



## VALUATION OF IMAGE PROCESSING SYSTEM SURFACE ROUGHNESS ON MACHINED ELEMENTS

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### Abstract

Surfaces of industrial machined components need to be quantified based on their utility and application environment. Since the quality of surface influences the suitability of components for a specific application, more consideration had been given by researchers to measure the surface quality accurately. In recent years, with the beginning of high-speed general-purpose computers and powerful high speed vision systems image analysis have become simple, faster and more flexible. Images of surfaces captured using vision system can be used to identify analyze and quantify surface texture after the implementation of quality improvement algorithms. This paper presents a surface image acquisition system based on image processing technology. The image acquired by CCD is pre-processed through the method of image editing, image equalization, the image binary conversation and feature parameters extraction to achieve casting surface roughness measurement. Optical surface roughness parameter 'Ga' has been obtained from an image and is compared with the commonly used conventional average surface roughness 'Ra' obtained from the stylus instrument. Error compensation was performed and the calibration curves were tested with additional machined plates of known Ra. The technique showed good accuracy and reliability. Consequently, this technique could be used as an economical, precise and reliable way to measure and visualize surface roughness.

**Keywords:** Assessment, Surface Roughness, Machine Vision, Image Processing, Components

### 1. Introduction

Surface roughness often shortened to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. Surface roughness inspection is one of the important quality control processes that are carried out to ensure that manufactured parts imitate to specified standards. It is normally done through the use of stylus-type devices which is a contact type measurement. Some of the contact type measurements are Profilometer, Tomlinson surface meter, Talysurf, Profilograph. The major drawback for such instruments is that they require direct physical contact which limits the measuring speed. In addition, the instrument readings are based on a limited number of line samplings which may not represent the real features of the surface. In order to overcome this draw backs the non-contact type measurements are preferred. Some of the non-contact type measurements are Coherence scanning interferometry, Confocal laser scanning microscopy and Scanning laser microscope. These non-contact type measurements are costlier than the contact type measurement. In this paper the digital image processing technique is used for evaluating the surface roughness of the component. The roughness of

the component is the function of intensity value of image at each pixel. The Figure 1 shows the surface roughness profile for the machined component. The various roughness parameters are  $R_a$  (Centre Line Average method),  $R_q$  (Root mean square value),  $R_z$  (Ten Point Average method),  $R_t$  (Total roughness from peak to valley).

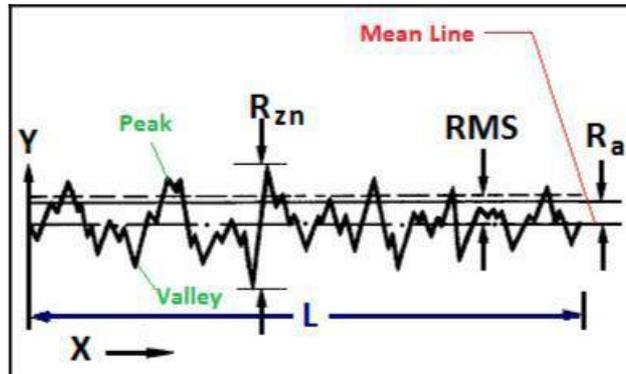


Figure 1. Surface Roughness Profile

Machine vision systems play a vital role in the monitoring and control of automated machining systems. The various applications of Machine vision includes automatic inspection, process control and robot guidance. Researchers have shown that the application of machine vision has the advantage of being non-contact and has well faster than the contact methods. The application of machine vision system offers better solution in on-line and real-time monitoring surface roughness. Machine vision involves the use of camera, and image processing software to acquire and analyzing the image. An image is an array, or a matrix, of square pixels (picture elements) arranged in columns and rows. RGB (red, green, and blue) refers to a system for representing the colors to be used on a computer display. Red, green, and blue can be combined in various proportions to obtain any color in the visible spectrum. Levels of R, G, and B can each range from 0 to 100 percent of full intensity. Each level is represented by the range of decimal numbers from 0 to 255 (256 levels for each color). In a (8-bit) grey scale image each picture element has an assigned intensity that ranges from 0 to 255. A grey scale image is generally a black and white image, but the name emphasizes that such an image will also include many shades of grey.

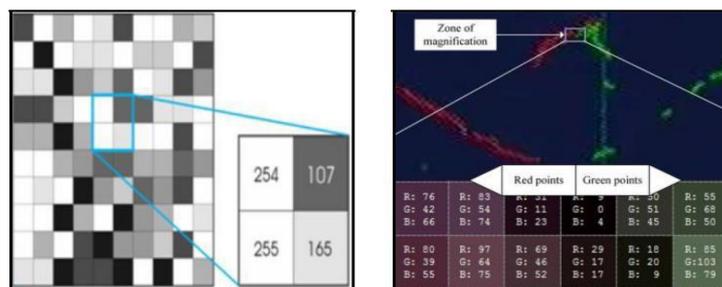


Figure 2. Grey Scale Image and RGB Image Intensity Values

Gadelmawla and Tian and Lu used the Gray Level Co-occurrence Matrix (GLCM) method. This statistical method considers the spatial relationship of pixels on the surface image. Surface roughness is extracted by exploring the relationships of average surface roughness ( $R_a$ ) with the features of GLCM of the surface image. Dhanasekar and Ramamoorthy and Gary Wagner described geometric search as the most accurate and appropriate method for improving the quality of images by enhancing the edges in image processing. Kiran et al have utilized the grey level intensity histograms etc., for establishing new optical parameters for roughness evaluation.

Lee et al proposed a method to assess surface roughness using texture features of image data. Their results demonstrated the validity of the proposed approach to achieve accurate  $R_a$  measurements, although it was not stated how much  $R_a$  acquired values may vary with light or material change. Jeyapoovan et al worked on the estimation of surface roughness using digital image processing. In this

the reference image is stored in database and acquired image is compared to it. Based on the Hamming and Euclidean distances between the image the surface roughness is predicted. Luk et al founded the statistical parameters, derived from the grey level intensity histogram such as the range and the mean value of the distribution and correlated them with the Ra value determined from the stylus method. Al-Kindi et al implemented a technique utilizing a roughness parameter based on both the spacing between grey level peaks and the number of grey level peaks per unit length of a scanned line in the grey level image to estimate the surface roughness.

## 2. Methodology

### 2.1 Preparation of work piece material

The material used for experimentation is Aluminium. The size of the material is 100 x 100 x 6 (mm). In this work, the specimens are prepared by vertical milling. The feed, Cutting speed are varied so that different roughness specimen is obtained. These specimens are used for experimentation. Surface Roughness of the specimens are measured using stylus instrument, the values are tabulated below in Table 1.

**Table 1 Roughness Value of the Specimens**

Specimen No	Surface Roughness $R_a(\mu\text{m})$
Specimen 1	0.56
Specimen 2	0.63
Specimen 3	0.76
Specimen 4	0.93
Specimen 5	4.87
Specimen 6	5.75
Specimen 7	6.39
Specimen 8	8.12
Specimen 9	10.25
Specimen 10	11.92
Specimen 11	12.4
Specimen 12	16.21

### 2.2 Experimental Setup

Experimental set-up shown in Figure 3 consists of a vision system (CCD camera, stand, and processing hardware), appropriate lighting arrangement and computer with MATLAB software. The camera used is 5MP (Megapixel) with 120 FPS (Frames per Second). The lighting system used is co-axial light whose intensity is changed by controlling the voltage using intelligent power supply. Intensity of the light is changed based on the surface to be inspected. The images of each specimen are captured using the vision system and these images are processed using an image processing software tool in MATLAB. Images are digitized and stored in the form of a rectangular matrix where each element corresponds to the pixel intensity. The digitized image has an array of 2456 x 2054 with 24 bit pixels brightness resolution. Each pixel had a definite illumination intensity value. Once required portion of surface is reached then the image acquisition software is used to acquire the image. The acquired grey scale image is shown in Figure 4.

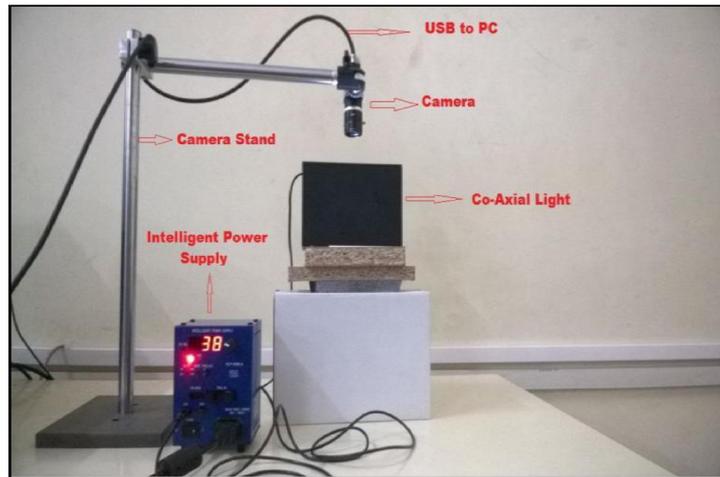


Figure3. Experimental Setup

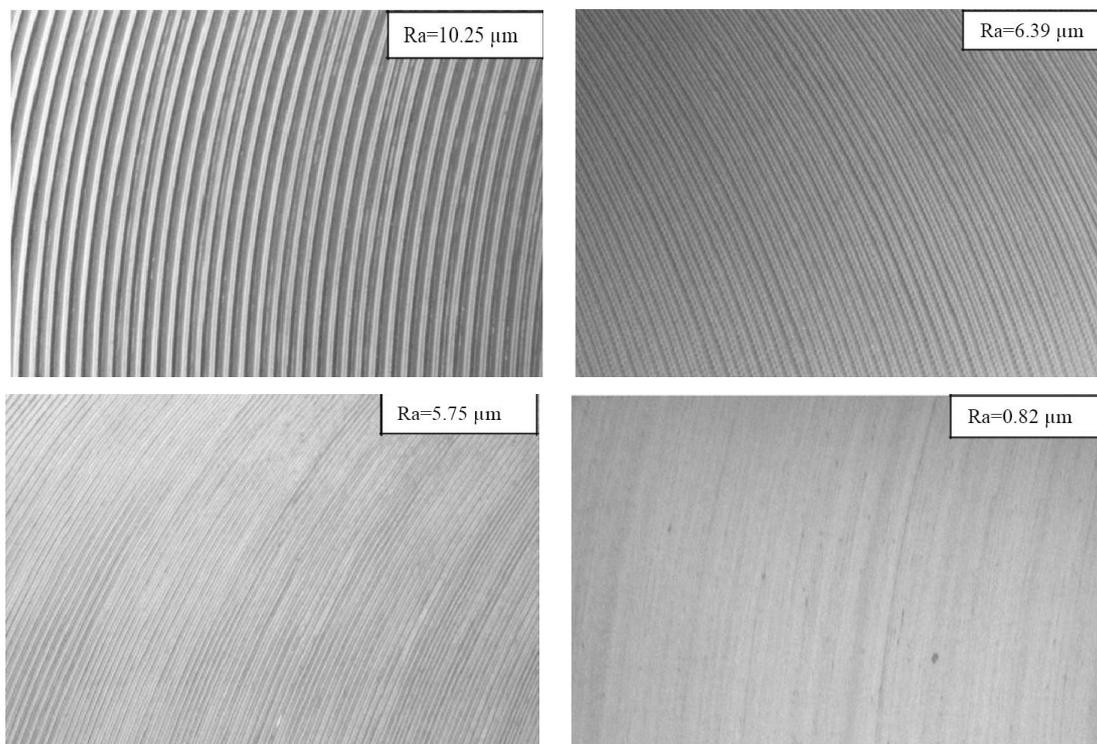


Figure 4. Grey Scale Images of Machined Components

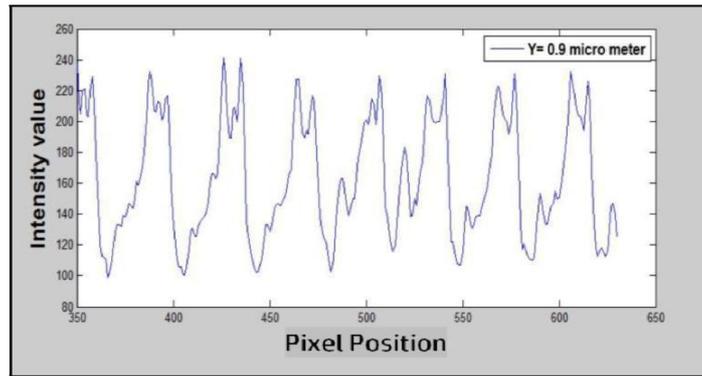
### 2.3 Processing the image

#### Generation of Intensity profile:

Step 1: Capture the RGB image of the Specimen whose roughness is to be determined. Convert RGB (Color image) into Grey Scale image( $R_{[i,j]}$ ) using MATLAB.

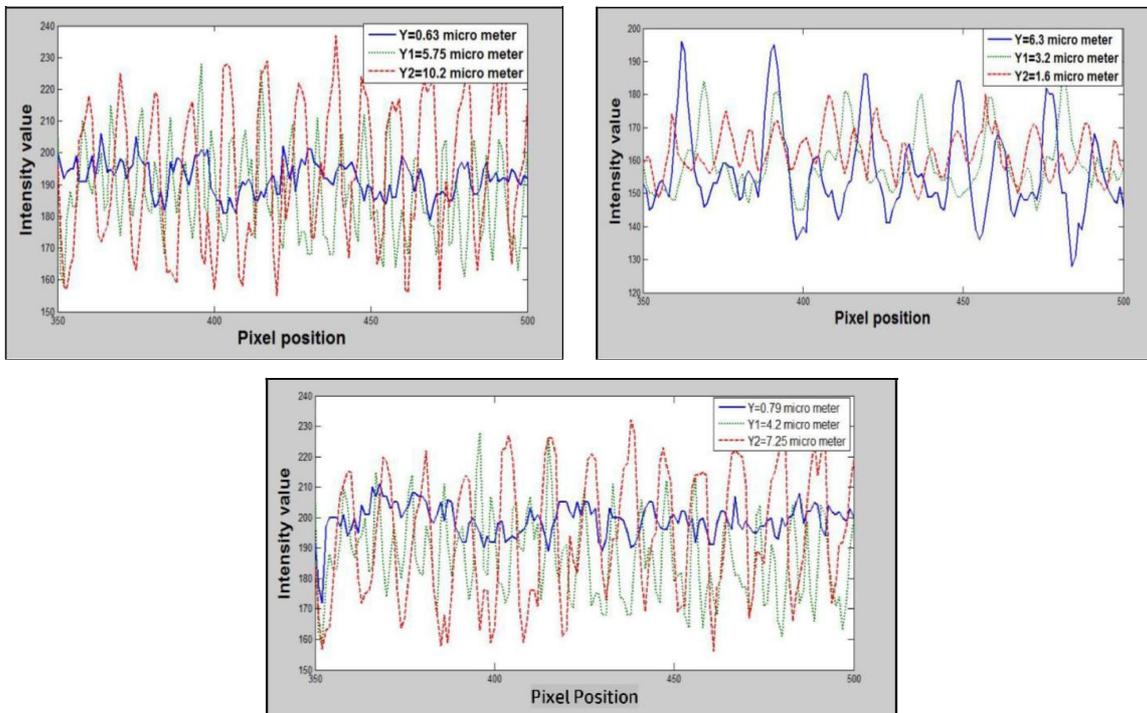
Step 2: Extract the pixel values of the matrix along the middle row of the image ( $\text{size}(R_{[i]}/2)$ ).

Step 3: Plot the graph using the extracted pixel values. The X-axis of the graph is Pixel Position and Y-axis of the graph is intensity value which is extracted from the matrix. The Figure 5 shows the sample intensity profile of the machined surface.



**Figure5. Intensity Profile**

Step 4: Compare the graphs for all the specimens prepared. In this paper, the graphs for different specimens are plotted. The comparison graph for different specimen is shown in Figure 6. From the Figure 6 it is inferred that the deviation of peak to valley of intensity profile increases as the surface roughness of the specimen increases.



**Figure 6. Comparison of Intensity Profile for Different Specimens**

### Different specimens

From the above graph, solid line represents the intensity profile of the specimen of roughness ( $R_a=0.79\mu\text{m}$ ), dashed line represents the intensity profile of the specimen of roughness ( $R_a=4.2\mu\text{m}$ ), dashed-dotted line represents the intensity profile of the specimen of roughness ( $R_a=7.25\mu\text{m}$ ). The inference from this graph is that the peak to valley deviation of intensity profile increases as the roughness of the specimen is increasing, whereas for smooth surfaces with lower roughness the deviation of peak to valley is lesser. Deviation of peak to valley of the intensity profile is directly proportional to the roughness of the specimen.

### Determining the Arithmetic Average of Grey level ( $G_a$ )

Step 1: Capture the RGB image of the Specimen whose roughness is to be determined. Convert RGB (Color image) into Grey Scale image using MATLAB.

Step 2: The image in MATLAB will be represented by the rectangular matrix  $R_{[i,j]}$ . Extract the pixel values of the matrix along the specific row (size( $R_{[i]}/2$ )).

Step 3: Find the mean of intensity values along the specific row. The mean ( $Y_m$ ) is founded by adding all the intensity values along that row and their sum is divided by the No of Pixels.

Where

$$Y_1 \dots Y_n = \text{Intensity values at each pixel along the specific row of matrix}$$

$$n = \text{No of Columns along the specific row of matrix}$$

Step 4: Find the sum of difference ( $G_m$ ) between the mean intensity value ( $Y_m$ ) and individual pixel value ( $Y_n$ ). The following table consists of feed, Cutting Speed, Arithmetic average of grey value ( $G_a$ ) and corresponding measured roughness of the specimen ( $R_a$ ).

**Table 2 Machining Parameters for Vertical Milling and Roughness Values**

S.No	Specimen No	Cutting Speed(rpm)	Feed(mm/min)	Depth of Cut(mm)	Surface Roughness( $R_a$ )	Arithmetic Average value of Gray Level( $G_a$ )
1	Specimen 1	1050	120	0.5	0.56	4.8259
2	Specimen 2	1000	120	0.5	0.63	5.0234
3	Specimen 3	950	120	0.5	0.76	6.2635
4	Specimen 4	900	130	0.5	0.93	7.5767
5	Specimen 5	785	140	0.5	4.87	12.1048
6	Specimen 6	750	150	0.5	5.75	13.8312
7	Specimen 7	750	165	0.5	6.39	15.0126
8	Specimen 8	675	180	0.5	8.12	16.5253
9	Specimen 9	520	200	0.5	10.25	21.5481
10	Specimen 10	425	220	0.5	11.92	23.6384
11	Specimen 11	350	280	0.5	12.4	24.895
12	Specimen 12	275	280	0.5	16.21	33.4992

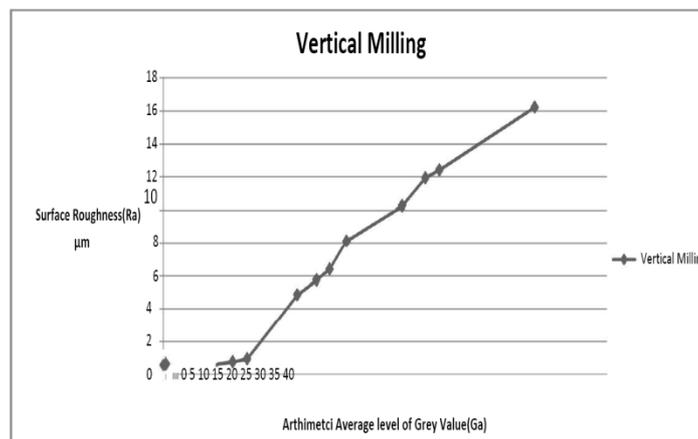
The following graph is plotted between the calculated Arithmetic average of gray value ( $G_a$ ) and known roughness ( $R_a$ ) measured using Talysurf.

Deviation of intensity value is summed up together irrespective of the arithmetic signs.

Where

$$Y_m = \text{Mean intensity value}$$

Step 5: To find arithmetic average value of gray level ( $G_a$ ) the sum of difference ( $G_m$ ) between mean intensity value ( $Y_m$ ) and individual pixel value ( $Y_n$ ) is divided by the No of columns.



**Figure 7. Graph Plotted between  $G_a$  and  $R_a$**

### Development of Regression Equation

Fifth order polynomial regression equation has been developed for vertical milling operation based upon the data presented in Table 2.

The equation is  
 Where,

$R_a$ = Surface Roughness of the Specimen to be captured  
 $G_a$ = Arithmetic average gray value of the captured image

### 3. Results and Discussion

#### Validation of Regression equation

Table 3 Surface Roughness of Unknown Specimen and Error Value

Specimen No	Optical roughness value( $G_a$ )	Surface roughness by Image Processing ( $R_a$ )	Measured Surface roughness	Error (%)
1	6.4806	0.652	0.68	4.11
2	6.9064	0.801	0.82	2.32
3	8.1331	1.4621	1.41	3.69
4	15.6394	7.1794	7.12	0.83

### 4. Conclusion

In this work, a vision based system has been tried for measuring the surface roughness using the gray scale image approach. From the above results, as the roughness of the specimen increases, the deviation of peak to valley height of the intensity profile also increases. The roughness of the surface is directly proportional to the deviation of peak to valley of the intensity profile. The present work clearly indicates that the machine vision approach can be used to evaluate the surface roughness of machined surfaces and it is established as well that there is a good linear relationship between  $R_a$  and  $G_a$  with a high level of accuracy. By finding the Arithmetic average gray value of the captured surface image, the surface roughness of the specimen is calculated

### 8. References

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