, the proposed fabric defect detection has achieved detection accuracy of 98.5% with 45 of both defect free and defective images dataset.

There are many methods that can be used for defect detection by using texture and edge detection on various products. As comparison from all the methods in prior works, Gabor filter provides the highest average accuracy in defect detection. Hence, we employed Gabor filter to detect defects from wiper arm as our main contribution in this paper.

III. SYSTEM DESIGN

In this work, we proposed Gabor filter to identify defects on the wiper arms. A basic flow chart is constructed as shown in Fig. 2 to illustrate our proposed approach. The process starts with the image acquisition where the car wiper arm images are captured and go through the pre-processing stage as well as segmentation before defect detection. During the defect detection process, the proposed system will check if the defect exists. If there is any defect detected, defect extraction process will be performed on defective car wiper arm. Otherwise, wiper arms without defect will not be inspected.

Fig. 2 Basic Flow Chart of Car Wiper Arm Defect Detection System

A. Image Acquisition

Images of both good and defected car wiper arm are captured under a similar background and fixed angle. As for the light source, the first setup is using fluorescent light while the second setup is using the CCS Camera-Window type LED Flat Light. Therefore, 2 dataset of car wiper arm
images are produced and compared in the discussion section.

B. Image Pre-Processing

Before defect detection, some pre-processing process is applied to enhance the images so that the defects can clearly be identified with minimum false positive rate. In this work, image is converted to grayscale and Black Tophat Filter is applied on the captured car wiper arm images.

The original car wiper arm images are first converted into grayscale image before it can proceed with the defect detection process. Then, Black Tophat filtering is applied to eliminate the nonuniform lighting condition caused by external light source. Black Tophat filtering can be defined by the equation (1):

$$T_b(f) = f \cdot b - f$$

where $f$ is the original image and $b$ is the closing operation which is shown in equation (2):

$$A \circ B = (A \oplus B) \ominus B$$

where $\oplus$ represent the dilation process and $\ominus$ represent the erosion process. Therefore, nonuniform lighting condition on the car wiper arm images can be solved.

C. Segmentation

K-Means is one of the unsupervised method used for segmentation of interest area from the background which developed by MacQueen in 1967. [12] In this paper, we use K-Means to segment the wiper arm from background of captured images since it have high contrast in between them. Thus, K-Means clustering is able to clearly identify the foreground and background of an image with minimal false positive.

After preprocessing, the enhanced image will go through image segmentation before detecting defects. Image segmentation is done by applying K-Means clustering on the grayscale image where the foreground and background of the car wiper arm images are separated. K-Means Clustering can be defined as equation (3):

$$J = \sum_{j=1}^{k} \sum_{i=1}^{m} ||x_i^{(j)} - C_j||^2$$

where $||x_i^{(j)} - C_j||^2$ is the chosen distance to be measured in between a data point $x_i^{(j)}$ and the cluster centre $C_j$, indicates the distance of the n data points from their respective cluster centres and can be represented in equation (4):

$$C_j = \frac{\sum_{i=1}^{N} x_i^{(j)} y_i}{N}$$

By segmenting the foreground and background of car wiper arm images, the defect detection process can focus on the car wiper arm, ignoring the unwanted noises and particles at the background.

D. Defect Detection

After going through the segmentation process, car wiper arm images are now ready for the defect detection. If there is defects on the filtered image, the filtered image will proceed with the defect extraction. If there is no defect, the car wiper arm is considered as good unit.

Gabor Filter is proven to perform good detection in different domains. Application such as textures analysis, edges detection, object recognition, illustration of images and segmentation has been commonly using Gabor filter as the filtering method. By having multiple kernels as shown in Fig. 3, images can be decomposed into components corresponding to different scales and orientations through the implementation of Gabor filter. [3]

![Various Gabor Wavelet](image)

Through the application of Gabor filter in the defect detection process, multidirectional defects on the car wiper arm can be identified with various Gabor kernel parameters. Gabor Filter consists of both real and imaginary part which can be defined by the following equations:

**Real Part,**

$$g_r(x, y) = \frac{1}{2\pi \sigma_x \sigma_y} e^{-\frac{1}{2} \left[ \left(\frac{x}{\sigma_x}\right)^2 + \left(\frac{y}{\sigma_y}\right)^2 \right]} \left\{ \cos \left[ 2\pi \omega_0 \left( x \cos \theta + y \sin \theta \right) + \psi \right] \right\}$$

**Imaginary Part,**

$$g_i(x, y) = \frac{1}{2\pi \sigma_x \sigma_y} e^{-\frac{1}{2} \left[ \left(\frac{x}{\sigma_x}\right)^2 + \left(\frac{y}{\sigma_y}\right)^2 \right]} \left\{ \sin \left[ 2\pi \omega_0 \left( x \cos \theta + y \sin \theta \right) + \psi \right] \right\}$$

And can be jointly written as

$$g(x, y) = \frac{Y}{2\pi \sigma} e^{-\frac{1}{2} \left( \frac{x'}{\sigma} \right)^2} e^{j \left( \frac{2\pi \gamma'}{\lambda} \right)}$$

where $x' = x \cos \theta + y \sin \theta$ and $\gamma' = -x \sin \theta + y \cos \theta$, $\sigma_x$ and $\sigma_y$ are the scale factors of neighbourhood, $\gamma'$ as the ellipticity of the Gabor Filter and $\lambda$ as the wavelength of the sinusoidal factor.

Defects such as bumps, scratches, orange skin and dents can be identified through the capability of Gabor filter in generating multidirectional kernel to locate the defects part while filtering out the body of car wiper arm. Examples of
multiple kernels applied on the same car wiper arm image are illustrated in Table I.

**TABLE I. RESULT OBTAINED WITH MULTIPLE GABOR KERNELS**

<table>
<thead>
<tr>
<th>Gabor Kernel</th>
<th>Filtered Images</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Gabor Kernel 1" /></td>
<td><img src="image2.png" alt="Filtered Images 1" /></td>
</tr>
<tr>
<td><img src="image3.png" alt="Gabor Kernel 2" /></td>
<td><img src="image4.png" alt="Filtered Images 2" /></td>
</tr>
<tr>
<td><img src="image5.png" alt="Gabor Kernel 3" /></td>
<td><img src="image6.png" alt="Filtered Images 3" /></td>
</tr>
</tbody>
</table>

**E. Defect Extraction**

If defects are detected on car wiper arm, the defects will be extracted and masked into the original image as final result. To extract the defect from the filtered image, morphological operation is applied. Morphological closing operation which is the combination of both erosion and dilation process can be defined by equation (8):

\[ f \ast s = (f + s_{rot}) - s_{rot} \]  

(8)

where \( f \) is an image of the regions and \( s \) is the structuring element. In this proposed defect detection system, morphological closing is used to close the small gaps and remove unwanted noises within the defective area, thus making the defect part to be more visible.

After the morphological filtering process, there will only be the defective part left on the filtered images. Then, contours is drawn around the defects on the original images. Based on the drawn contours, similar contours is masked back on the original car wiper arm images and the defects will be extracted from the original car wiper arm images as shown in Fig. 4.

**IV. EXPERIMENTAL RESULT**

During the simulation of proposed defect detection system, several parameters has been set empirically to obtain optimal result. For K-Means clustering processing, the centroid (segmentation layer) is set to 2 so that only foreground and background of the car wiper arm images is being clustered. As for the Gabor Filter’s parameter such as kernel size is set to be (21, 21), \( \lambda \) and \( \gamma \) is set to 7.5 and 0.5 respectively because these parameters give the optimal results.

Along the system development, different type of environment is tested for the image acquisition process in order to find the optimum environment for the car wiper arm defect detection process.

**TABLE II. RESULT OBTAINED WITH DATASET 1 IMAGES**

<table>
<thead>
<tr>
<th>Types of Defects</th>
<th>Defects on Car Wiper Arm</th>
<th>Extracted Defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Defects</td>
<td><img src="image7.png" alt="No Defects" /></td>
<td><img src="image8.png" alt="Extracted Defects" /></td>
</tr>
<tr>
<td>Bump</td>
<td><img src="image9.png" alt="Bump" /></td>
<td><img src="image10.png" alt="Extracted Defects" /></td>
</tr>
<tr>
<td>Scratches</td>
<td><img src="image11.png" alt="Scratches" /></td>
<td><img src="image12.png" alt="Extracted Defects" /></td>
</tr>
<tr>
<td>Orange Skin</td>
<td><img src="image13.png" alt="Orange Skin" /></td>
<td><img src="image14.png" alt="Extracted Defects" /></td>
</tr>
<tr>
<td>Dent</td>
<td><img src="image15.png" alt="Dent" /></td>
<td><img src="image16.png" alt="Extracted Defects" /></td>
</tr>
</tbody>
</table>
TABLE III. RESULT OBTAINED WITH DATASET 2 IMAGES

<table>
<thead>
<tr>
<th>Types of Defects</th>
<th>Defects on Car Wiper Arm</th>
<th>Extracted Defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Defects</td>
<td><img src="image1" alt="No Defect" /></td>
<td>No Defect</td>
</tr>
<tr>
<td>Bump</td>
<td><img src="image2" alt="Bump" /></td>
<td><img src="image3" alt="Bump" /></td>
</tr>
<tr>
<td>Scratches</td>
<td><img src="image4" alt="Scratches" /></td>
<td><img src="image5" alt="Scratches" /></td>
</tr>
<tr>
<td>Orange Skin</td>
<td><img src="image6" alt="Orange Skin" /></td>
<td><img src="image7" alt="Orange Skin" /></td>
</tr>
<tr>
<td>Dent</td>
<td><img src="image8" alt="Dent" /></td>
<td><img src="image9" alt="Dent" /></td>
</tr>
</tbody>
</table>

The proposed defect detection system is evaluated based on the accuracy as well as the average processing time. Since two different setups are used during the image acquisition process, evaluation has been made based on 2 set of car wiper arm images, where the first set is the images captured with setup 1 (dataset 1) while the second set of images is captured with setup 2 (dataset 2). As comparison, images shown in both Table II and III has significant difference as both dataset is taken using different setup which varies in term of lighting as well as camera model.

A. System Accuracy

As for the first system evaluation which is based on the accuracy, the accuracy of the proposed car wiper arm defect detection system is calculated in term of percentage (%) based on the number of correctly detected sample by the system. The system accuracy is evaluate in term of True Positive (TP), True Negative (TN), False Positive (FP) and False Negative (FN) rules and the equation for calculating the accuracy is shown in equation (9).

\[
\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \tag{9}
\]

TABLE IV. SYSTEM ACCURACY BASED ON DATASET 1

<table>
<thead>
<tr>
<th>Types of Defect</th>
<th>Number of Samples</th>
<th>TP</th>
<th>TN</th>
<th>FP</th>
<th>FN</th>
<th>Number of correctly detected sample</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Defect</td>
<td>5</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>80</td>
</tr>
<tr>
<td>Bump</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>80</td>
</tr>
<tr>
<td>Scratches</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>Orange Skin</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Dent</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>60</td>
</tr>
</tbody>
</table>

Average Accuracy (%) = 56

Based on Table IV, the average accuracy of the proposed car wiper defect detection system based on images from dataset 1 is 56%. The accuracy is based on the 10 TP and 10 FN from 20 defective car wiper arm as well as 4 TN and 1 FP from 5 good car wiper arm. Among the types of defect, car wiper arm with orange skin defect are the hardest defect to be detected as the accuracy is only 20% which is the lowest accuracy among the other types of defect. The low accuracy with orange skin defects is due to the less significant defects feature detected by the proposed method.

B. System Processing Time

Since the proposed car wiper arm defect detection system has to meet the optimum detection time which is less than 10 sec, a simple time recording algorithm is added into the final python code to calculate the average processing time.

TABLE V. SYSTEM ACCURACY BASED ON DATASET 2

<table>
<thead>
<tr>
<th>Types of Defect</th>
<th>Number of Samples</th>
<th>TP</th>
<th>TN</th>
<th>FP</th>
<th>FN</th>
<th>Number of correctly detected sample</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Defect</td>
<td>20</td>
<td>0</td>
<td>18</td>
<td>2</td>
<td>0</td>
<td>18</td>
<td>90</td>
</tr>
<tr>
<td>Bump</td>
<td>20</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>19</td>
<td>95</td>
</tr>
<tr>
<td>Scratches</td>
<td>20</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>18</td>
<td>90</td>
</tr>
<tr>
<td>Orange Skin</td>
<td>20</td>
<td>9</td>
<td>0</td>
<td>11</td>
<td>9</td>
<td>9</td>
<td>45</td>
</tr>
<tr>
<td>Dent</td>
<td>20</td>
<td>17</td>
<td>0</td>
<td>3</td>
<td>17</td>
<td>17</td>
<td>85</td>
</tr>
</tbody>
</table>

Average Accuracy (%) = 81

Based on Table V, the average accuracy of the proposed car wiper defect detection system based on images from Dataset 2 is 81%. The accuracy is based on the 63 TP and 17 FN from 80 defective car wiper arm as well as 18 TN and 2 FP from 20 good car wiper arm. Among the types of defect, car wiper arm with orange skin defect remains to be the hardest defect to be detected as the accuracy is only 45% which is also remain as the lowest accuracy among the other types of defect due to the less significant defect feature detected. Also, the comparison of our proposed approach to the other state-of-the-art methods is not available, since the studies of defect detection from the wiper arm are still in lacking.
for the system to detect a defects from taken images. The experiment were run on a computer with Intel Core i7-8850H processor running on 2.6 GHz using 16GB of RAM with Window 10 as the operating system.

As for processing time, the proposed car wiper arm defect detection system requires less time to process dataset 2 (3.47sec) as compared to dataset 1 (6.21sec). This is due to the different in image file format as dataset 1 is saved as JPEG images while dataset 2 is saved as BMP images. Despite BMP images having a larger file size as compared to JPEG images, BMP images allows system to perform image processing directly on the data without decoding it thus taking lesser processing time for every defects.

C. Discussion

![Image](https://example.com/image.png)

**Fig. 5 Comparison in term of Accuracy between Dataset 1 & 2**

**TABLE VII. SYSTEM PERFORMANCE VALIDATION**

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Total Samples</th>
<th>Correctly Detected Samples</th>
<th>Accuracy</th>
<th>Processing Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25</td>
<td>14</td>
<td>56%</td>
<td>6.21 sec</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>81</td>
<td>81%</td>
<td>3.47 sec</td>
</tr>
</tbody>
</table>

In short, the proposed car wiper arm defect system perform better with dataset 2 in term of high accuracy as well as short processing time. With 81% of accuracy and average processing time of only 3.47 seconds, images captured with setup 2 are the optimum setup for the proposed car wiper arm defect detection system. Despite having the different image file types, the significant difference between two setups is the uniformity of light on the car wiper arm images. Images from dataset 2 has a better light uniformity as compared to images from dataset 1 thus improving the system accuracy by considering the important of uniform lightning setup for precise defect detection.

V. CONCLUSION & RECOMMENDATIONS

In this paper, the primary goal of this project to develop an automated defect detection system for car wiper arm production line has been achieved. The proposed car wiper arm defect detection system is able to identify defects in a short period of time which is 3.47 seconds which is significantly faster as compared to current manual defect detection process with 10 seconds of detection rate per car wiper arm on the production line. With accuracy of 81%, defects such as scratches, bump, dents and orange skin on car wiper arm can be detected by the proposed defect detection system. Therefore, the proposed car wiper arm defect detection system is able to identify the defects based on the images of car wiper arm captured by extracting relevant features at instance for the system to decide if the unit is acceptable.

Nevertheless, there is still improvement space for this developed system in term of accuracy. Further research work still can be done to improve the overall accuracy of the proposed method. For instance, the accuracy of the proposed car wiper arm defect detection system can be further improved by increasing the amount of images in each dataset. Besides, classification on the defects can be implemented using machine learning techniques to provide better performance for user authentication.

ACKNOWLEDGMENT

The author would like to thank Nippon Wiper Blade (M) Sdn. Bhd. for the financial assistance and data in this project, in particular Mr. Loh Shin Khong provided many useful discussion as well as suggestion.

REFERENCES


