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Design of Burr Detection System for Inside the Shaft Holes Using Computer Vision

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Abstract. The automotive sector aims to reduce the production of scraps or burrs, which requires the adoption of a deburring procedure and the utilization of inspection techniques. The existing inspection procedures involve the use of visual examination techniques. Nevertheless, as a result of the substantial quantity of components that necessitate examination and the small dimensions of the hole. Inspectors get weariness after prolonged periods of work. It commits errors with such ease. This study aims to investigate and develop a system for the inspection of burrs in shaft holes resulting from drilling operations. A system was designed to support the workpiece for examination holes of two different diameters-5 millimeters and 3 millimeters. The process of inspection sequentially examines each hole individually after the workpiece is positioned within the fixture. The image will be captured by the system via web camera, subsequently imported into the image analysis procedure via the blob analysis method, and finally converted to binary format. In the case of a defective hole, including the burr, a clean hole image will display a larger pixel on the bright or white side compared to the white side pixels. The confusion matrix was utilized for the purpose of evaluating accuracy. The 320 x 240 resolution with F-Score of 0.933 was selected for the system due to its efficient processing speed (18.6 seconds), lack of false positives, and capacity to optimize storage space.

Keywords. Vision inspection, image processing, defect detection, drilled hole

1. Introduction

Automotive parts industries currently need high precision in manufacturing processes. The burr in the drilled hole is one of the serious problems in manufacturing, which may affect the precision assembly process. Therefore, a burr inspection must be required for the quality assurance of the product.

During the drilling operation on the automotive parts shaft in a company, the CNC machine effectively drilled four holes. Two of these holes had a diameter of 5mm, while the other two had a diameter of 3mm. The deburring process was established by manually utilizing an electric drill, which was subsequently followed by an inspection. The current inspection approach entails employing human visual inspection to detect any burrs or debris that may be present in the hole. If debris was found and then brought back for more deburring. However, the process of human visualization is both time-consuming and prone to mistakes. Due to the high volume of production and the rigorous 100%

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inspection process, the inspector often becomes fatigued and makes erroneous inspections, resulting in customer complaints, product returns, and company problems. Thus, in order to prevent this issue, the inspector tends to do inspections with increasing the amount of time which causes the increasing lead time in production process.

In order to enhance the efficiency and precision of the company's burr inspection process, numerous previous studies have employed various modern technologies, including vision systems [1]. The utilization of vision systems and image processing is currently widespread in inspection systems. A real-time image processing technique was utilized to detect the burr of grooves on a mechanical component. In addition, a more improved edge detection method was employed to accurately identify the position, size, and characteristics of the burr, while also achieving both high speed and accuracy [2]. Image processing is effectively used to classify the sorts of burrs on the edge shape of microscopic scale machined parts. This work [3] introduced a novel approach named RUSTICO, which demonstrates exceptional resistance to both noise and texture. The defect inspection procedure utilized real-time computer vision with the aid of the OpenCV function and a Raspberry Pi4 board. This allowed for effective detection and recognition of the location of the defect in part [4].

The significance of a vision system extends beyond just software and algorithms for image processing. It also includes essential hardware components, such as the light source that controls the image's environment and the camera that affects image quality [5]. The vision system typically incurs high expenses due to the requirement for precision hardware. However, the low-resolution camera is equally suitable for tasks that need limited precision. For example, an autonomous system that utilizes Python and the OpenCV package is used to do drill hole inspection on carbon fiber composite panels [6]. This system utilizes a low-resolution webcam to figure out the position and orientation of the panels relative to the motion platform. The inspection procedure utilized a high-resolution camera attached to the end effector of a cartesian robot to capture photographs. In addition, the Raspberry Camera was used for burr inspection in a hole, together with the OpenCV library for image processing [7]. The vision hardware used was low-cost. The findings demonstrate rapid processing speed and exceptional precision.

This study aims to utilize the reliable and highly accurate computer vision technique for burr detection to identify burrs in small, drilled holes in automotive parts. To reduce costs, the computer vision system will use a single low-cost webcam, and an automatic fixture for part movement during inspection.

2. Method and materials

The deburring process of the holes is needed after the drilling process to ensure that the insides of the holes are clear and clean. Figure 1 displays the shaft holes required to detect the burr inside after deburring using the computer vision system. The burr detection method must inspect both the 5mm and 3mm diameter holes on the shaft.

This study designed a fixture to support the shaft and locate the holes in the camera's focus. Moreover, the fixture's base can rotate 90 degrees and move up and down to adjust the holes' position during capture. (Figure 2.)

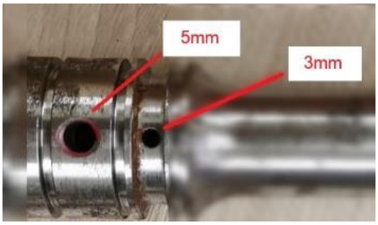


Figure 1. The two sizes of shaft holes.

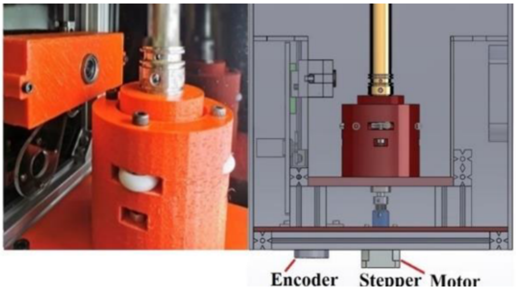


Figure 2. The fixture for supporting and locating the shaft.

2.1. Experimental setup

A 1920x1080-pixel webcam is selected for image capture at 30 frames per second. The experiment uses LED backlight to control the illumination intensity of the environment to 800–1600 lux (Figure 3(A)). The image was captured by the camera with LED blacklight, as shown in Figure 3(B).

(A) 

(B) 

Figure 3. (A) Image acquisition device, (B) Image from the device.

2.2. Image processing

The image processing flow for the burr detection system is shown in Figure (4). The images are captured using a webcam in RGB format with 24 bits per pixel, and subsequently transformed into grayscale images. The processing process uses the Blob analysis to examine the pixels that are expected to be the same object, frame them around, calculate the area in the squares, and display the square frame as illustrated in Figure 5 (A) & (B).

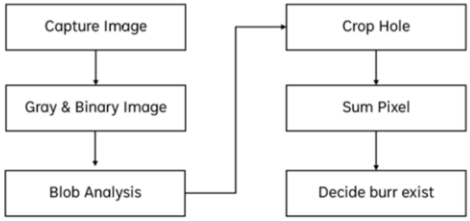


Figure 4. Image processing flow for the burr inspection system.

Based on the size of the holes, the exact area of the hole is estimated, and for the sake of certainty, the area and arrangement of the 3mm and 5mm holes are tested, as are the other workpieces, until the space between the two holes has been estimated.

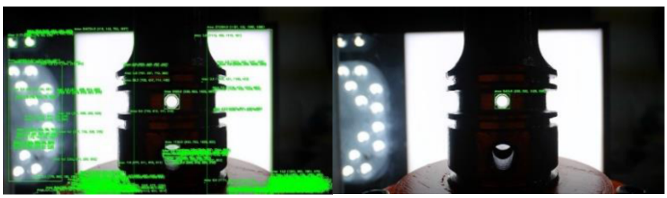


Figure 5. The Area size and scatter of a square frame.

After that, the crop is used for cutting the image to retain only the point of interest and converting the gray scale image (Figure 6 (A)), into a binary image (Figure 6 (B)), or 1 and 0 pixels.

(A)  (B) 

Figure 6. (A) Gray scale image, (B) Binary image.

The calculation of the pixels of the holes is based on the positive value of the binary image in the previous step. The result found that a clear hole, free of burrs, contains more pixels than a defect. Figure 7 (A) shows the total pixels of a clear hole is equal to 1,178,610 pixels, and Figure 7 (B) shows 1,164,840 pixels of a defective hole in the original size of 1,280x960 images.

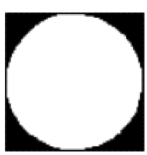
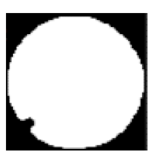
(A)  (B) 

Figure 7. (A) Clear hole. (B) defective hole.

3. Experimental and results

In the experiment, the image is cut to the remaining area of the hole and transformed into a binary image. The 3 mm 40 holes, and the 5 mm 40 holes were collected in the resolution of 1280x960, 640x480, and 320x240. The detecting system will use the maximum pixels of a defective hole at each resolution as the criterion number to detect burr. Table 1 shows the results of maximum pixels at each resolution.

Table 1. The maximum pixels of a defective hole at various resolutions.

Image resolution	Maximum pixels of a defective hole	
	3mm in diameter	5mm in diameter
1280x960	1164840	2786840
640x480	295800	720120
320x240	73956	222511

3.1. Burr detecting

The maximum pixels of the binary picture are used as the threshold value to distinguish between burr and non-burr holes. The confusion matrix depicted in Figure 8 was utilized to assess the model's accuracy in avoiding a False Positive (FP) result the model accuracy will be calculated from equation (1).

$$Accuracy=\frac{TP+TN}{TP+FP+FN+TN} \tag{1}$$

Where, TP is "True Positive", TN is "True Negative", FP is "False Positive" and TN is "True Negative".

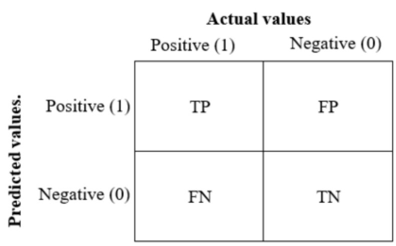


Figure 8. Confusion Matrix table.

Equation (2) provides the equation for the precision of the efficiency of True Positive prediction.

$$Precision=\frac{TP}{TP+FP} \tag{2}$$

The recall equation (3) is utilized to evaluate the efficacy of True Positive detection.

$$Recall=\frac{TP}{TP+FN} \tag{3}$$

F1-score (equation (4)) is the harmonics mean average of precision and recall for measuring the ability of the model.

$$F1 = \frac{2xPrecision\ x\ Recall}{Precision + Recall} \quad (4)$$

The experiment results presented in Table 2 demonstrate the calculation of the F-Score, which is an average derived from Precision and Recall. The F-Score was computed at three different resolutions: 1280x960, 640x480, and 320x240. The total accuracy of the shaft hole examination was determined to have F-Scores of 0.972, 0.931, and 0.933, respectively.

Table 2. The confusion matrix and evaluation at various resolutions.

Resolution	TP	FN	FP	TN	Accuracy	Precision	Recall	F1-Score
320x240	35	5	0	0	0.875	1	0.875	0.933
640x480	34	5	0	1	0.875	1	0.871	0.931
1280x960	36	2	0	2	0.950	1	0.947	0.972

3.2. Processing time

Table 3 shows the operation time for inspecting eight holes on a shaft at resolutions of 640x480, 320x240, and 1280x960. The time includes all the consecutive activities performed throughout the inspection procedure, starting from the initial inspection of the hole, encompassing both the rotation to other holes and the rise of the fixture. At resolutions of 1280x960, 640x480, and 320x240, the total time taken is 45.0 seconds, 29.0 seconds, and 18.6 seconds, respectively.

Table 3. Inspection operation time per 8 holes.

Resolution	Time/Hole (Sec)	8 Hole (Sec)	Rotation time /hole (Sec)	Rotation time for 8 holes (Sec)	Fixture moving time (Sec)	Total time (Sec)
320x240	0.7	5.6	1.5	12	1	18.6
640x480	2	16	1.5	12	1	29.0
1280x960	4	32	1.5	12	1	45.0

4. Conclusions

The development of a fixture to support workpieces and conduct hole-by-hole inspections by the 3mm and 5mm hole monitoring system, which was inspired by experiments with burr detection systems, can reduce the workload of employees associated with visual inspection. Good work is achieved when all holes are inspected without the presence of burrs. The inspection time for all holes of a shaft does not exceed 45 seconds. The experiment aims to assess the accuracy of the inspection model through F-Score analysis. The results indicate that the F-Score for (Resolution) 1280x960 is 0.972, which is the total operation time equal to 45.0 seconds. In contrast, the F-Score for (Resolution) 640x480 is equal to 0.931, as the total time is 29.0 seconds. Additionally, the 320x240 resolution has an F-Score of 0.933 which is total time equal to 18.6 seconds.

This study chose the 320 x 240 resolution for the system because of its short processing time, absence of False Positives, and ability to conserve storage space.

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