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Comparative Study on the Size of Mechanical Parts using Computer Vision

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Abstract: Industrial machines are designed from the various mechanical parts. These mechanical parts play a huge significant part in different regions of economy of country and so are manufactured in huge quantity worldwide. The mechanical parts parametric dimensions measurement is the important step in the manufacturing process. There are various traditional methods which are used to find the size some of these are calipers, gauges etc. Now these machines are easy to handle. But when you have to measure the dimensions of huge specimens then efficiency will become very low and also the efficiency of human also becomes low.

So it becomes nearly impossible to measure the dimensions of each product in mass production at satisfactory level. As the measurement of dimensions of mechanical parts using digital image capturing technology has numerous advantages with having good efficiency and there is no contact measurement can become the alternative to the old conventional industrial mass production measurement methods.

In this dissertation a study is done on the various methods of measurement of the dimensions of the mechanical parts using digital image measurement technology and tries to improve the technology by providing desirable results. It will be tried to improve the robustness as well as to make the method fully automatic so that human intervention is less and so human error will also be low.

I. INTRODUCTION

A. Development

Industrial machines are designed from the various mechanical parts. These mechanical parts play a huge significant part in different regions of economy of country and so are manufactured in huge quantity worldwide. The mechanical parts parametric dimensions measurement is the important step in the manufacturing process. There are various traditional methods which are used to find the size some of these are calipers, gauges etc.

Now these machines are easy to handle. But when you have to measure the dimensions of huge specimens then efficiency will become very low and also the efficiency of human also becomes low. So it becomes nearly impossible to measure the dimensions of each product in mass production at satisfactory level.

Machine vision comes into existence in early of 1990 and is still a very predominant and fastly developing area. This technology has been broadly utilized in different types of industries which includes remote sensing image generation, medical science image processing, the computer document processing, and inspection of industrial production parts and also multimedia database and nanometer technology.

This system works on both the hardware as well as on the software. The hardware has many components like light source, lens, camera and computer and the use of these devices in the measurement system includes transmitted light to highlight the boundary feature of mechanical parts.

As the measurement of dimensions of mechanical parts using digital image capturing technology has numerous advantages with having good efficiency and there is no contact measurement can become the alternative to the old conventional industrial mass production measurement methods.

As the measurement of dimensions of mechanical parts using digital image capturing technology has numerous advantages with having good efficiency and there is no contact measurement can become the alternative to the old conventional industrial mass production measurement methods. This method has combined feature of machine vision as well as digital image processing technology. With the help of this hybrid technology the overall productivity of the mechanical parts will increase and also the processing quality and hence the success of the mechanical parts industry.

B. Machine Vision

Machine vision is a technology which has vast amount of applications ranging from graphics, vision and optoelectronics which have been implemented in many industries like medicine, mechanical, automotive, micro measurement technology [1].

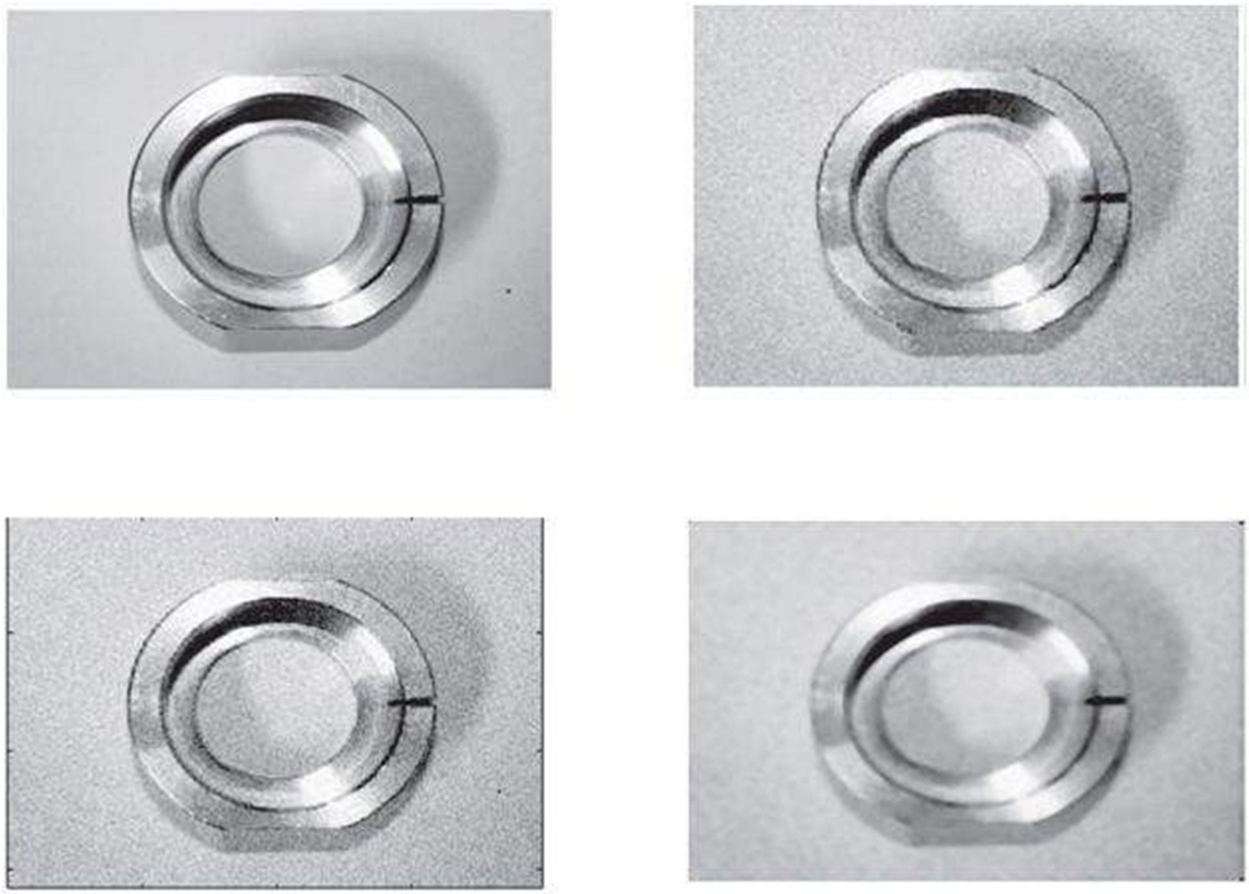

Figure 1.1: Original image and processed image by three noise reduction algorithms [1]

Figure 1.1 shows the original image and the other three images in which noise is removed by various algorithms median filter, Gaussian filter and the mean filter respectively. When the camera system captures the images then it may contain different types of noises. So before processing the image for getting its measurement the preprocessing of input image is done with the help of various image processing filters.

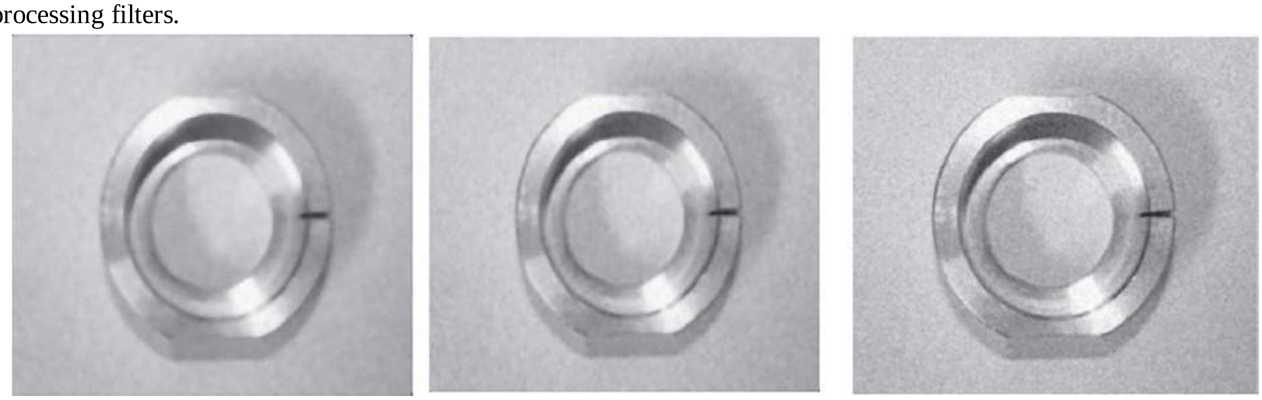

Figure 1.2: Median filtered image with different size windows of 3X3, 5X5 and 7X7.

Figure 1.2 shows the median filtered images with various masks of different window sizes. It is done to check whether the output image does not contain salt and pepper noise.

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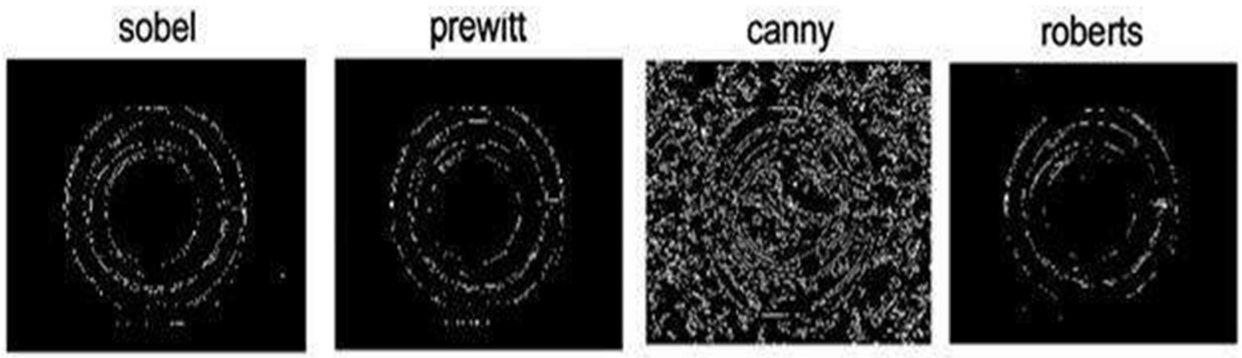

Figure 1.3: edge detection of various algorithms on the original image of figure 1.2 [1]

Figure 1.3 shows that various edge detection algorithms are used for detecting the edges of the mechanical part. Sobel, Prewitt, Canny and Roberts are the famous operators that are used for standard edge detection.

One of the researchers has combined the machine vision and vibration feed terminology to find out the various shapes, sizes and colors of the mechanical parts automatically. So this system is used to change the current mechanical positioning system. Some of the researches has used the machine vision with digital imaging which uses image analysis as well as processing relied techniques to find the fish quality and assess their quality. Some industrialists are using this machine vision technology to find the quality of food and agricultural products [2].

Figure 1.4: Mechanical part under investigation

Figure 1.4 shows the standard setup for the mechanical part measurement used by various industries.

Further some of the industrialists are using this technology to find the defect in the potato and also specify the size of potato also. Researchers used support vector machine for classification technique which has high accuracy in terms of size matching and classification. Some of the researches had used this defect detection technology to find the various defects on the bearing cover. Authors used projection distribution strategy to find out the defects [2].

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Some of the industrialists have used machine vision technology for automatic detection of defects present on the surface of the material. It includes various types of electronic components. Other machine vision applications include conversion of binary image and digital image processing, correction of position as well as angle, differential level digital image processing to find the detection of various defects in the mechanical parts. Further researchers had used machine vision with linear control systems to cut as well as position the cutting machine of microchips [2].

C. Image Procssing

Image processing is a methodology which is used for converting analog image into the digital image and then some mathematical operators are used for further processing so that an enhanced digital image is received and this image is used to extract some meaningful information. Here the input signal is digital image or may be some video frame and output of the process might be digital image or some attributed of the image. Basically images are generated from sampling and quantization process which is also known as digitization of signal. It is one of the fastest growing technology which have numerous application is various areas of business. It has application is all fields of engineering whether it is aerospace, marine, mechanical, computer science, information technology, civil engineering and many more.

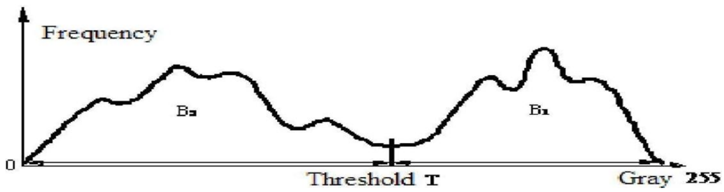

Figure 1.5: The gray frequency diagram with the single object [31]

Digital image processing fundamentally contains three steps
1) Capturing the image with the help of some optical scanner instrument or with the help of digital photography.
2) Second one is the checking and manipulation of digital image which may be enhancement or compression and finding some patterns that are not visible to naked eye like satellite photographs.
3) Third one is output or processed image which is result of second step

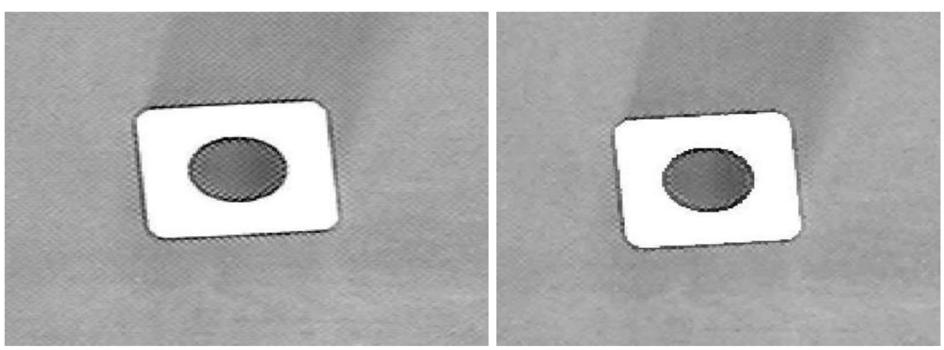
Figure 1.6: 3×3 Filter result by edge preserving filters [31]

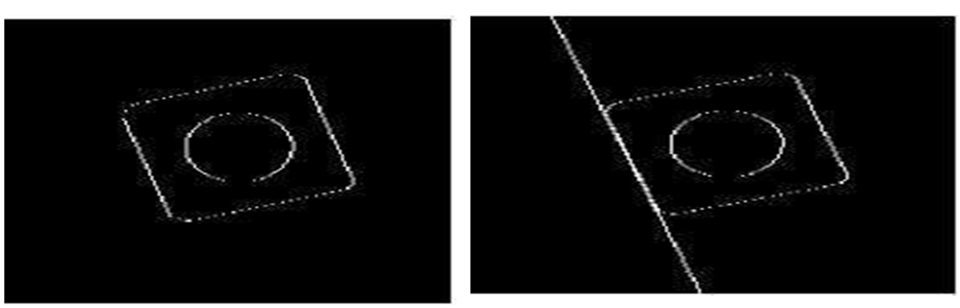
Figure 1.7: Edge detection result and Linear fitting results [31]

Figure 1.6 is showing the results obtained by special class of edge preserving filters. While the figure1.7 shows the edge detection result as well as the linear filtering results.

D. Purpose Of Image Processing

This section shows the five groups which are backbone of image processing.

1) *Visualization:* In this stage objects are observed that are not visible to human eye generally.
2) *Image Sharpening and Restoration:* This stages is used for generating a better image.
3) *Image Retrieval:* It is used for getting the image of interest.
4) *Measurement of Pattern:* It is used for measuring different objects in an image.
5) *Image Recognition:* This stage is used to distinguish the various objects in an image.

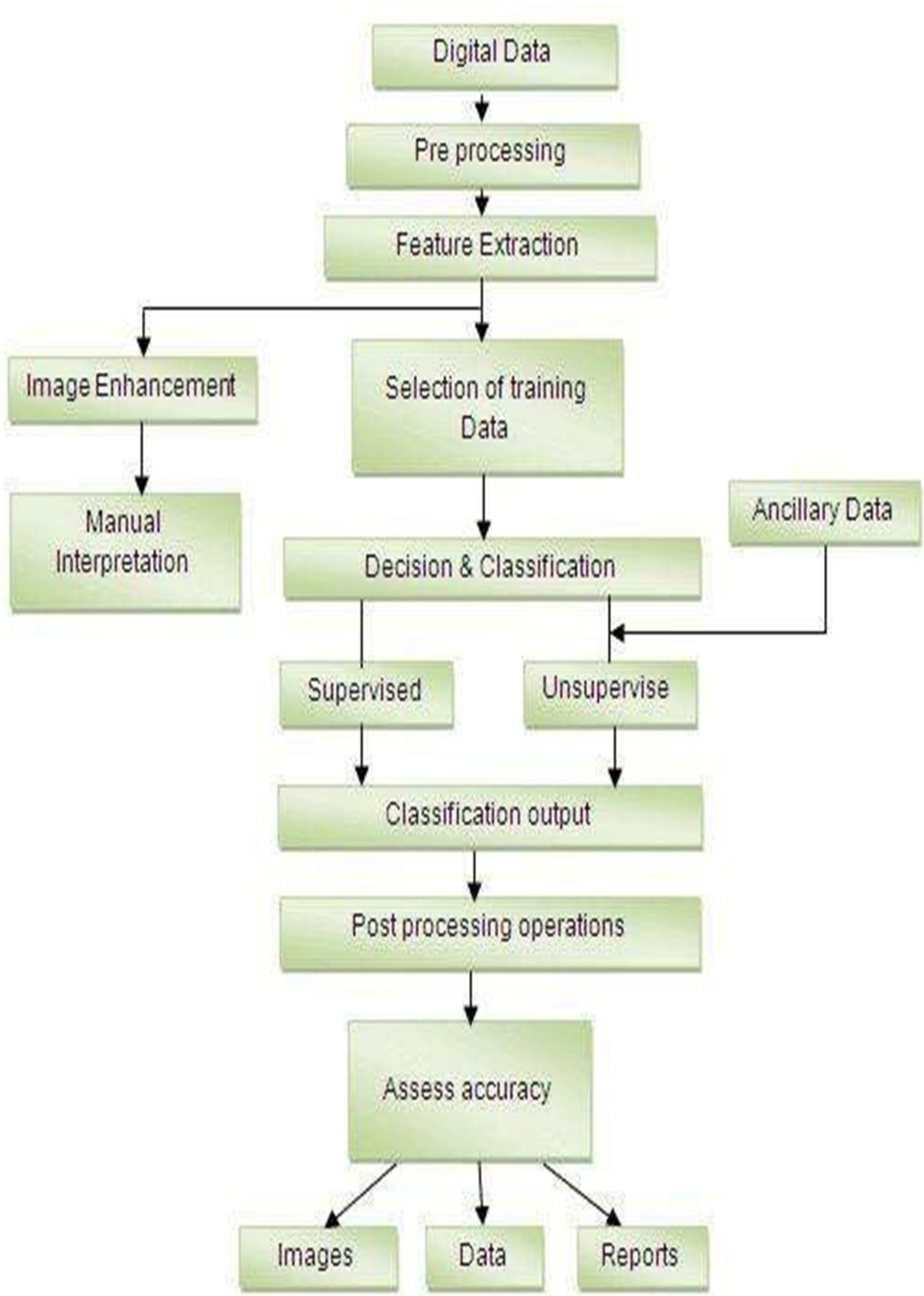

Figure 1.8: Steps of image processing [1]

E. Image Segmentation

Basically it is a process in which a digital image is divided into set of pixels or say in multiple parts so that various objects separated or merged could be identified or to get other meaningful information. This step of image segmentation is considered or regarded as one of the most difficult and complex tasks in digital image processing. Fully automatic segmentation at present still is a very complex process and also domain dependent. So in the last decade an interactive approach of image segmentation is used where a partial supervision is required. Segmentation is connected with the problems of pattern recognition. Image segmentation is supposed to be first step of pattern recognition process and also known as object isolation.

F. Image Labeling

When some object is extracted from an image it means some pixels are identified that make it up. For getting this information there is need of creation of an array of the same size as the original image and then each and every pixel is labeled. If the object is same then for that particular object label is same. Actually label is just a number and could be used for anything like letter or color. Usually labeled images are regarded as the classified images as they indicate the class to which each pixel belongs

G. Hurdles In Segmentation

Image segmentation is considered as the most complex and difficult tasks for various regions. Some of the reasons are explained here.

1) Presence of non- uniform illumination
2) There is no control of the environment variation
3) Inadequate model of the object of interest
4) Presence of noise
5) Presence of other objects

H. Advantages Of Segmentation

Image segmentation algorithms have numerous applications in almost all fields. Some of the applications are listed here.

1) Colorization of Motion Pictures
2) Detection and measurement of parts or instruments in images.
3) Automatic Target Acquisition
4) Optical character recognition (OCR)

I. Types Of Segmentation

There are two types of image segmentation. First one is contextual and second one is non-contextual segmentation.

1) *Contextual Segmentation:* These segmentation techniques additionally use the relationships amid image features. So a contextual image segmentation technique groups together all pixels that have similar pixels and areclose to one another.
2) *Non-Contextual Segmentation:* These segmentation techniques do not use the relationships that exist amid features in an image. Here pixels are simply classified together on the basis of some global attribute.

J. Matlab

Matlab is very well known matrix laboratory which is utilized in the world by various researchers, scientists and also by engineering professionals. This matrix library has a rich set of collections of distinct type of tools for various engineering simulations that can happen in the real world. The Matlab framework has image acquisition toolbox which is used for capturing data by webcam and by any other camera and also has image processing toolbox which is used for manipulating digital images as well as frames of video of various sizes for various others specific purposes. Matlab has specialty that it has variety of toolboxes and features which can be can be used worldwide for unknown tasks. In the present research work this simulation tool is used to solve the specific problem [39].
Matlab word is created by the mixing of two distinct words which are matrix and other one is laboratory. All the matlab copyrights are taken by the parent company MathWorks. Basically it is a technical computing framework which is utilizing C programming language for its business logic and as well as utilizing Java programming language for its front end interfaces. The matlab is used worldwide for its computing performances and for performing scientific complex calculations and also for visualization problems [39].

Figure 1.9: Mathworks logo [39]

Image Acquisition Toolbox provides various functions and as well as blocks for synchronizing and as well as connecting cameras to MATLAB and with the Simulink also. It works by connecting Matlab application that automatically detect and as well as configure the hardware based on its properties. After this the researcher or the user can generate its equivalent Matlab code to automate the process of acquisition in the future sessions. The advantage of this toolbox is that it has variety of acquisition modes like looping, triggering in hardware, background capturing and as well as the performing synchronization among many devices.
This image acquisition toolbox of Matlab supports usually all the major standards and as well as the almost all hardware vendors which includes USB vision, GigE and GenICam and many more. User can handshake with the machine vision special cameras and also with the high-end scientific and as well as with the industrial devices.
Other toolbox which is used for capturing images and video frames is known as Image Processing Toolbox that has very deep and as well as have complex functions and contains various algorithms which works with the aid of computer graphics. This toolbox usually supports every type of image format like jpg, png, tif, dicom and etc. are all supported by this toolbox. Various types of preprocessing and as well as processing, enhancement functions are present so that software can help user to get specified result. Also the detection and recognition of objects and shape analysis can also be performed quite easily [39].

II. LITERATURE SURVEY

L. Zhang et al. [1] in 2019 studied the various mechanical parts dimension measurement methods which was relied on image recognition and tried to improve the related concept. In their research authors first designed a measurement method and then they analyzed the formation of noise, and then de- noised using selecting a fast median filtering algorithm. Edge or boundary extraction was performed with the help of polynomial interpolation which was applied to the sub-pixel edge location. Other morphological operators are also used to extract the objects completely. Authors demonstrated that with the help of morphological gradient operators edges could be effectively refined. After performing different experiments, the mean detection time of the supposed measurement method for precision standard mechanical parts was found to be 0.0156 s which was very good and the measurement limit error was found to be nearly +0.007 mm. authors found the measurement accuracy reached approximate to 1 micrometer, and also the measurement reliability was also high which showed the worthiness of the measurement system.
D. Zhang et al. [2] in 2016 proposed object detection model which had two novel ideas. First one was the use of convolutional neural network with hidden layers to find the semantic properties of the object and second one was the use of neighboring pixels values so that it could be helpful to suppress the background regions. Authors explored the object properties using windows property of the images. Calculation of different co-saliency values was performed with the Bayesian estimation which added the advantage of combined effect of contrast and separability. These values were then converted into maps by foreground region strategy. Authors performed various experiments and showed the overall consistent performance benefits of the proposed approach.
Y. F. Li et al. [12] in 2015 introduced a dimension parameter measurement system which was relied on machine vision as well as digital image processing. In this setup the proposed dimension measurement system took mechanical parts as the target by using cameras for image acquisition and then further image processing, edge detection and geometric elements location was performed for the noncontact measurement of mechanical parts. From the results authors showed that the proposed setup was feasible and the measurement efficiency of mechanical parts was also increased considerably. Authors used the Visual Studio 2010 platform and programming is done with C++. The supposed mechanical parts dimension measurement model had two parts. First one was the hardware system and the second one was the software system. The hardware system consisted of the image acquisition devices and a computer while the software system contained the fundamental modules of image capturing, image preprocessing and detection of geometric elements as well as dimension measuring mathematical models.

H. Ali et al. [17] in 2014 worked on the improvement of gear profile management system safety as well as reliability and presented an effective measurement system which was based on computer vision. In the scenario of the precision engineering the gear measurement system had wide importance. Authors found that with the help of camera there would be increase in safety as well as reliability of the precision measurement.

Further authors stated that for increasing the reliability of the measurement system it should be automatic. Usually contact relied measurement system was used for measuring gear profiles. Authors found that in case of gear measurement to avoid accident we should be very cautious as the stylus was sharp as well as thin and if it collided with gear teeth then there would be maximum chances of its breakage as well as its scattering. Authors implemented the color relied stylus tracking algorithm which showed very good reliability for the gear profile measurement system.

K. D. Lawrence et al. [21] in 2014 successfully used the hybrid feature of machine vision and image processing and developed an efficient automatic dimension measurement model for the the measurement of the dimensions of the cylinder bore. For this the authors increased the efficiency of the image processing algorithm and tried to conduct different iterations so that various defects could be detected of the cylinders. This was because of the reason that strain appeared in mechanical properties of materials. The results showed by authors were reliable.

G. Li et al. [23] in 2014 proposed a technique to measure the normal strain with the help of machine vision methodology with quite good precision values. In this technique authors modeled the use of planar projection so that there is no need of imaging measurement system coplanar with the measured plane. Authors used the translational displacements of the known value for finding the values of some of the model parameters. Further authors utilized the concept of correction of distortion so that there would be good precision in the measurement method.

Authors used the pixel coordinates of the image center and also scale factor. Authors performed various experiments so that the accuracy of the supposed method could be verified with other methods and also find various factors which could change the measurement outcomes. The outcome of the experiment showed that result obtained from the experiment had very small errors and were closed to the results obtained from the extensometer.

A. Ayub et al. [22] in 2014 proposed a computer vision method which was used to inspect the roundness error. Authors used the camera with work holding tools and as well as lighting instruments and digital image processing software for the measurement of roundness of the mechanical parts.

Authors took the camshaft specimen of the cylindrical part. The prime aim of the study was to calculate the error in the roundness measurement in between the manual and the machine vision proposed method.Authors used the lighting instruments to provide enough light so that high contrast digital image of the particular portion of the specimen was achievable. Authors used the cylindrical parts which had diameter of around 46 mm and were processed by digital image acquisition and as well as processing

C. Qiu et al. [37] in 2012 proposed a mechanical and as well as computer vision method which was not contact for the dynamic measurement of the shaft components.

Authors used the Sobel edge operators from the edge detection masks so that edges could be easily gathered from the visual of the shaft component. Authors used the least square technique for locating the edge subpixel locations so that discrete points could be fitted on the edges of the digital image.

Authors performed calibration with the gain consideration when the value of k was increased then the size of the specimen was exact as it was for the actual size. From the results it was found that the precision of the measurement system was reliably improved and further it was found that the value of error was less than ±15um with the condition that CCD camera resolution should be near to 1392×1040 pixel and the pixel size was around 4.65um.

E. S. Gadelmawla [38] in 2011 developed spur gear parametric automatic measurement model with the help of computer vision technology. The developed model was based on the non contact method and was fast and showed quite good accuracy by inspection methods. The proposed system had utilized camera for taking digital images for the size measurement of the gears. The software developed had been named as Gear Vision and used the Microsoft Visual C++ as programming language. This software used the camera to capture the digital images and then outputs the measurement results. Then comparison was performed between the calculated parameters and the original values of the gear specimens. The original values of spur gear specimens were taken with the help of MITCalc software which was generally used for Mechanical, Industrial and Technical Calculations for various gear designs. Further authors found that the maximum contrast was found to be ±0.101 mm amid the calculated and the original parameters of design spur gear having outer diameter of 156 mm

III. PROBLEM FORMULATION

Industrial machines are designed from the various mechanical parts. These mechanical parts play a huge significant part in different regions of economy of country and so are manufactured in huge quantity worldwide. The mechanical parts parametric dimensions measurement is the important step in the manufacturing process. There are various traditional methods which are used to find the size some of these are calipers, gauges etc. Now these machines are easy to handle. But when you have to measure the dimensions of huge specimens then efficiency will become very low and also the efficiency of human also becomes low. So it becomes nearly impossible to measure the dimensions of each product in mass production at satisfactory level.

So there is need of some alternative method that can find the measurement of the dimensions of the mechanical parts accurately as well as rapidly so that human intervention is less and so human error will also be low. The work was carried on Digital Image Correlation System, 230V, 50Hz at KC Steel (J&K).

IV. RESEARCH GAP AND OBJECTIVES

A. Research Gap

After having a comprehensive literature survey, the various research gaps that were identified which are described here :

1) Reliability of dimension measurement of mechanical parts
2) Time consumption is measurement of dimensions in case of mass production
3) Human error arises as mass production increases

B. Research Objectives

This research work will be focused to achieve the following objectives

1) To design, study and implement the non-contact dimension measurement system of mechanical parts.
2) System could be able to detect the dimensions of one part at single time.

V. RESEARCH METHODOLOGY

A. Research Methodology

The following steps will be performed to complete this research work

1) Take pictures of the various machine parts.
2) Create the algorithm to find the dimension of these parts
3) Perform the experiment.
4) Check the parametric values of these results with the traditional tools.
5) Check the accuracy of result obtained from the given model.

B. Mechanical Parts

In this research experiment, the precise standard mechanical parts with an average diameter of 10 mm to 100 mm will be used to find the diameter of these parts automatically. The measurement limit error of the measurement should be small as much as possible. The diameter measurement procedures are repeated 10 times on the all testing mechanical parts. Various image processing algorithms are used to find out the position and location of the edges accurately.

C. Image Processing Setup

The experimental procedure for the measurement of size of various mechanical parts is discussed below:

1) Capture the digital image of the mechanical part with image acquisition module.
2) Now apply the image processing to enhance the digital image.
3) Remove the various types of unwanted signals like noise points using various filters present in the digital image
4) Perform the digital image segmentation to separate foreground from the background.
5) Morphological operations will be applied to find out edges or boundaries of the part.
6) Try to find out the centre of the outermost boundary so that centre of the mechanical part digital image can be detected.
7) Find out the radius from the centre to the boundary using the Euclidean distance formula.
8) Perform the experiment 10 times to get the valid results.

VI. RESULTS AND CONCLUSION

A. Results

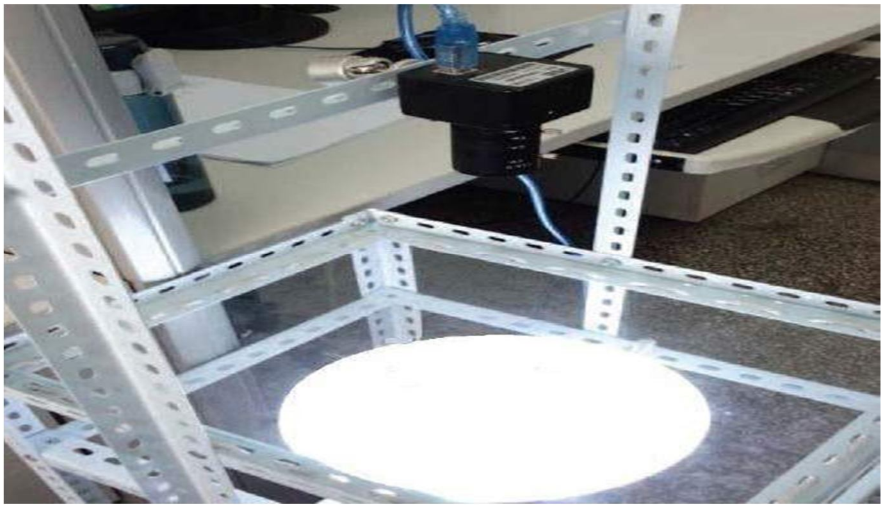

Figure 6.1: Hardware system for size calculation of mechanical part

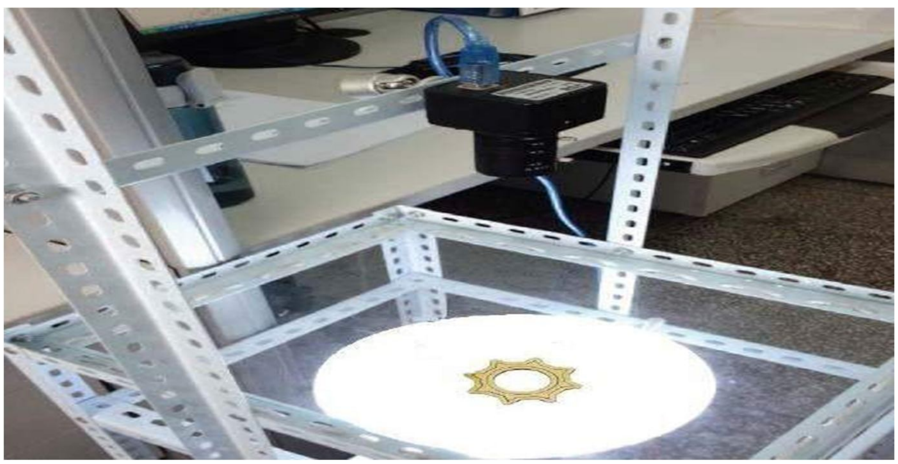

Figure 6.2: First part under inspection

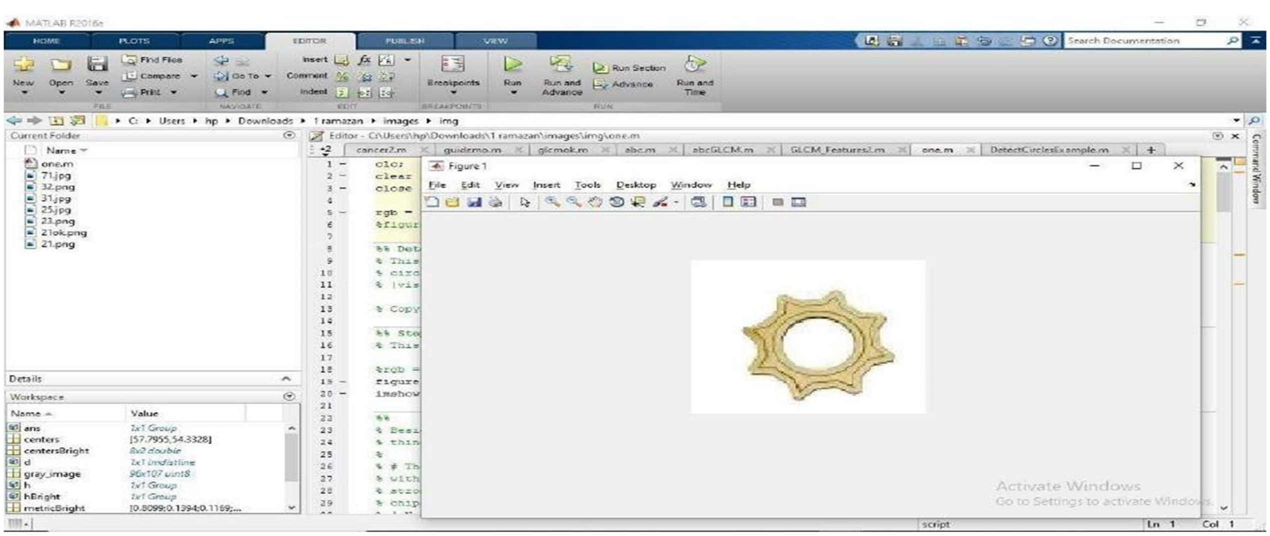

Figure 6.3: First part under Matlab inspection

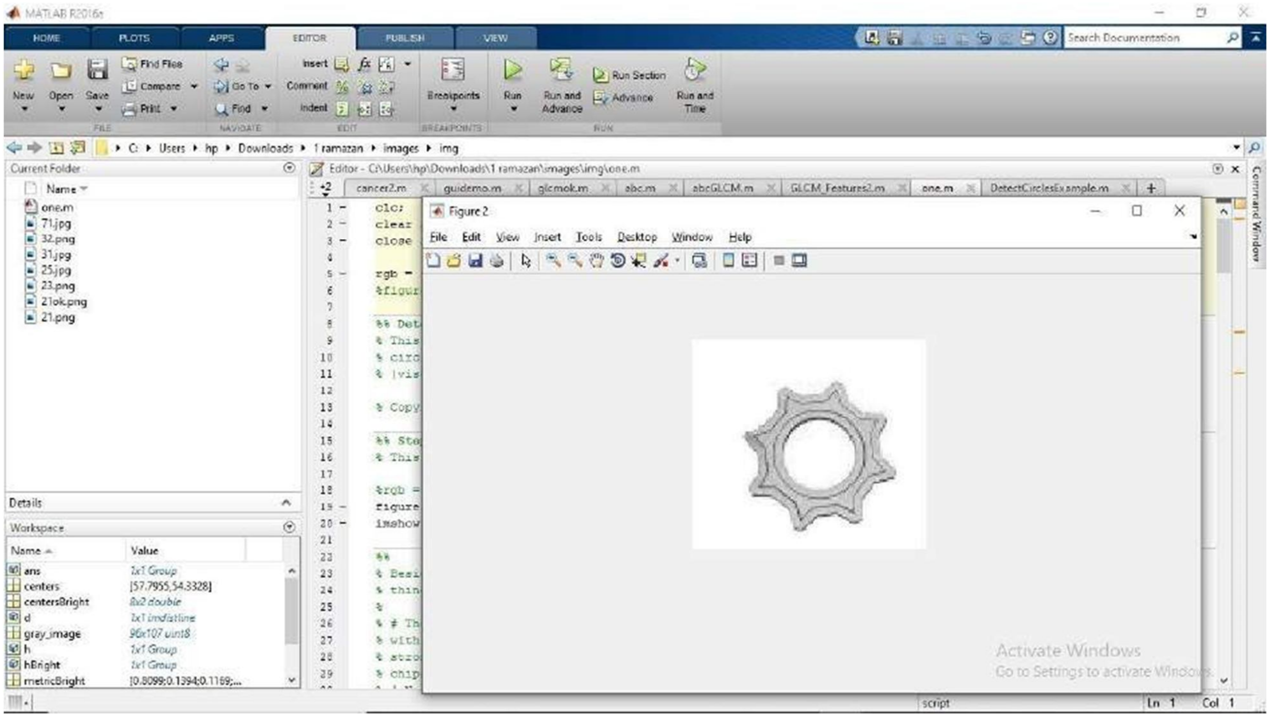

Figure 6.4: First part under Matlab inspection showing gray scale image

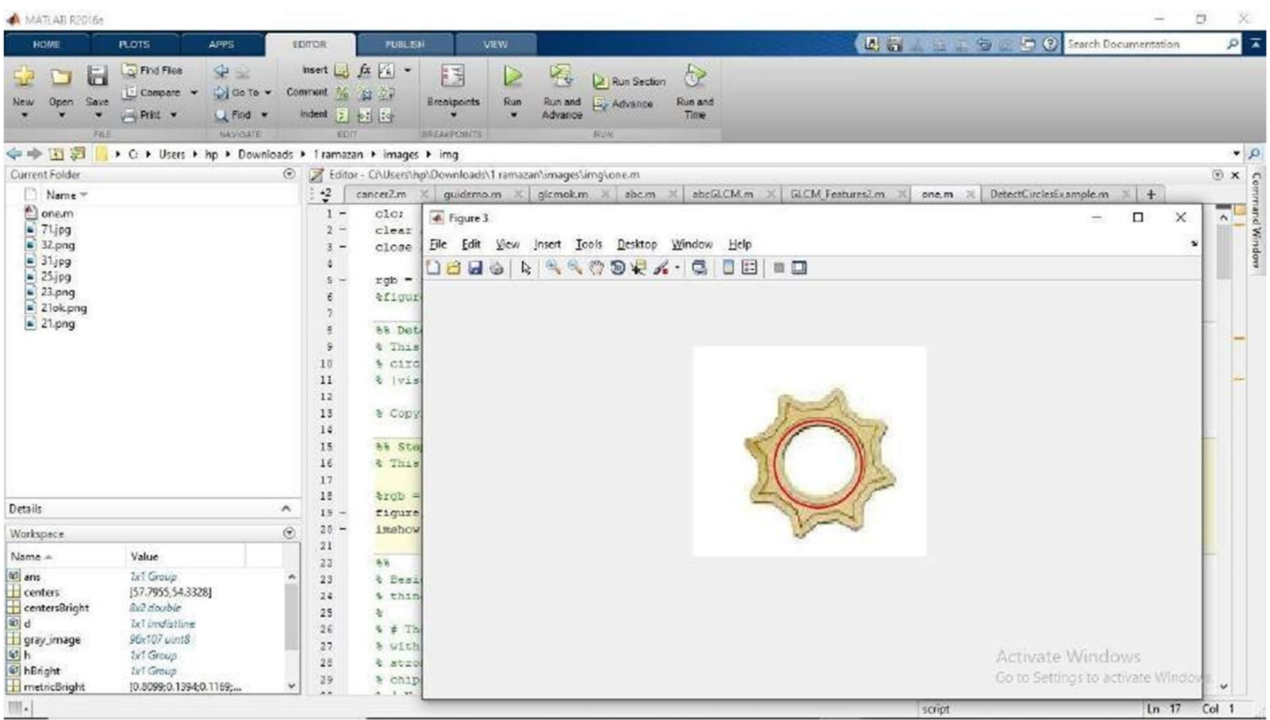

Figure 6.5: First part under Matlab inspection showing final image with diameter estimation

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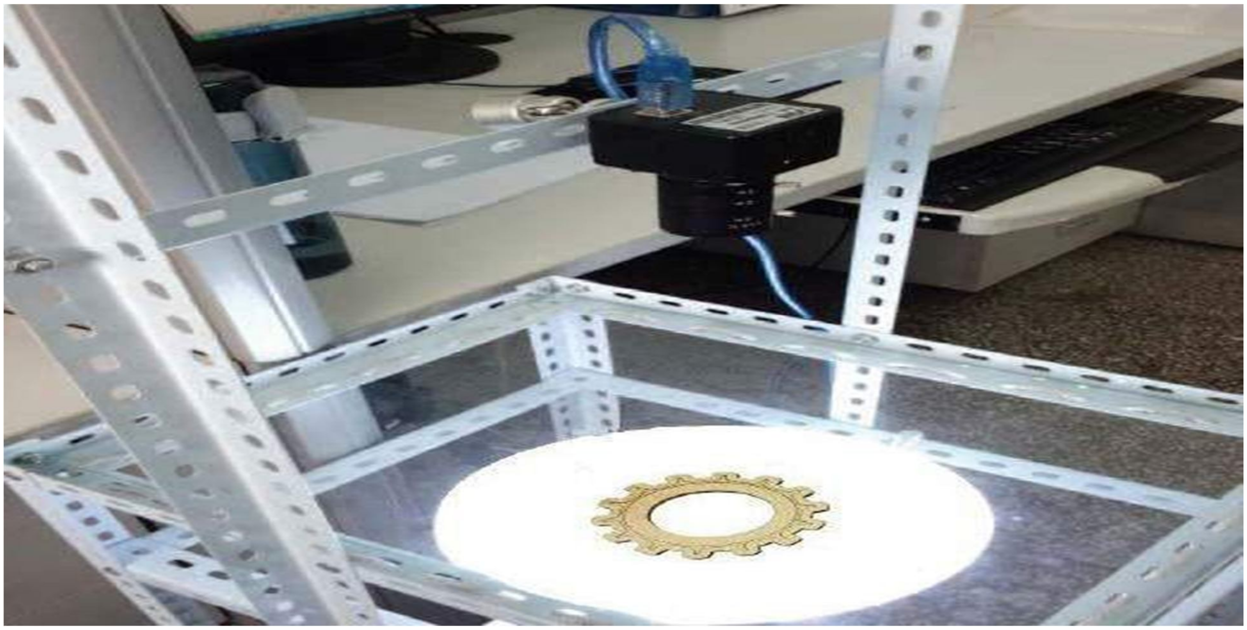

Figure 6.6 Second part under inspection

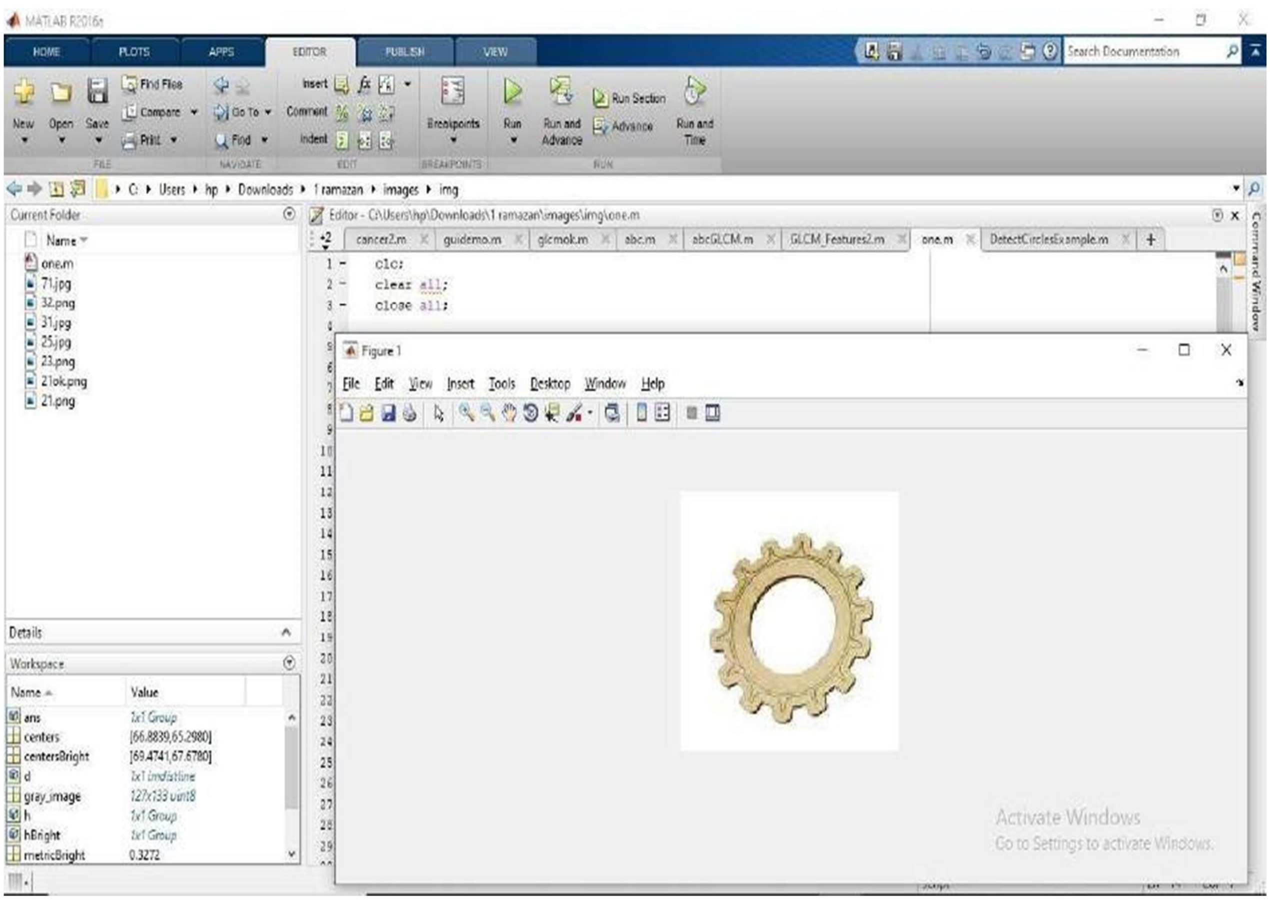

Figure 6.7: Second part under Matlab inspection

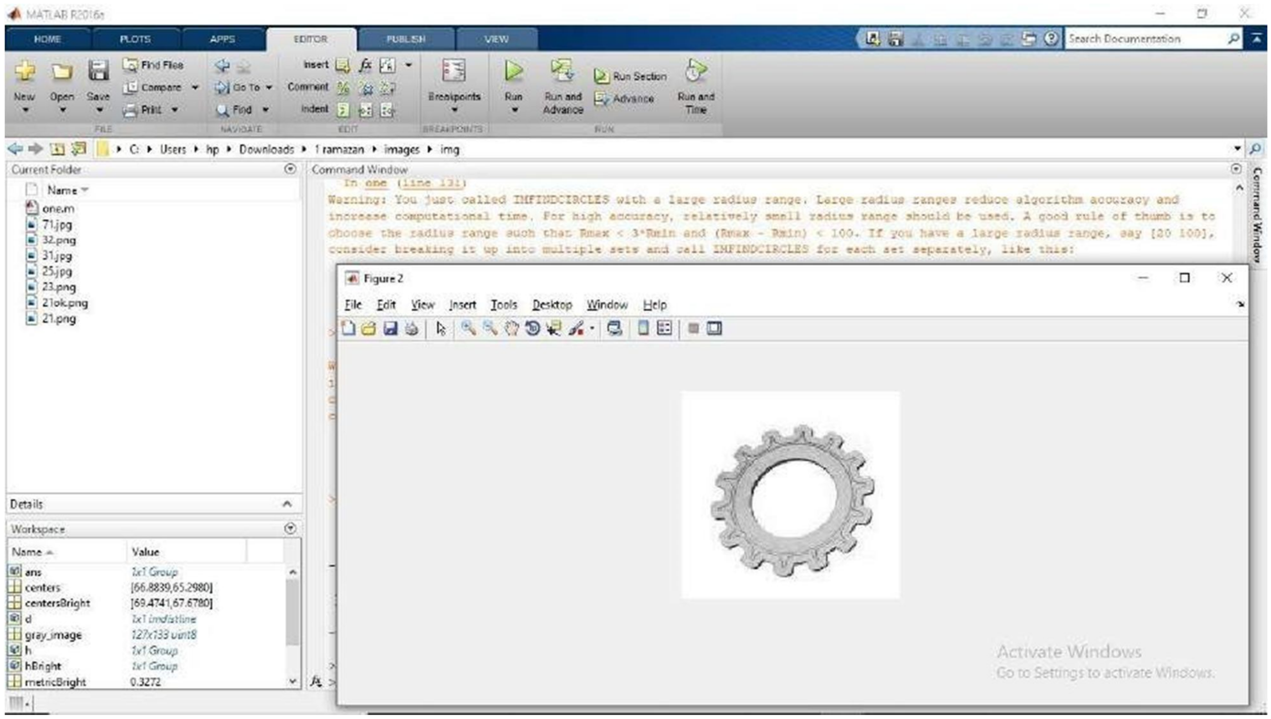

Figure 6.8: Second part under Matlab inspection showing gray scale image

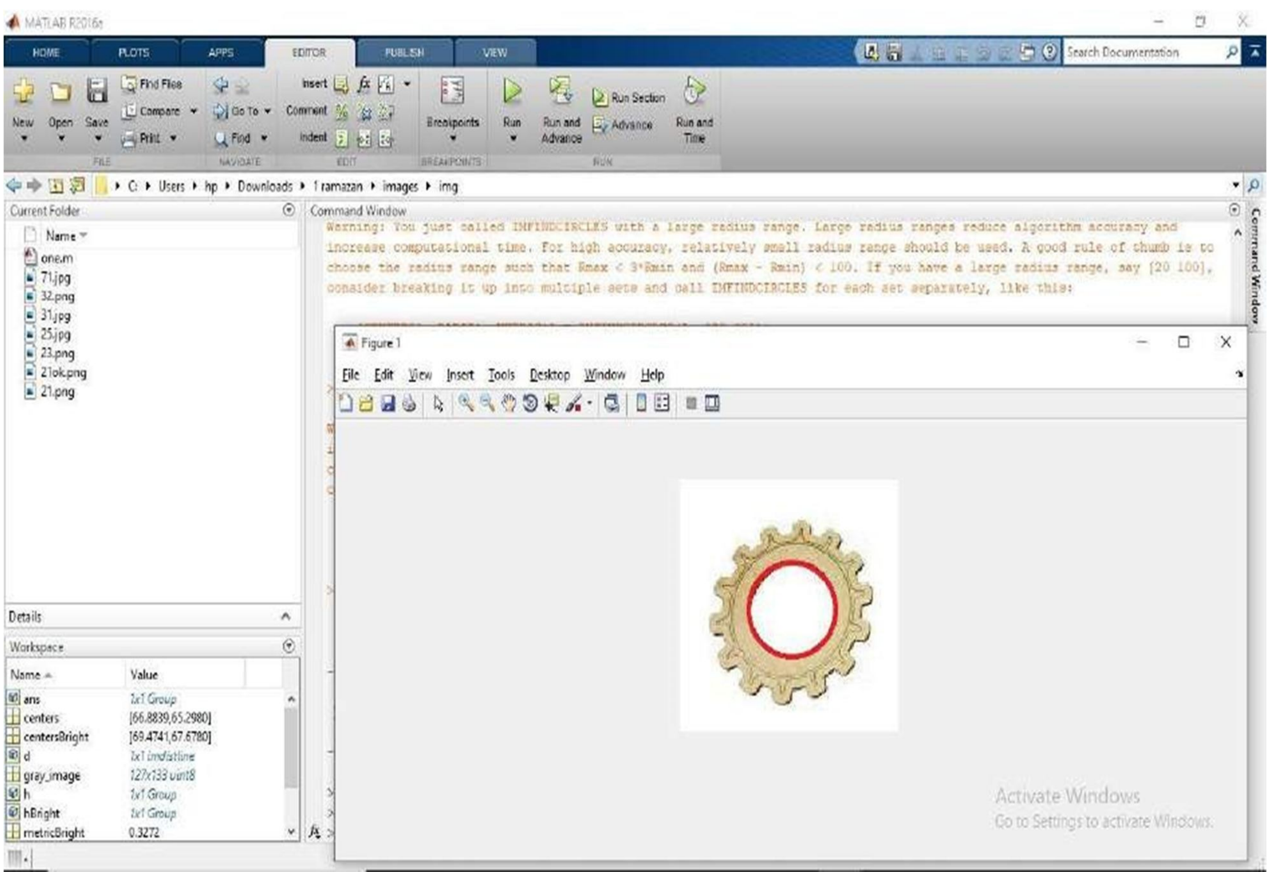

Figure 6.9: Second part under Matlab inspection showing final image with diameter estimation

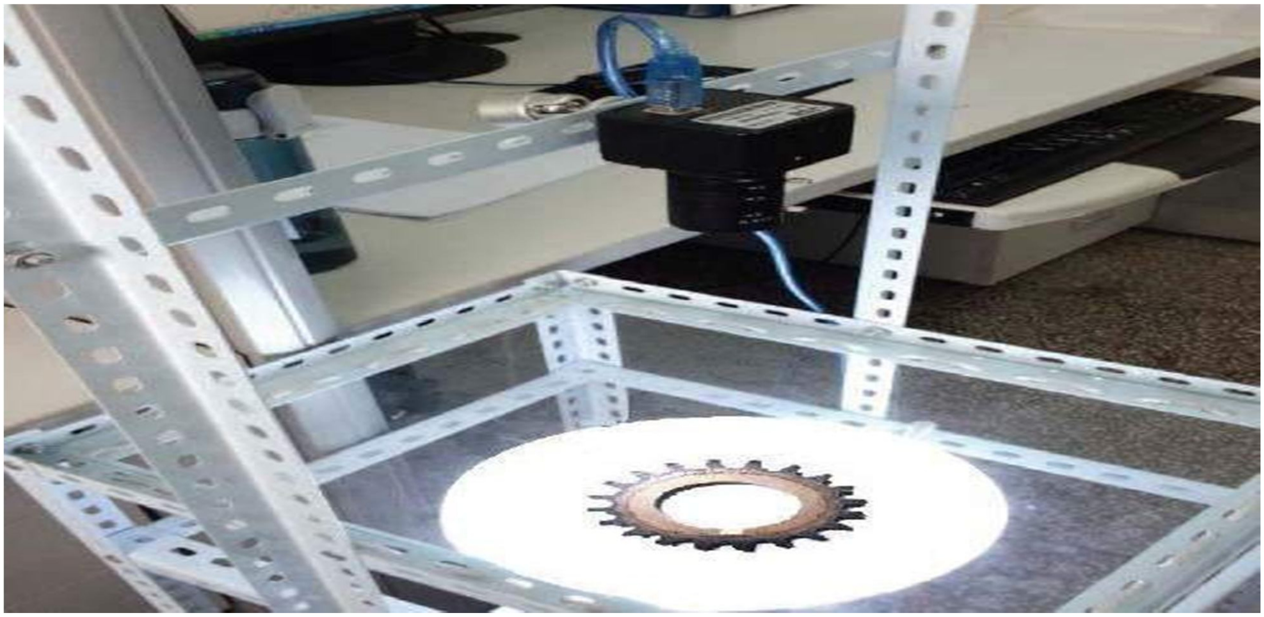

Figure 6.10: Third part under inspection

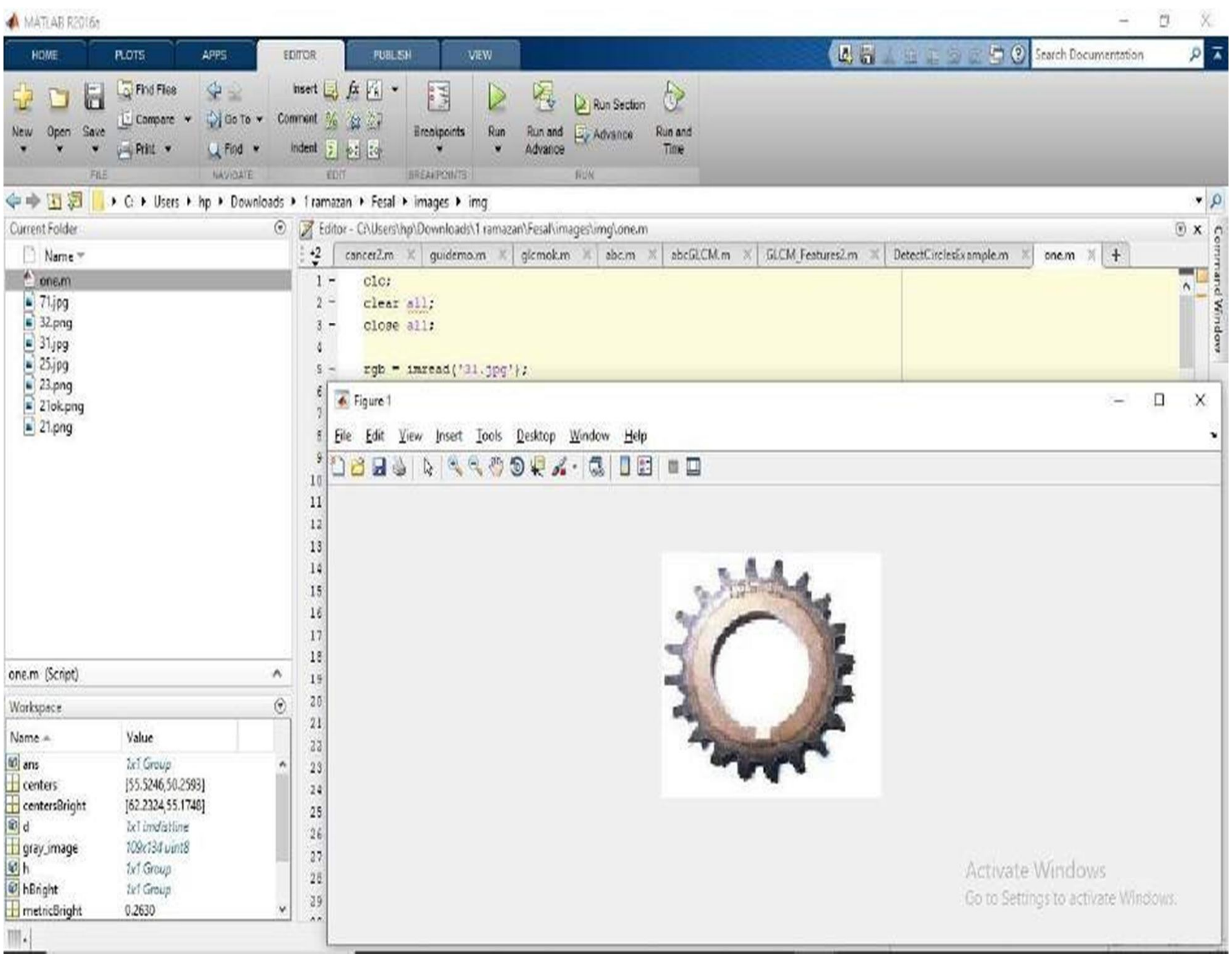

Figure 6.11: Third part under Matlab inspection

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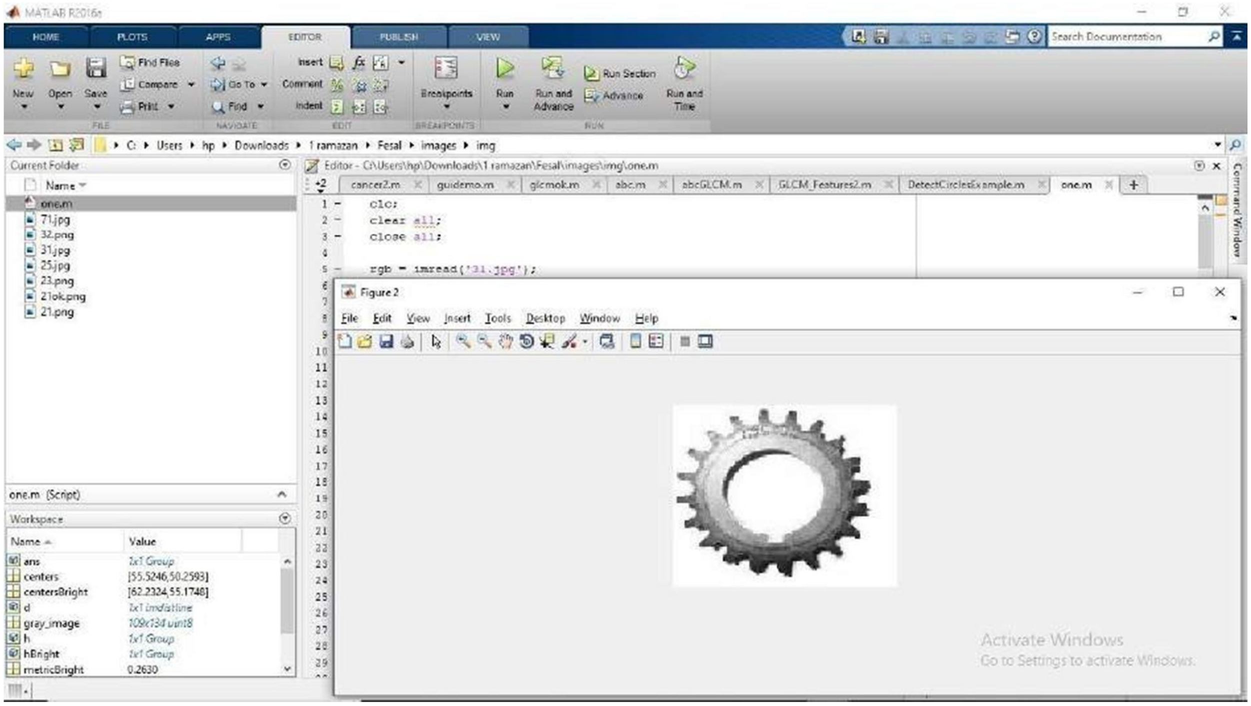

Figure 6.12: Third part under Matlab inspection showing gray scale image

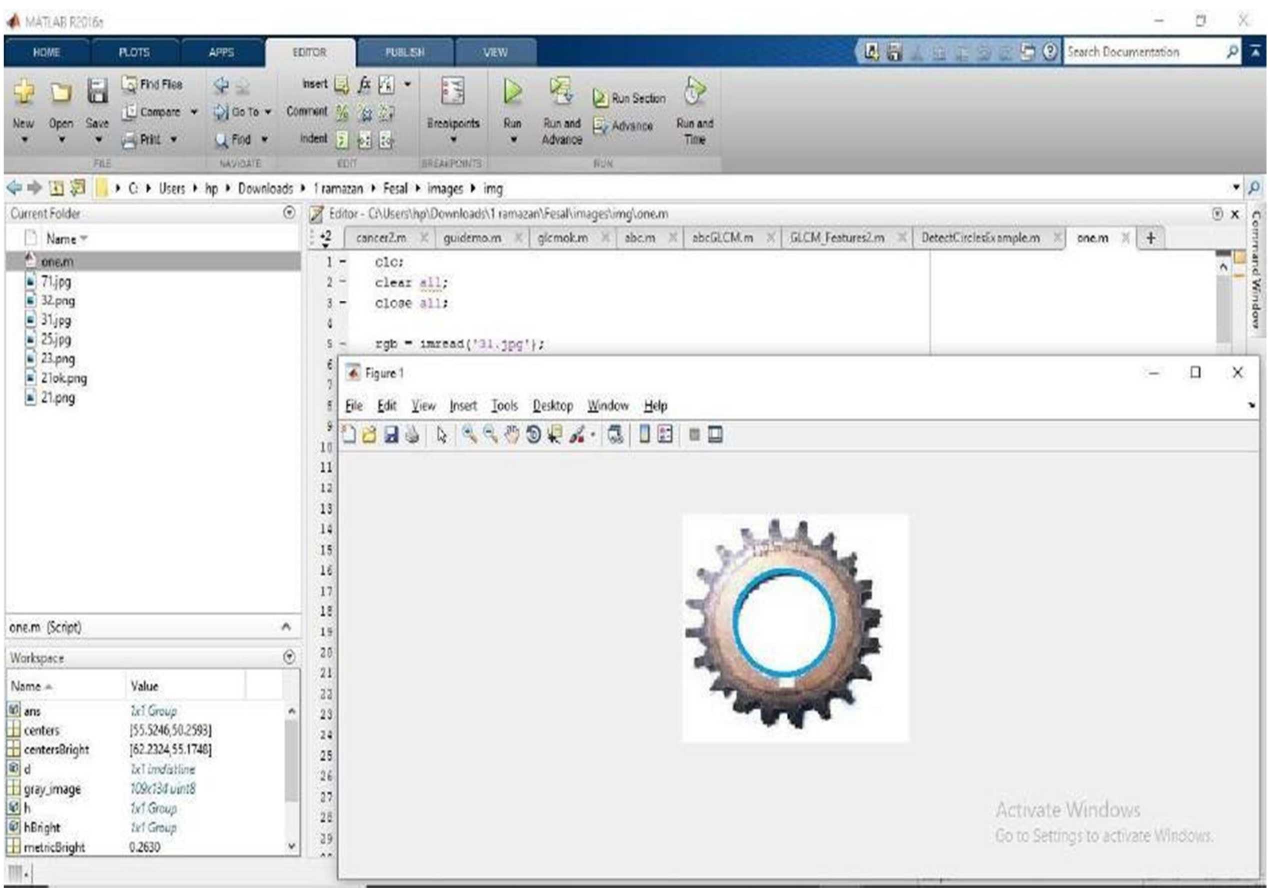

Figure 6.13: Third part under Matlab inspection showing final image with diameter estimation

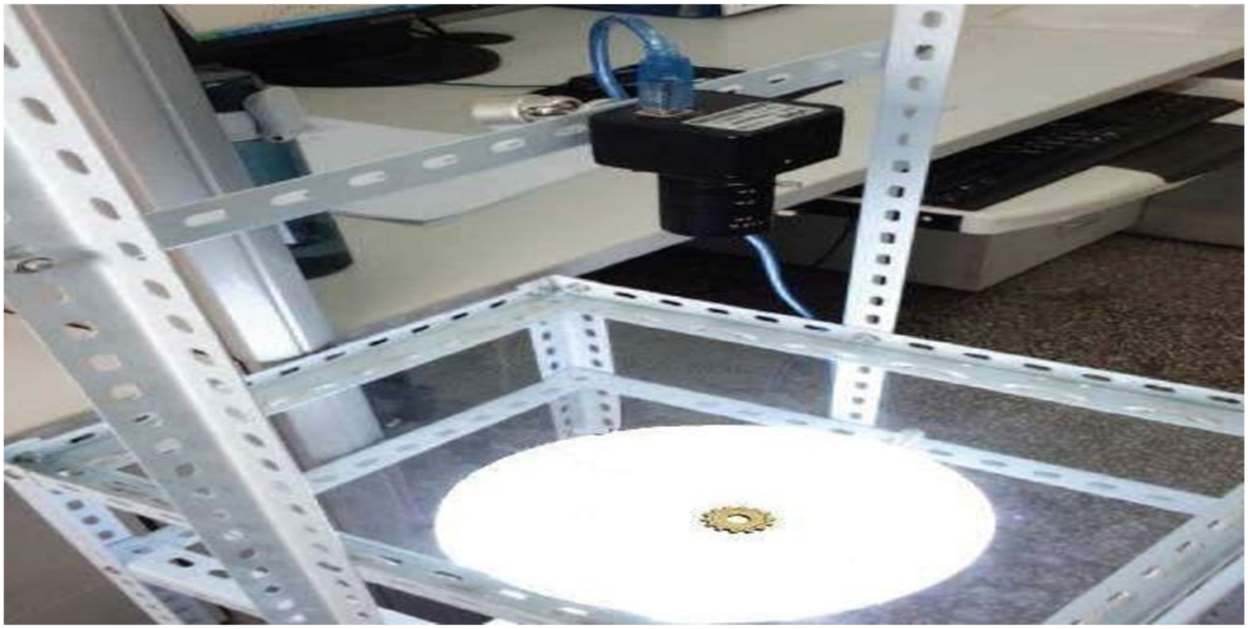

Figure 6.14: Fourth part under inspection

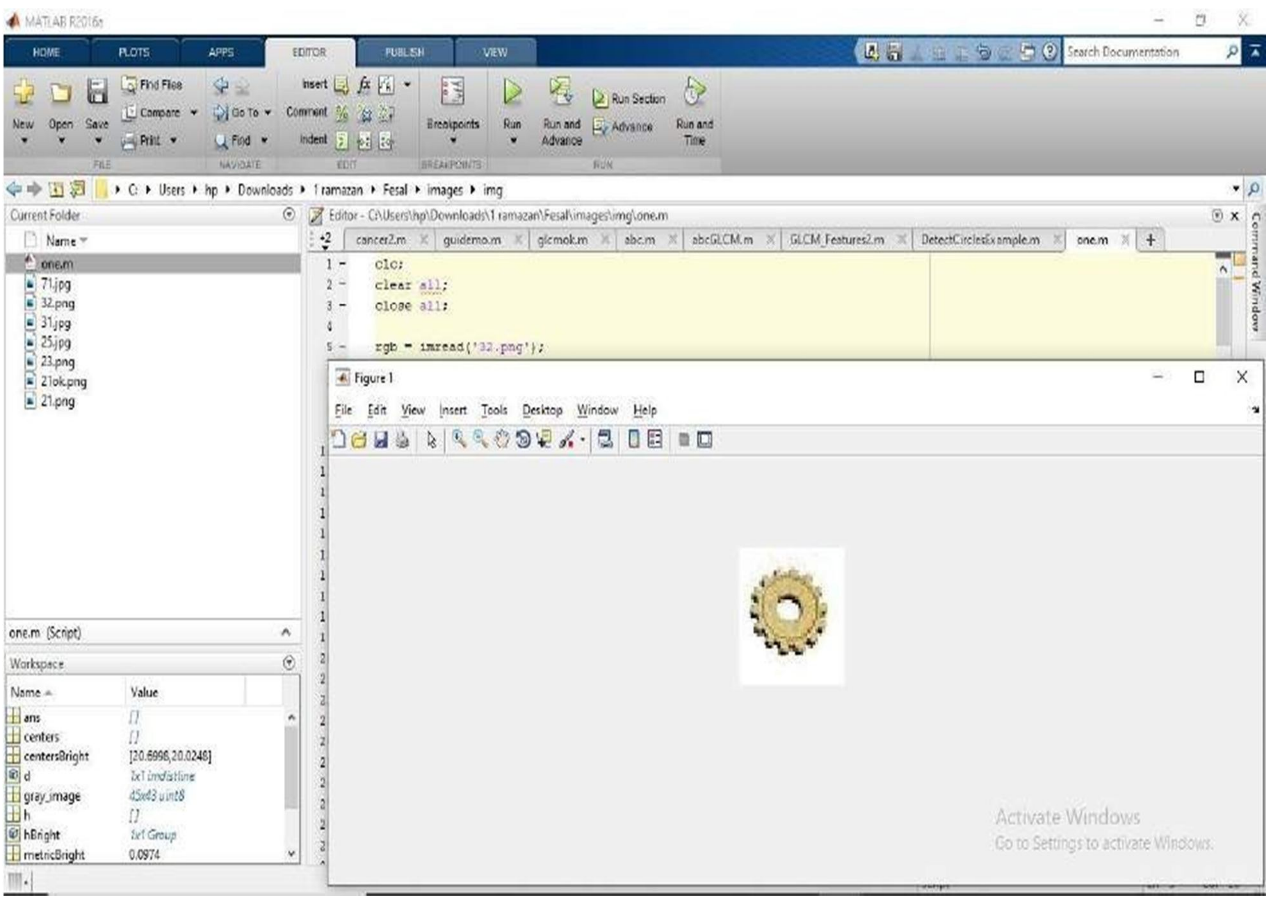

Figure 6.15: Fourth part under Matlab inspection

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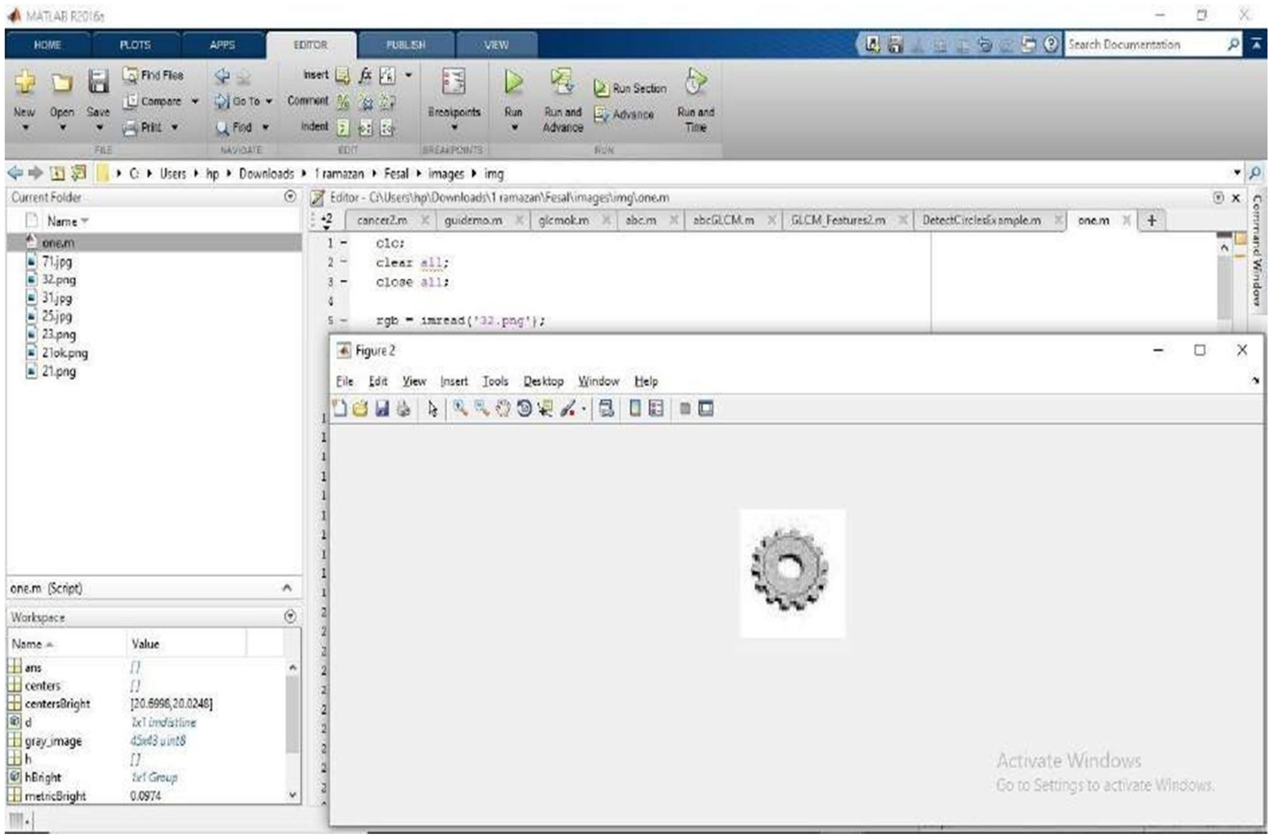

Figure 6.16: Fourth part under Matlab inspection showing gray scale image

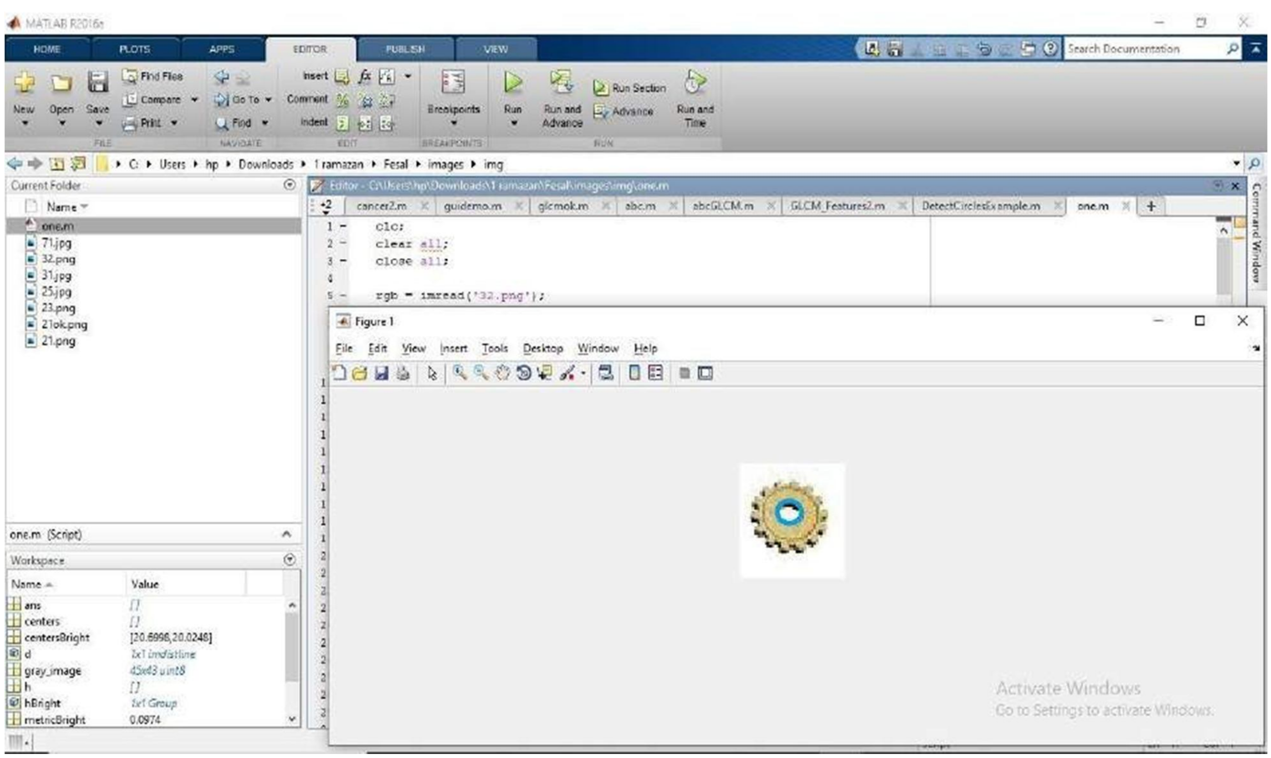

Figure 6.17: First part under Matlab inspection showing final image with diameter estimation

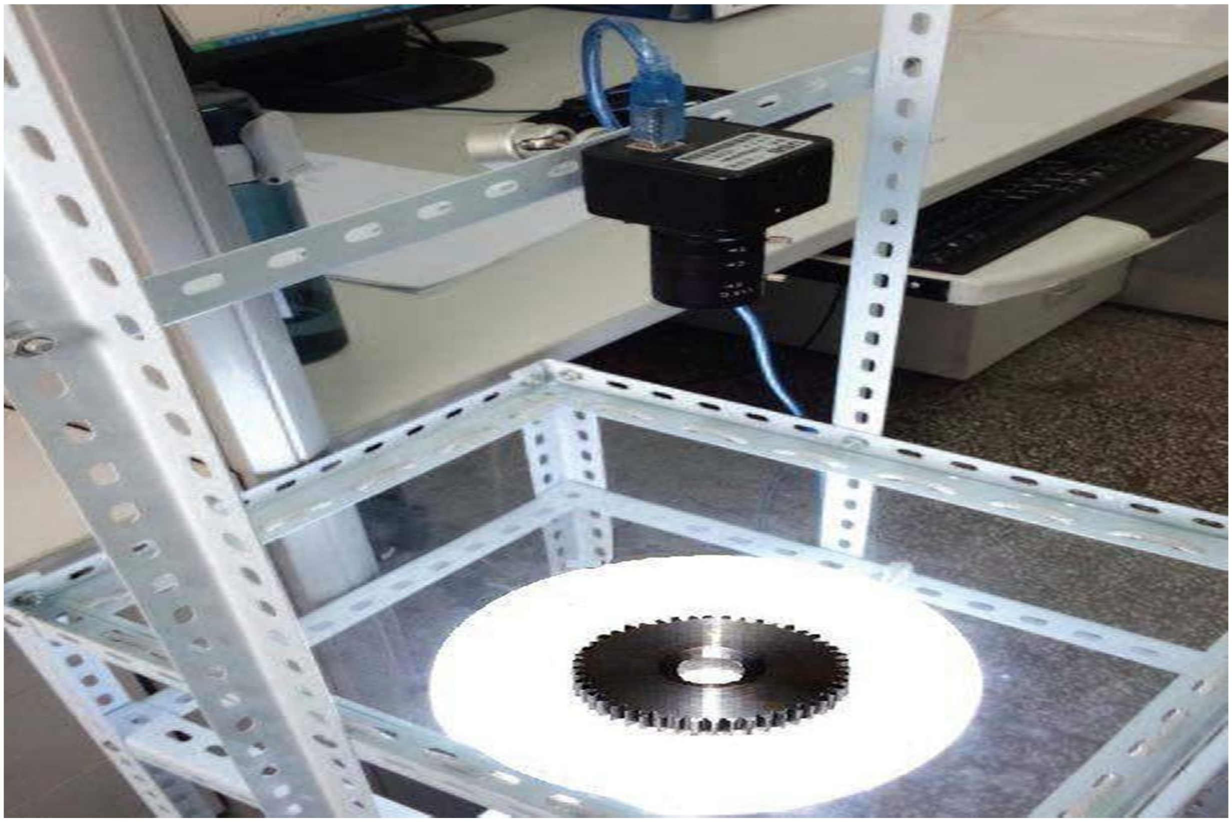

Figure 6.18: Fifth part under inspection

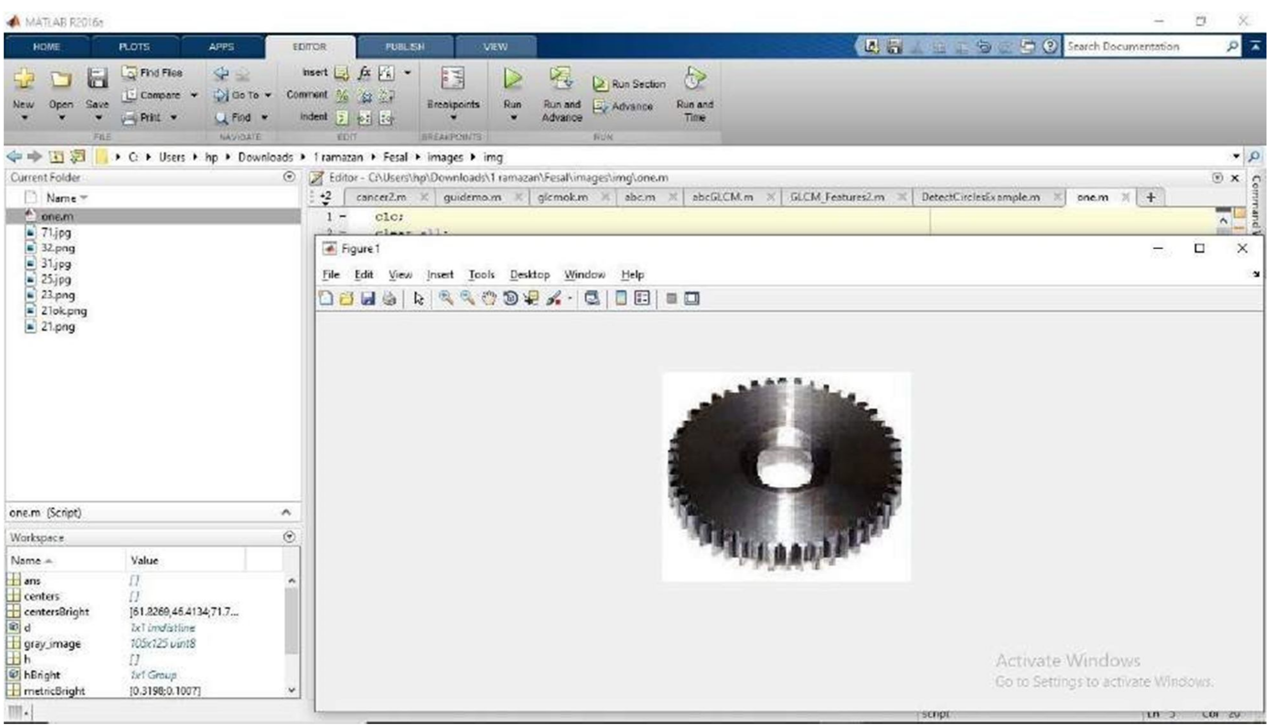

Figure 6.19: Fifth part under Matlab inspection

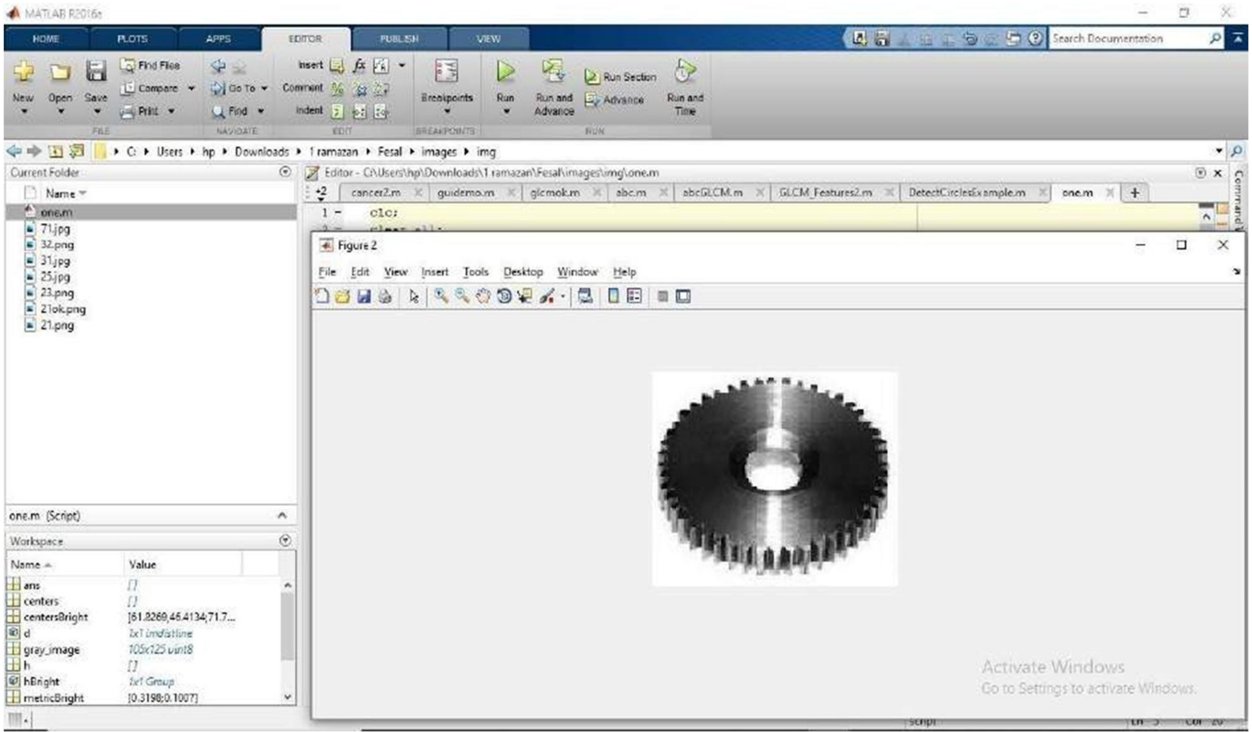

Figure 6.20: Fifth part under Matlab inspection showing gray scale image

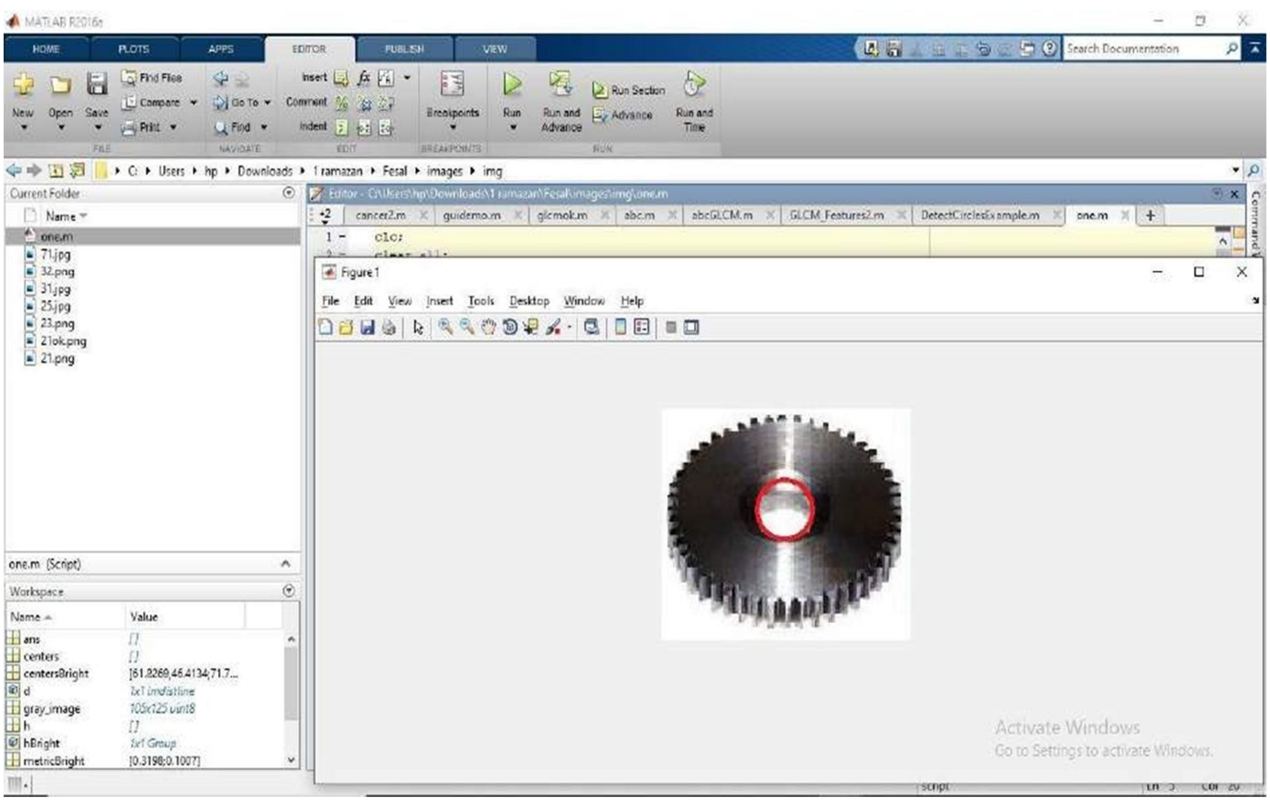

Figure 6.21: Fifth part under Matlab inspection showing final image with diameter estimation

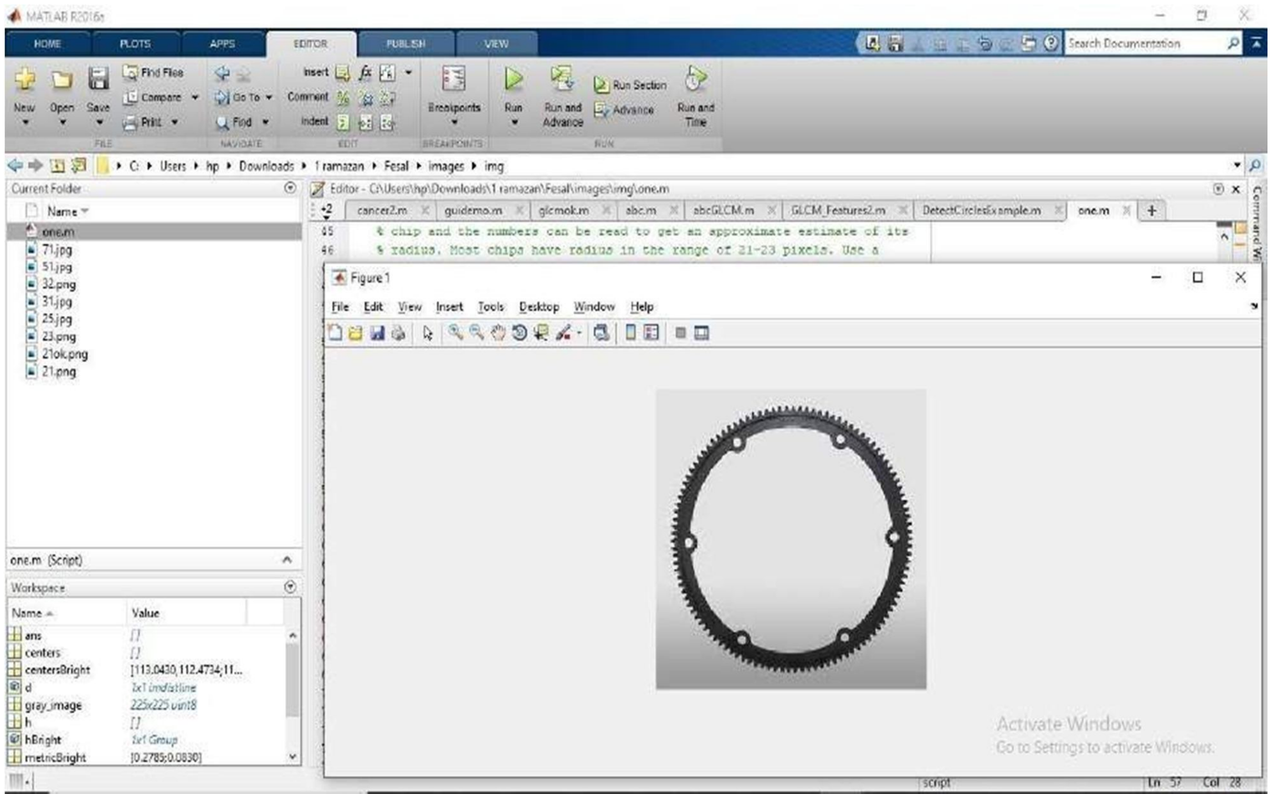

Figure 6.22: Sixth part under Matlab inspection

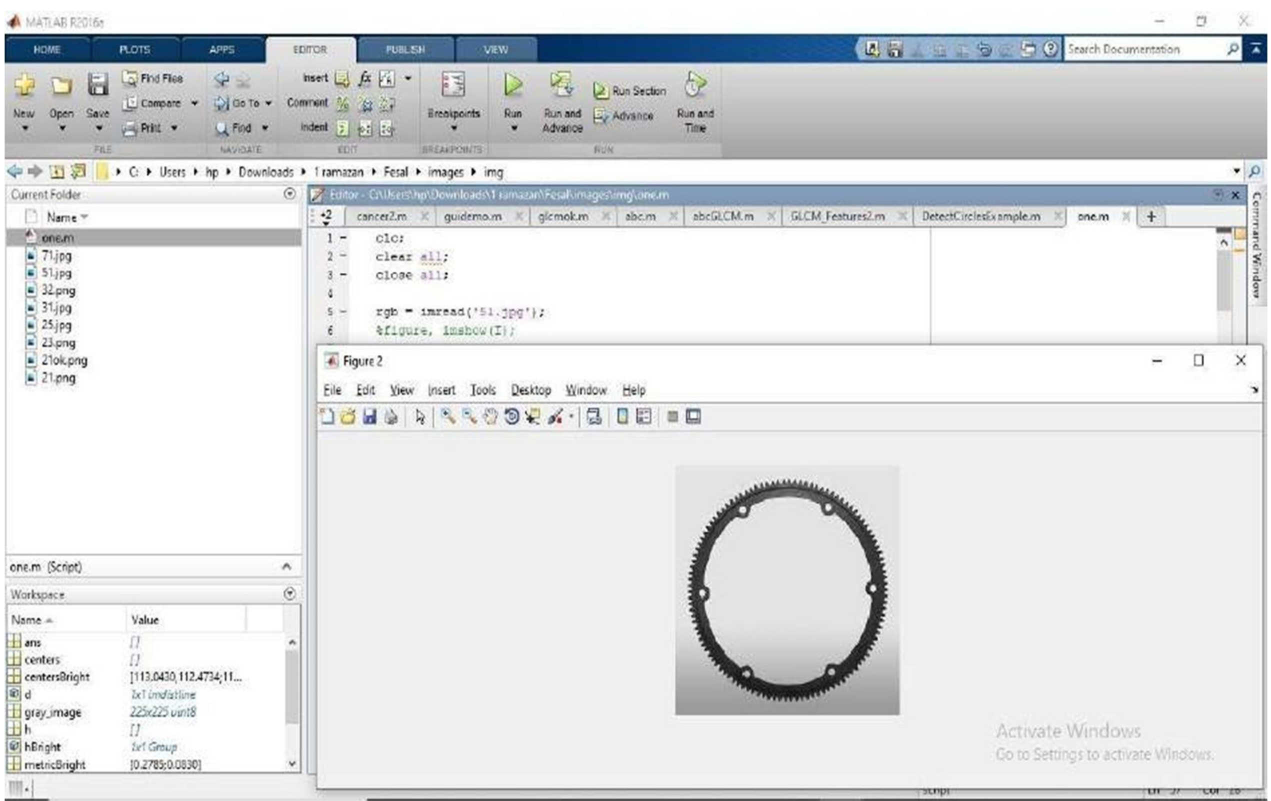

Figure 6.23: Sixth part under Matlab inspection showing gray scale image

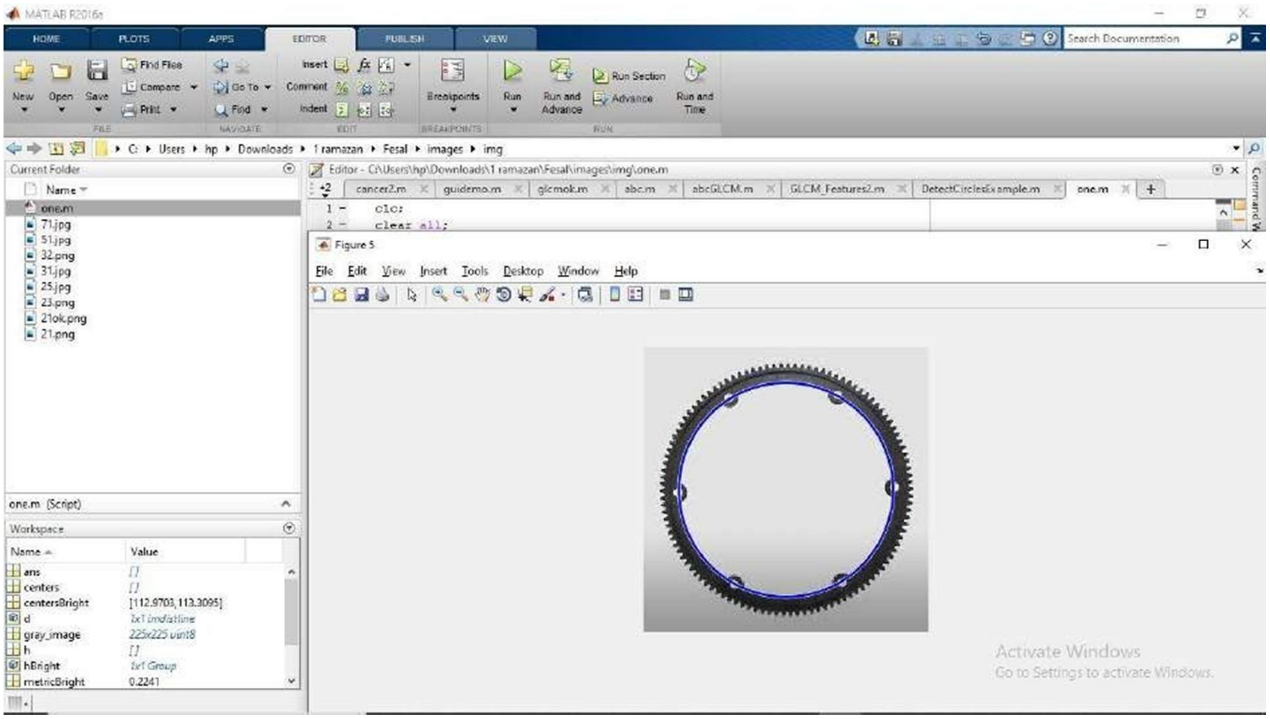

Figure 6.24: Sixth part under Matlab inspection showing final image with diameter estimation

Table 6.1: Comparison of actual and obtained diameters

	Actual Dia.	Measured Dia.	Difference	Result Estimation
First	8.01	8.00	-0.01	OK
Second	10.02	10.03	+0.01	OK
Third	12.03	12.01	-0.02	OK
Fourth	2.01	2.03	+0.02	OK
Fifth	4.05	4.06	+0.01	OK
Sixth	16.03	16.04	+0.01	OK

B. Conclusion
From the overall observations it is found that the proposed method gives very good results which are in comparison to standard method of measurement of mechanical parts. This non contact measurement system is very fast and reliable. This system is designed for just one part measurements only. This machine vision dimension measurement system gives very small difference in actual and measured values. This proposed system can be used in measuring the sizes of various mechanical parts.

C. Future Work
In the future work algorithm can be designed to measure dimensions of various parts in single click. It means one can find the dimensions of several parts at one moment. Also the algorithm can be designed to give accurate length and other parameters.

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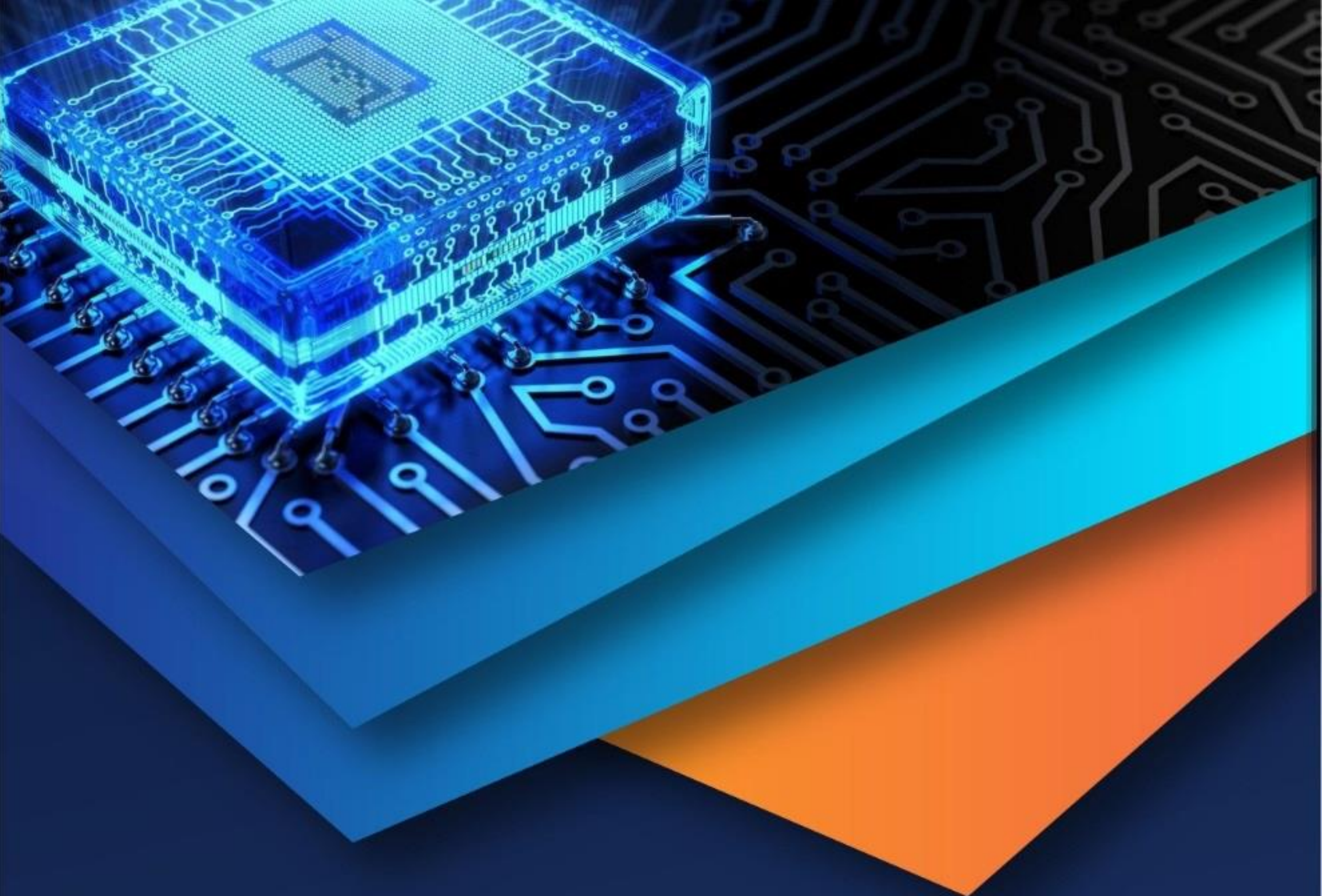

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