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MACHINE VISION APPLICATION IN MANUFACTURING: INSPECTION OF DIMENSIONS

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ABSTRACT :
Computers have been used for numerous applications involving the automatic or semiautomatic recognition of patterns in image. Advanced manufacturing system requires automated inspection and test method to increase production and yield best quality of product. Methods are available today is machine vision. Machine vision systems are widely used today in the manufacturing industry for inspection and sorting application. The objective of this paper is to apply machine vision technology for measuring geometric dimension of an automotive part. Vision system usually requires reprogramming or parameterization of software when it has to be configured for a part or product. A web camera used to capture an image of an automotive part that has been chosen. In the machine vision, Matlab software is used to develop an algorithm to measure a geometric dimension of the part. The measurement system has been calibrated using gauge block. This work considers the factor influencing parameters on accuracy and precision of calibration as the pixels were used to perform the unit of measurement. This measurement has been performed by the conversion through the equation of the image processing. Formulation of the calibration is important from unit in pixel to mm taking into account the perfective effect of the camera view. Finally the measurement system has been tested for accuracy and precision.
Keywords: machine vision, measuring geometric dimension, Matlab software, standard deviation, accuracy, precision

تطبيق الة الرؤية في التصنيع : فحص الابعاد

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الخلاصة :-

استخدمت أجهزة الكمبيوتر للعديد من التطبيقات التي تنطوي على التميز التلقائي أو شبه التلقائي أنماط في الصورة.التصنيع المتقدم يتطلب نظام فحص الآلي وطريقة الاختبار لزيادة الانتاج وتحسين نوعية من المنتجات . الأسلوب المتوفر اليوم هو الة الرؤية .تستخدم أنظمة رؤية على نطاق واسع اليوم في الصناعة التحويلية للتفتيش وتطبيق الفرز .في هذه الدراسة هو تطبيق تكنولوجيا آلة الرؤية لقياس البعد الهندسي للجزء السيارات .نظام الة الرؤية عادة يتطلب بناء و برمجة او تطوير بعض من البرنامج عندما يتطلب تكوين لجزء أو المنتج .كاميرا الويب تستخدم لالتقاط صورة لجزء السيارات الذي تم اختياره .في برنامج ماتلاب و الة الرؤية ، يتم تطوير خوارزمية لقياس البعد الهندسي للجزء .تم معايرة نظام القياس باستخدام جزء قياسي .ويعتبر هذا العمل من العوامل التي تؤثرعلى دقة المعلومات ودقة المعايرة وحدة القياس بكسل مع المليمتر التي استخدمت لأداء وحدة القياس .وقد تم تنفيذ هذا القياس بعد الخضوع المعادلة على معالجة الصور .صياغة معايرة مهمة من وحدة في بكسل إلى ملم مع الأخذ في الاعتبار تأثير متحسن من وجهة نظر الكاميرا .وأخيرا نظام القياس تم اختبارها للتأكد من دقتها ودقة .

Introduction :

Machine vision uses sensors (cameras), processing hardware and software algorithms to automate complex or mundane visual inspection tasks and precisely guide handling equipment during product assembly. Applications include positioning, identification, verification, measurement, and flaw detection. Sathiyamoorthy S. (2014) has discussed in his paper the measurement dimension of product parts using image processing, as well checking of presence and absence of finished. Huijie et. al. (2015) have studied the detecting part shape of objects to define the original object using computer vision technology. Chen and Wang, (2008) have developed vision system. They designed mathematical algorithms for several image process algorithms. In the process, the inspection algorithm is based on the two-value image provided by the machine vision system. A machine vision system will work tirelessly performing 100% real time inspection, resulting in improved product quality, higher yields and lower production costs. Consistent product appearance and quality drives customer satisfaction and ultimately market share. Its system consists of several critical components, from the sensor (camera) that captures a picture for inspection, to the processing engine itself (vision appliance) that renders and communicates the result. Fadare and Oni, (2009) have studied that for any machine vision system to work reliably and generate repeatable results, it is important to understand how these critical components interact.

The camera contains a sensor that converts light from the lens into electrical signals. These signals are digitized into an array of values called pixels and processed by a Vision Appliance to perform the inspection. The resolution (precision) of the inspection depends upon the working distance, the field-of-view (FOV), and the number of physical pixels in the camera's sensor. Some researcher study the improvement the visual quality of photographs such as Jianzhou et. al. (2013). They present the automatic cropping technique for object when shooting a photo. The sensors used by machine vision cameras are highly specialized, and hence more expensive than say, a web cam (Sipponen, 2010). First, it is desirable to have square physical pixels. This makes measurement calculations easier and more precise. Second, the cameras can be triggered by the machine vision system to take a picture based on the Part-in-Place signal. Third, the cameras have sophisticated exposure and fast electronic shutters that can 'freeze' the motion of most parts (Zakaria et al, 2012). This paper focuses for measuring geometric dimension of automotive part using machine vision technology.

Methodology

Computers have been used for numerous applications involving the automatic or semiautomatic recognition of patterns in image or signal data. A particular application area with growing interest is machine vision for robotics and industrial quality control. The basic components of a machine vision system are shown in **Fig. 1**. **Fig. 1** shows the system arrangement for current work.

The sensor is web camera, acquire an image of the object that is to be recognized or inspected. The Matlab image processing converts this image into an array of numbers, representing the brightness values of the image at a grid of point; the numbers in the array are called pixels. The pixel array is input to the processor, a general-purpose or custom-built computer that analyses the data and makes the necessary decisions (identifying the object, detecting flaws). There is an endless variety of possible vision tasks, but they all tend to involve a common set of basic step. The process of discriminating part of an image from its background is called segmentation. The size and shape also need to determine so that if it is too small, it can be ignored. To inspect a complex pattern, the comparison with the reference pattern is needed in order to detect discrepancies. In the segmentation, the image comes into the processor as an array of pixels, representing samples of the image brightness at a grid of points . In order to detect an object or a feature, able to distinguish it from the surface on which it lies. Two basic methods of doing this are thresholding and edge detection. Thresholding is the process of distinguish dark pixels from light ones. The method used for experiment simplified as flowchart.

Calibration of Measuring System derivation

From (a) can get:

$$\frac{a}{L} = \frac{h}{k-d} \qquad (1)$$

From (b) can get:

$$\frac{b}{L} = \frac{g}{k-e} \qquad (2)$$

From (c) can get:

$$\frac{c}{L} = \frac{g}{k-f} \qquad (3)$$

Divide Eq. 1 by Eq. 2 to get

$$\frac{a}{L} \times \frac{L}{b} = \frac{h}{k-d} \times \frac{k-e}{g} \qquad (4) \qquad (elimination\ of\ L)$$

$$k = \frac{agd - bhe}{ag - bh} \qquad (5)$$

Divide Eq. 2 by Eq. 3 to get

$$\frac{b}{L} \times \frac{L}{c} = \frac{g}{k-e} \times \frac{k-f}{g} \qquad (6) \qquad (elimination\ of\ L)$$

$$k = \frac{beg - cgf}{bg - cg} \qquad (7)$$

Eq. 5 = Eq. 7 $(elimination\ of\ k\ and\ solve\ to\ get\ h\ as\ a\ objective\ function)$

$$\frac{agd - bhe}{ag - bh} = \frac{beg - cgf}{bg - cg} \qquad (8)$$

$$h = ag\left(\frac{be - cf - bd + cd}{bc(e - f)}\right) \qquad (9)$$

Where:
g = gauge diameter (mm)
d = object height (mm)
e = gauge height (mm)
f = gauge height on top of a block (mm)
a = object image dimension at d (pixel)
b = gauge image diameter at e (pixel)
c = gauge image diameter at f (pixel)
h = object dimension (mm)

Converting Pixel Ratio to mm Unit

To convert pixel ratio to mm unit, Equation (9) is used after rearrangement

$$\frac{h}{a} = g\left(\frac{be - cf - bd + cd}{bc(e - f)}\right) \qquad (10)$$

The dimension of object and gauge used in this experiment are:
g = 8.0 mm
d = 59.56 mm
e = 50 mm
f = 71.5 mm
b = gauge image diameter at e (pixel) = 34.6322 pixel
c = gauge image diameter at f (pixel) = 35.0706 pixel

$$\frac{h}{a} = 8.0\left(\frac{(34.6322 \times 50.0) - (35.0706 \times 71.5) - (34.6322 \times 59.56) + (35.0706 \times 59.56)}{(34.6322 \times 35.0706)(50.0 - 71.50)}\right)$$

$\frac{h}{a} = 0.2297$ (The pixel ratio to mm)

Determine Diameter of Gauge Using Matlab Software

Here it should determine the diameter of gauge that has used in this study. Two times have done to this job one for gauge only and other for gauge with block. The purpose of this step is to determine the relation between two levels of object for on dimension. **Fig. 3** shows the M-file and its descriptions.

RESULTS :-

As the result, apply the Matlab M-file shown in **Fig 3** to find the diameter of gauge. Based on the experiment conducted, the pixel to mm ratio can be calculated using equation 10. After calculated, the ratio that 0.2297 was obtained. Using this ratio, it can convert from pixel unit to millimetre (mm) unit. The standard gauge diameter that used was 8.0 mm. From this experiment, the gauge diameter that 34.6322 pixels was obtained. After convert it, the gauge diameter that 7.955 mm was got which is only 0.045 mm or 0.56% error due to some factors that affect the measurement.

Fig. 4 shows the result output steps of diameter of gauge only. **Fig. 5** shows the result output steps of diameter of gauge when put it on block.

Table 1 shows the results of procedure to determine the angle between two consecutive screw holes using matlab software with the calibrated measuring system. The list of that result is shown in **Table 2**.

Precision can be defined as the difference between the instruments reported values during repeated measurements of the same quantity. The precision can be estimated by looking at the standard deviation of a system which. The smaller the standard deviation, the system will have high precision (Accuracy and precision 2015). The stander deviation is calculated directly from collecting data using MS excel software. The standard deviation for this system is 0.0821. By looking at this standard deviation, it shows that this measurement system have high precision since the standard deviation is too small. See **Table 2** for 30 trying of test. Determine the mean and standard deviation of data collected using Matlab software .

Accuracy can be defined as the difference between the measured and true value. In this experiment, is to find the angle between two circles at the automotive component. From manual calibration using measuring tool such as vernier calliper, goniometer and trigonometry equation can be measured triangular points to obtain the angle degree. The degree that 11.6° was got compared with result that have been got using Matlab software which is 11.649°**.** The error between these two values is too small which is 0.422% and it show us that this system has high reliability and high accuracy. **Tables 3 and 4** show the data and the final result of error.

CONCLUSION :

As a conclusion, this machine vision can be applied to the industries since this system has reliability, high precision which can be defined as the stander deviation, and high accuracy the can calculated as the difference between machine vision and measurement. The stander deviation is calculated directly from collecting data using MS excel software. So, this criterion is needed in industries since it will reflect to the product that we produced. So, based on our experiment, the mean of an angle between two circles is 11.649° and the standard deviation for the data is 0.0821.

In order to obtain more accurate result using this machine vision method, the specimen should be placed perpendicular to the lens in order to avoid some errors such as a shadow caused by lighting system during the experiment.

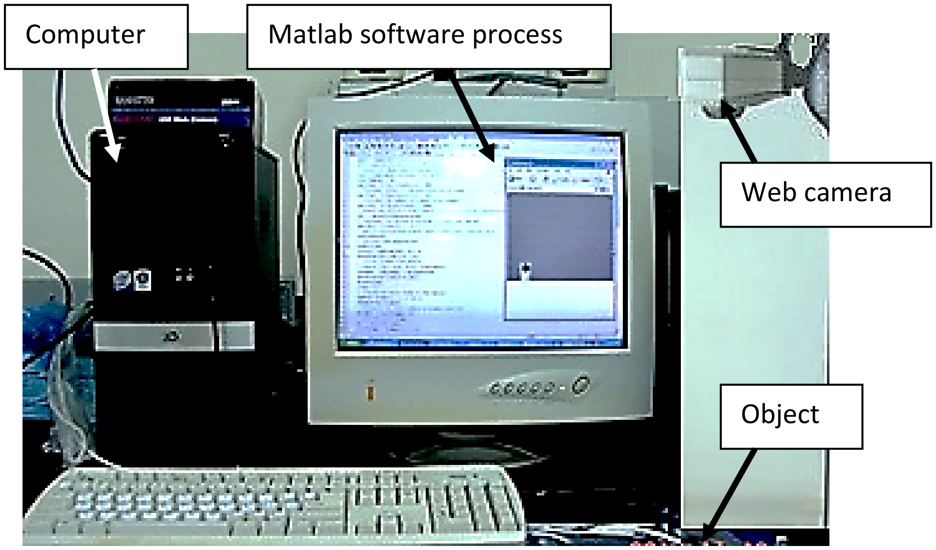


Figure 1 system arrangement for current work

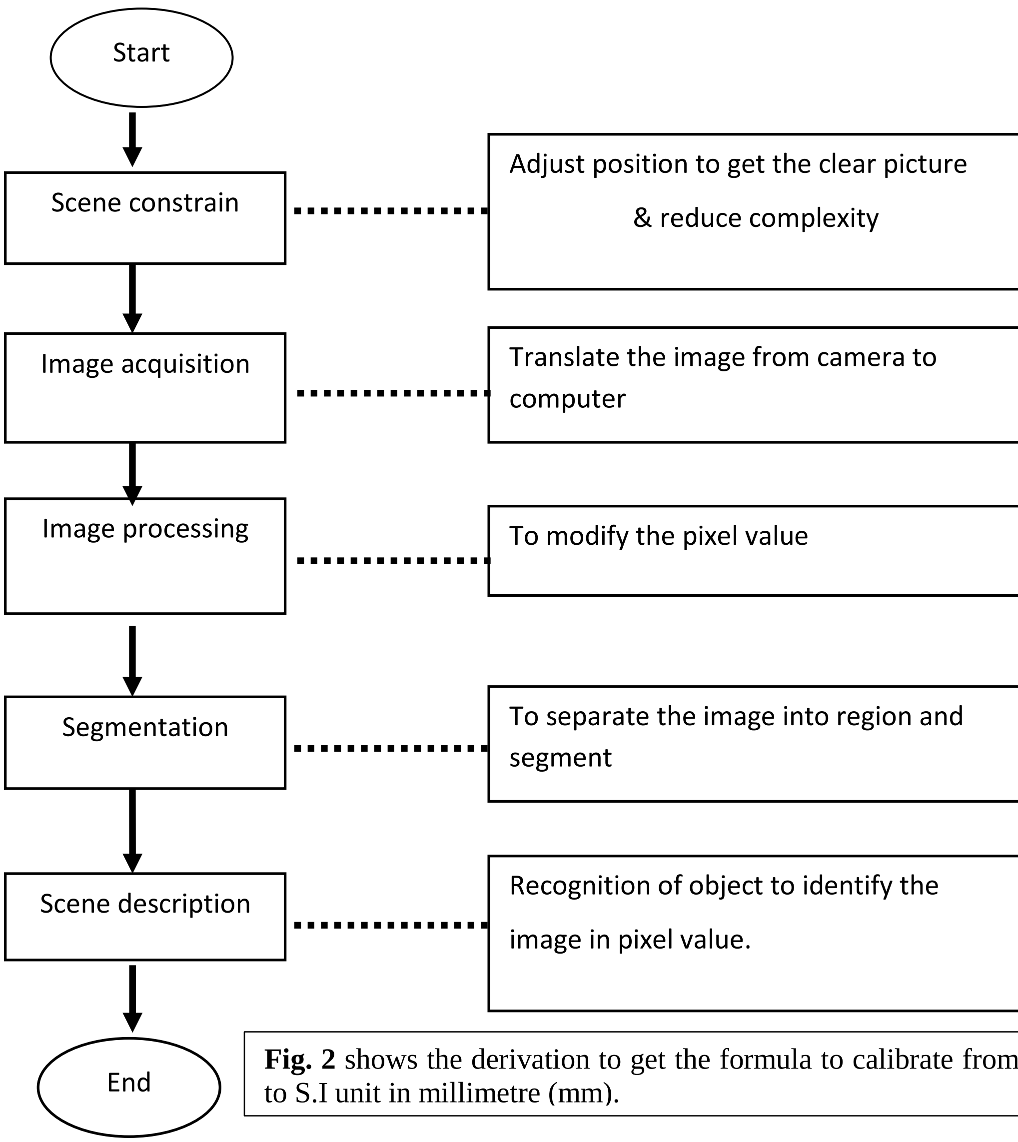


Fig. 2 shows the derivation to get the formula to calibrate from unit in pixel to S.I unit in millimetre (mm).

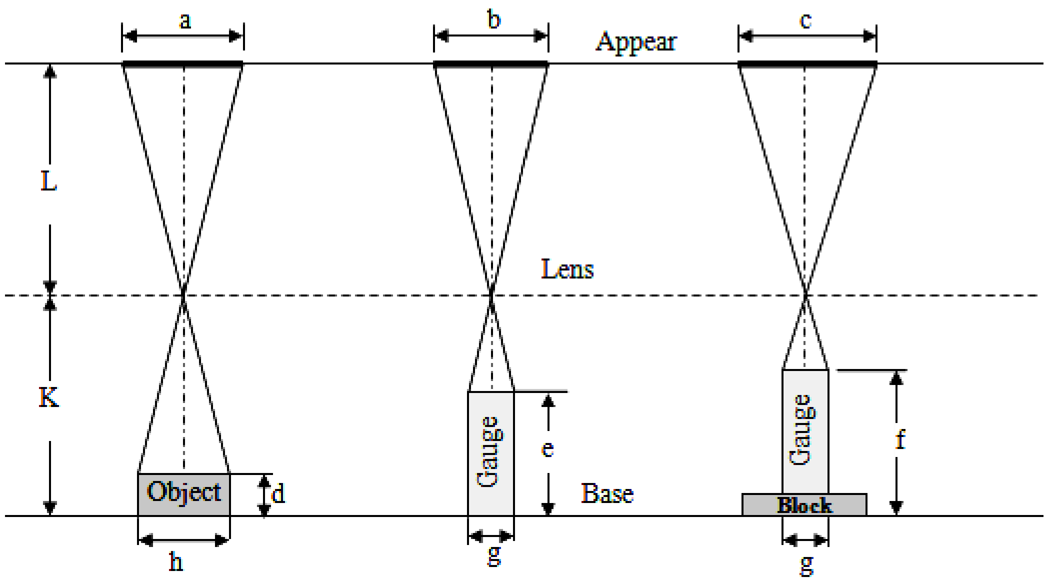


Figure 2 sechmatic to illustate the calibration of object

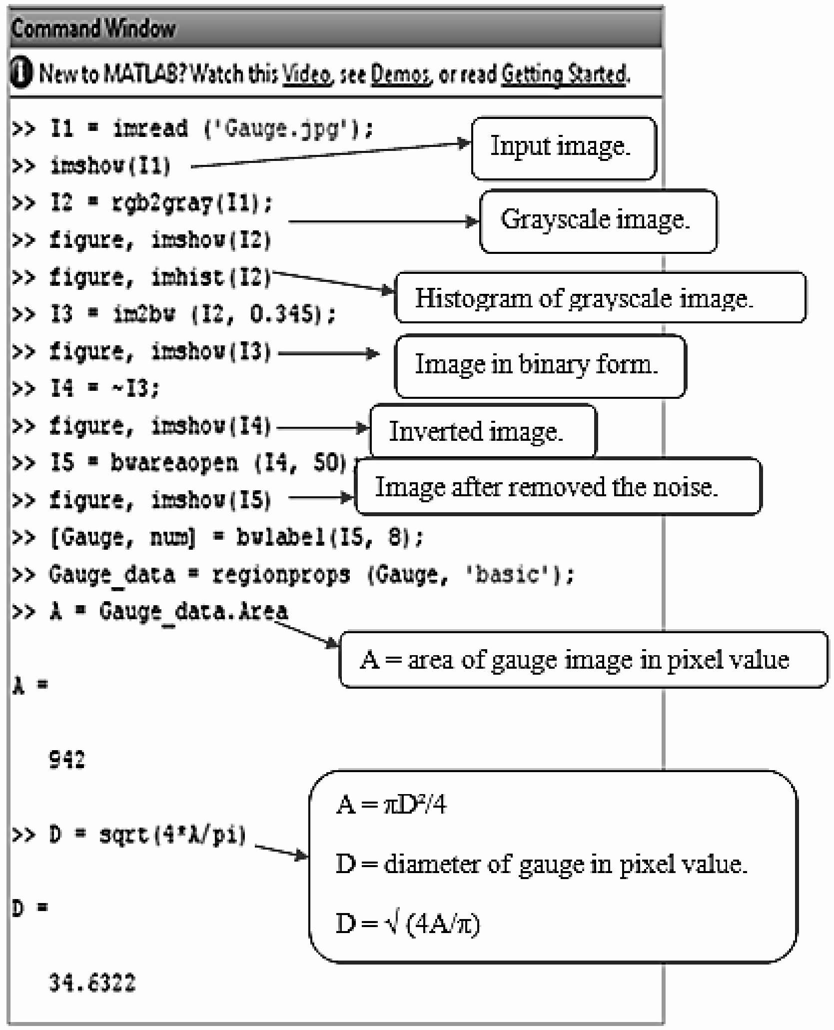


Figure 3 M.file Command of Matlab to Compute the Gauge diameter

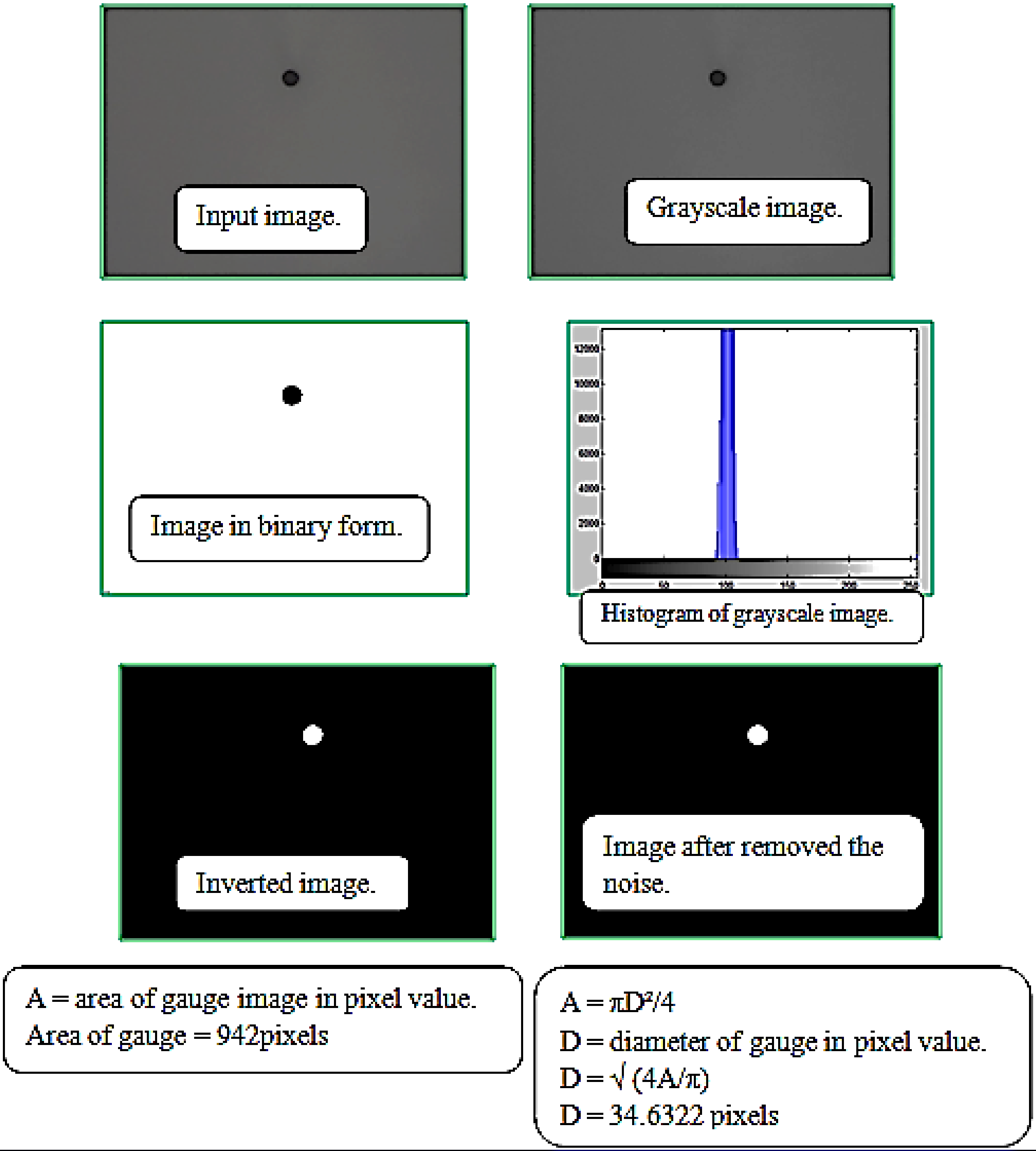
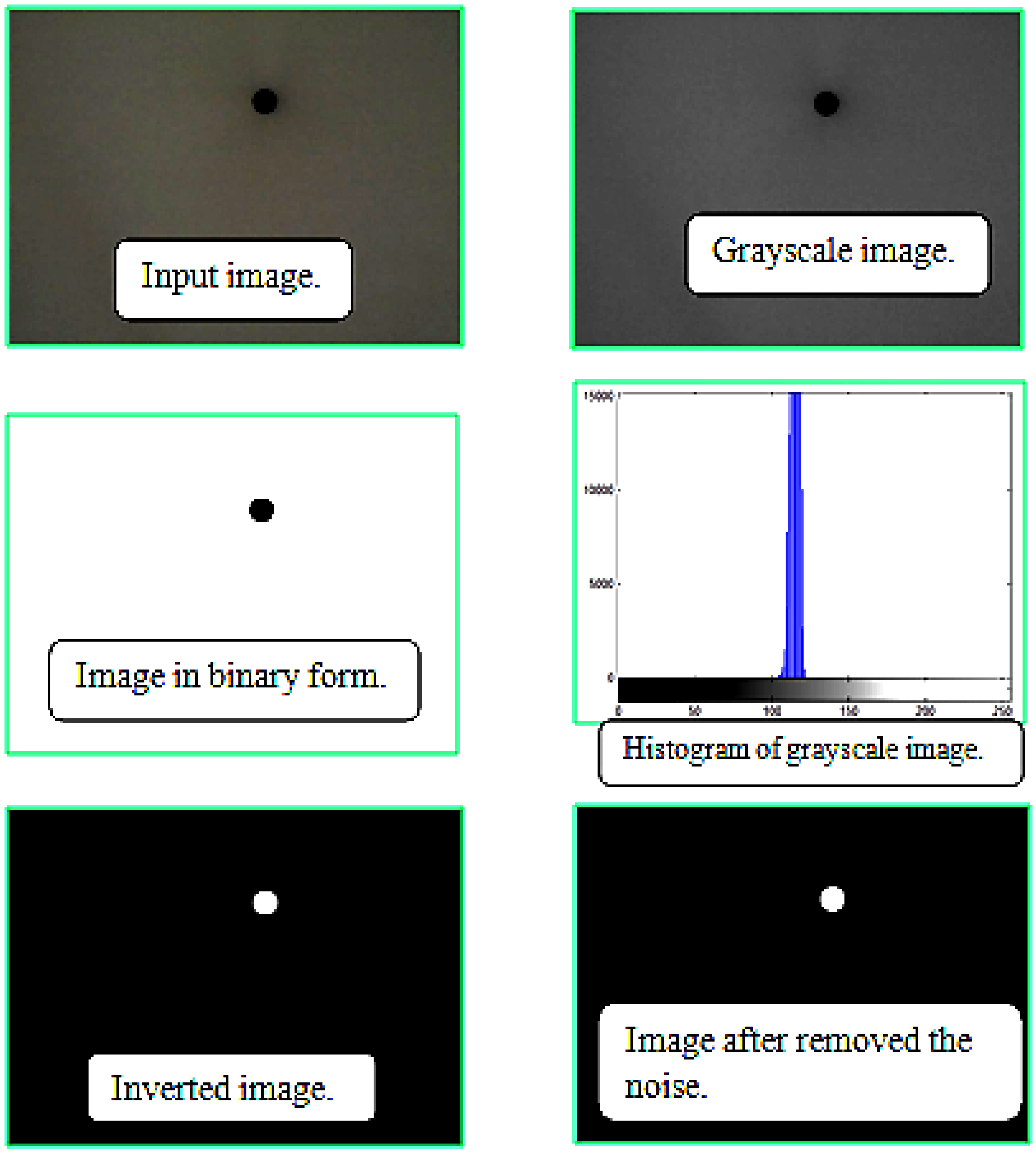


Figure 4 the result output of diameter of gauge only

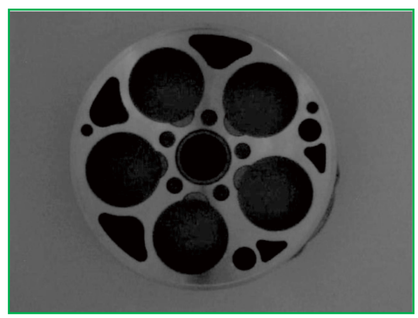
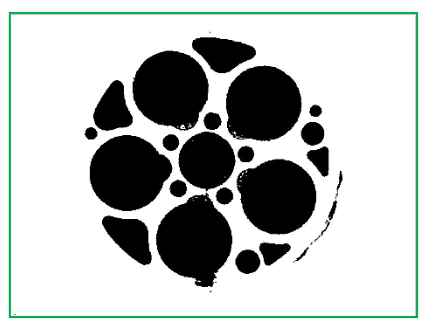


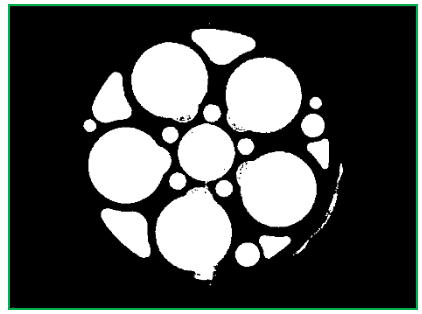
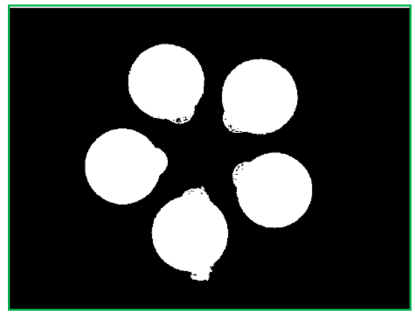
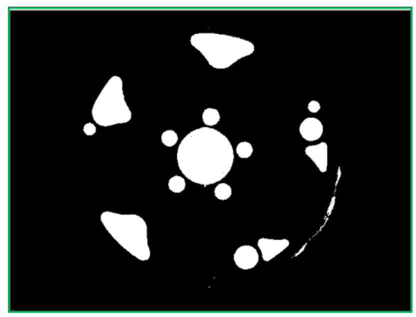
A = area of gauge image in pixel value.
Area of gauge = 966 pixels

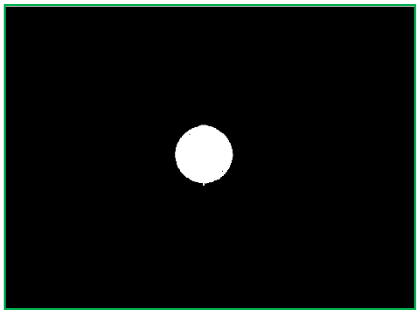
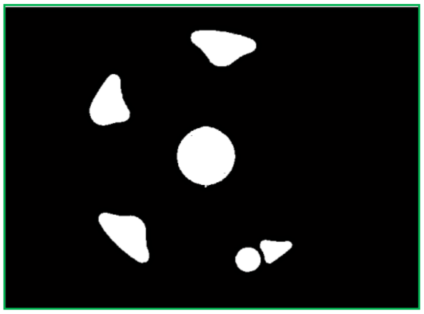
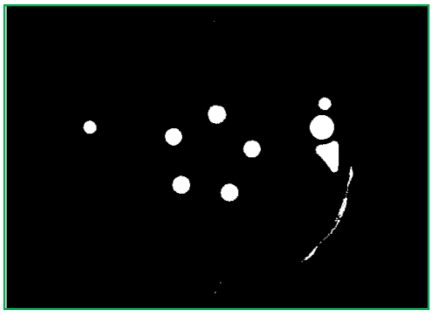
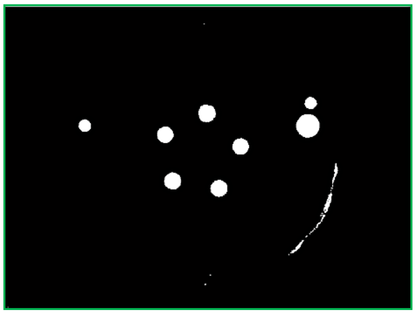
$A = \pi D^2/4$
D = diameter of gauge in pixel value.
$D = \sqrt{(4A/\pi)}$
D = 35.0706 pixels

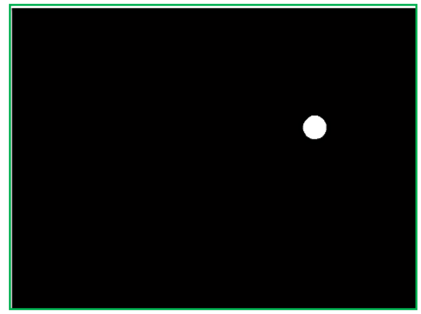
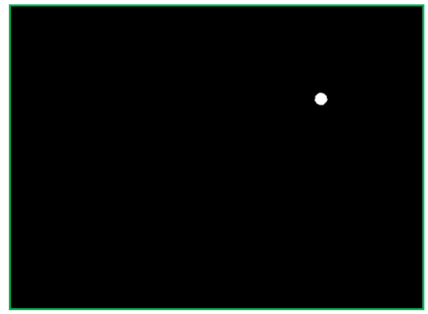
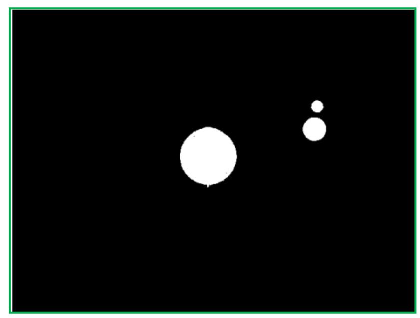
Figure 5 the result output of diameter of gauge when put it on block

Table 1 Matlab Command Window When Computing the AP M.file.

% Image acquisition. vid = videoinput('winvideo'); preview(vid) Automotive_part = getsnapshot(vid); image(Automotive_part)	
% Image preprocessing. I1 = imread('AP.jpg'); imshow(I1) I2 = rgb2gray(I1); figure, imshow(I1)	
I3 = I2 - 60; figure, imshow(I3)	
I3d = im2double (I3); I4d = I3d*(1/0.16); I4 = im2uint8(I4d); I5 = im2bw(I4,0.37); figure, imshow(I5)	

I6 = ~I5; figure, imshow(I6)	
[AP, num] = bwlabel (I6,8); APdata = regionprops(AP, 'basic'); APdata.Area; T1 = bwareaopen (AP, 11400); figure, imshow(T1) I7 = I6 - T1; figure, imshow(I7)	 

[AP, num] = bwlabel (I7,8); APdata = regionprops(AP, 'basic'); APdata.Area; D1 = bwareaopen (AP, 6200); figure, imshow(D1) T2 = bwareaopen (AP, 1080); figure, imshow(T2)	 
I8 = I7 - T2; figure, imshow(I8)	
[AP, num] = bwlabel (I8,8); APdata = regionprops(AP, 'basic'); APdata.Area; D2a = bwareaopen (AP, 1070); D2b = bwareaopen (AP, 1078); D2c = D2a - D2b; T2b = I8 - D2c; figure, imshow(T2b)	

[AP, num] = bwlabel (T2b, 8); APdata = regionprops (AP, 'basic'); APdata.Area; D2 = bwareaopen (AP, 610); figure, imshow(D2) T4 = bwareaopen (AP, 280); T5 = bwareaopen (AP, 300); D3 = T4 - T5; figure, imshow(D3)	 
result = D1 + D2 + D3; figure, imshow(result)	

[AP, num] = bwlabel(result,8); APdata = regionprops(AP, 'basic'); X1 = APdata(1).Centroid(1) Y1 = APdata(1).Centroid(2) X2 = APdata(2).Centroid(1) Y2 = APdata(2).Centroid(2) X3 = APdata(3).Centroid(1) Y3 = APdata(3).Centroid(2)	X1 = 310.2363 Y1 = 231.7818 X2 = 478.2588 Y2 = 188.9276 X3 = 482.5141 Y3 = 153.1092
d1 = sqrt((X1-X2)^2 + (Y1-Y2)^2) d2 = sqrt((X1-X3)^2 + (Y1-Y2)^2) d3 = sqrt((X2-X3)^2 + (Y2-Y3)^2)	d1 = 173.4014 d2 = 177.5278 d3 = 36.0704

if (d1 < d2) && (d1 < d3);
a = d1*0.2308
b = d2*0.2308
c = d3*0.2308
 	
else if (d2 < d1) && (d2 <d3);
a = d2*0.2308
b = d1*0.2308
c = d3*0.2308
 	
else
(d3 < d1) && (d3 < d2);
a = d3*0.2308
b = d2*0.2308
c = d1*0.2308
 	
end
end
	a =
	8.3250
	b =
	40.9734
	c =
	40.0210

angle = acosd((b^2 + c^2 - a^2)/(2*b*c))	angle = 11.7222

Table 2 Data Collected From Machine Vision System

NO.	Angle measured degree	Mean (overall)	Standard deviation (overall)
1	11.80	11.649	0.0821
2	11.70		
3	11.76		
4	11.73		
5	11.65		
6	11.58		
7	11.50		
8	11.72		
9	11.64		
10	11.55		
11	11.65		
12	11.55		
13	11.72		
14	11.60		
15	11.71		
16	11.50		
17	11.73		
18	11.68		
19	11.57		
20	11.70		
21	11.50		
22	11.70		
23	11.65		
24	11.71		
25	11.60		
26	11.58		
27	11.72		
28	11.69		
29	11.58		
30	11.70		

Table 3 Data Collected Using Vernier Calliper

Reading	Angle degree	Mean of angle
1	11.58	11.60
2	11.62	
3	11.60	

Table 4 Data Comparison

	Machine vision	Vernier calliper	Error
Angle °	11.649	11.60	$\frac{11.649 - 11.6}{11.6} \times 100\% = 0.422\%$

REFERENCE :

Accuracy and precision [19/05/2015] pm 02:27:0
http://en.wikipedia.org/wiki/Accuracy_and_precision

D. A. Fadare and A. O. Oni (2009) "Development and application of a machine vision system for measurement of surface roughness" ARPN Journal of Engineering and Applied Sciences Vol. 4, No. 5, july

Huijie Fan, Yang Cong and Yandong Tang (2015) "Object detection based on scale-invariant partial shape matching" Machine Vision and Applications Vol. 26, pp. 711–721

Jianzhou Yan∗ Stephen Lin Sing Bing Kang3 Xiaoou Tang (2013) "Learning the Change for Automatic Image Cropping ", IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp. 971 - 978

Joni Sipponen (2010) " Employing machine vision to a manufacturing line" saimaa university of applied sciences, Technology/ Lappeenranta Degree Programme in Mechanical Engineering and Production Technology Final thesis

Mechanical Measurements Sixth Edition (2007) by Thomas G. Beckwith, Roy D. Marangoni, John H. Lienhard V published by Pearson

Mohd Firdaus Zakaria, Hoo Seng Choon, and Shahrel Azmin Suandi (2012) "Object Shape Recognition in Image for Machine Vision Application" International Journal of Computer Theory and Engineering, Vol. 4, No. 1, February

Sathiyamoorthy S. (2014) "Industrial application of machine vision" International Journal of Research in Engineering and Technology, Vol. 03, Special Issue: 07, pp. 678-682

Yu-Chieh Chen and Yin-Tien Wang (2008) "Development of a Low-Cost Machine Vision System and Its Application on Inspection Processes" Tamkang Journal of Science and Engineering, Vol. 11, No. 4, pp. 425_431