

**Automated Dimensional Inspection of Mechanical Parts  
In Mass Production using Image Processing**

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A Final Year Project Report

Presented to

**SCHOOL OF MECHANICAL & MANUFACTURING ENGINEERING**

Department of Mechanical Engineering

NUST

ISLAMABAD, PAKISTAN

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In Partial Fulfillment  
of the Requirements for the Degree of  
Bachelor of Mechanical Engineering

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by

Kamran Shafi Khan

Mohammad Ahmad

Mohammad Saad

Huzaiifa Irfan

Batch 2019

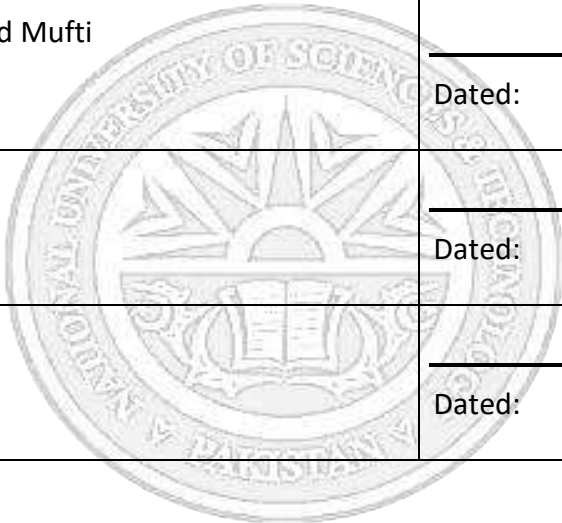
## **EXAMINATION COMMITTEE**

We hereby recommend that the final year project report prepared under our supervision by:

Kamran Shafi Khan	CMS ID # 284772
Mohammad Ahmad	CMS ID # 286378
Mohammad Saad	CMS ID # 282514
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Titled: “Automated Dimensional Inspection of Mechanical Parts in Mass Production using Image Processing” be accepted in partial fulfillment of the requirements for the award of Mechanical Engineering degree with grade \_\_\_\_

Supervisor: Dr. Riaz Ahmad Mufti	_____
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# Automated Dimensional Inspection of Mechanical Parts in Mass Production Using Image Processing

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**Abstract**—This abstract outlines the development of a dimensional inspection machine as a part of our final-year project. The report details the software techniques and algorithms being utilized, including image processing techniques such as image graying and binarization to identify the mechanical part's features. The image's contours are then extracted and compared with a reference image that has precise dimensions. At the same time, a method is employed to ensure that the corresponding contours of each image match with each other. The part is then inspected by setting a threshold of the difference between the contours of the two images. Experimental results demonstrate that the proposed method delivers an accuracy ranging from 250 to 100  $\mu\text{m}$ . For the hardware, a simple metallic structure is constructed which consists of a supporting base and four columns on top of which our camera is mounted. For lighting, we are using back-light technology to give us clear black-and-white 2D images with clearly identifiable features.

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## I. INTRODUCTION

In today's rapidly changing manufacturing landscape, quality control is a crucial aspect of any production process. One of its critical procedures is the dimensional inspection of manufactured parts, which ensures that each part meets the required specifications. Traditional methods of dimensional inspection are time-consuming, expensive, and prone to human error, especially in mass production.

### A. Modern Technology

The emergence of computer vision and image processing techniques provides an opportunity to automate the inspection process, significantly reducing the time and cost involved, while improving accuracy and consistency.

### B. Proposed Design

This report presents a novel approach to a smart and automated method of inspecting manufactured parts. The proposed system employs efficient computer vision algorithms and techniques to perform robust dimensional analysis. The results of this research can contribute to improving the quality

control process in mass production, and ultimately increasing profitability for manufacturers.

## II. LITERATURE REVIEW

This section provides a brief overview of the existing literature and research related to digital inspection. The review covers various topics, including the current state-of-the-art techniques and algorithms used in computer vision for dimensional inspection, and the challenges and limitations associated with these techniques.

TABLE I  
REVIEW OF RESEARCH PAPERS ON DIGITAL INSPECTION

Research Paper	Findings
Webcam based system for press part industrial inspection [1]	Use of CMOS technology that produces 10 times less noise as compared to CCD. Limited only to press parts
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A machine vision-based method of high-precision measurement of the size of workpiece [5]	Used a 5 MP industrial camera with panoramic imaging and the Hessian Paradigm line fitting technique to achieve a high level of accuracy of 15 $\mu\text{m}$

### A. Conclusion

In conclusion, the use of image processing techniques in the inspection process has gained significant attention in recent years. The section reviewed, the research material available for improving dimensional precision and achieving measurement accuracy. However, most studies have limitations in terms of sample size, generalizability, and environmental factors. Expensive commercial products exist that solve high-end industrial challenges and accuracy but our aim is to locally develop such machines with a good amount of accuracy. In short, the use of image processing techniques has great potential in improving the efficiency and accuracy of dimensional measurement.

## III. METHODOLOGY

The core principle of our methodology is to compare the parts to be measured to a reference part of the same batch. The reference part will be measured and the dimensions will be stored which will then be compared to the dimensions of the rest of the parts of the same batch. The difference between these dimensions will be calculated to check if the parts are in accordance with the tolerance or not.

Two libraries were considered for the purpose of image processing for dimensional inspection. One is OpenCV and the other is Dilib. OpenCV is a very well-documented and versatile library and offers a wide range of Image Processing functions. Dilib is also good for quantitative analysis but is not well documented which poses difficulties.

### A. Using DipLib

#### 1) Image Loading and Pre-processing:

- `dip.ImageRead` opens the image in RGB format.
- `dip.ColorSpaceManager.Convert(image, 'gray')`: Converts the image to greyscale
- `img.SetPixelSize(value, 'mm')`: Set the pixel size of image in terms of mm.



Fig. 1. Loaded Grey-scale Image

#### 2) Object Extraction:

##### • **dip.Gauss:**

A Gaussian distribution serves as the kernel of the convolutional filter known as the Gaussian filter. Each pixel in the image is subjected to the filter by being convolved with the Gaussian kernel together with its nearby pixels. By using this technique, key details and edges are preserved while high-frequency noise and abrupt transitions in the image are reduced.

##### • **dip.Threshold:**

Gaussian filtering is followed by thresholding to provide a binary image of the item. Thresholding divides pixels into foreground (object) and background depending on a set threshold value, converting a grayscale image into a binary image. Gaussian filtering is a smoothing technique that improves key elements in an image while lowering noise.

##### • **dip.EdgeObjectsRemove:**

Small connected regions that may not be a part of the primary object are removed from the area surrounding the image boundary.

3) *Noise Removal:* **dip.Opening** and **dip.Closing:** Removes noise from the binary image by opening and closing operations. Opening is a process of erosion and dilation that eliminates small foreground areas while leaving the bigger object's general size and shape intact. Closing, which fills in tiny cracks and crevices in the foreground, is dilatation followed by erosion.

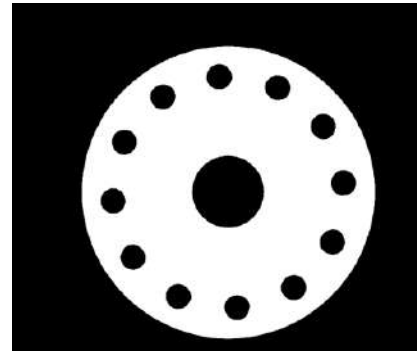


Fig. 2. Thresholded Image

#### 4) Measurement:

##### • **dip.Label:**

Label the binary image's connected elements. It gives each connected region (object) in the image a special identifier.

##### • **dip.MeasurementTool.Measure():**

It measures the area of each of the labeled region in terms of pixels and converts the pixels into mm as set by `img.SetPixelSize`. It also measures the circularity of the labeled regions which determines how close the region is to a circle.

5) *Calculations of Dimensions:* The formula for calculating the diameter of each contour is given by:

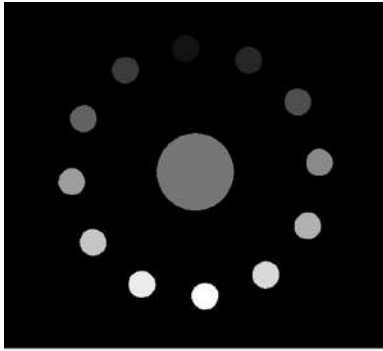


Fig. 3. Each Feature is Color Labelled

$$Diameter = 2 \times \frac{ObjectArea}{\pi} \quad (1)$$

In code form, the size and circularity of each feature is given by:

	Size	Circularity
	(mm <sup>2</sup> )	
1	57.24	0.008481
2	56.61	0.007530
3	56.08	0.01039
4	56.17	0.008318
5	55.49	0.01078
6	461.7	0.002227
7	56.47	0.01043
8	55.24	0.01117
9	55.99	0.01156
10	55.06	0.008574
11	56.47	0.01194
12	55.98	0.009362
13	55.39	0.01336

The diameters in mm are given below:

110.38464191462222  
8.55494178354087  
8.502478448178252  
8.458369660182038  
8.46601676999589  
8.40886051675724  
26.019082288258545  
8.491495346302687  
8.388062369918618  
8.451511763966563  
8.373435919441341  
8.491495346302687  
8.449920811601118  
8.401266564372307

## B. Using OpenCV

### 1) Reading and Pre-processing of the Image:

- **cv2.imread:**  
Reads the image in a BGR format.
- **cv2.cvtColor(image, cv2.COLOR\_BGR2GRAY):**  
Converts the BGR image to grayscale.

This step performed produces the same result as shown in Fig. 1 using the DipLib library.

### 2) Thresholding and Image Blurring:

- **cv2.GaussianBlur:**  
Apply Gaussian blur to the image in grayscale. Using a Gaussian kernel to convolve the image, the widely used blurring technique known as "Gaussian blur" lessens image noise and smoothes off the edges.
- **cv2.threshold(binary+otsu)[1]**  
Apply Otsu's thresholding technique on the blurred image to perform thresholding. The ideal threshold value is automatically determined by Otsu's approach based on the image histogram. The maximum value to be assigned to pixels over the threshold is 255, and the thresholding method is specified by the variables cv2.THRESH\_BINARY+cv2.THRESH\_OTSU. The function gives back a tuple, and [1] gets the image that was thresholded.

### 3) Morphological Operations and Edge Detection:

- **cv2.dilate(thresh, kernal, iterations=1):**  
Utilises a kernel to apply dilation on the thresholded picture. The morphological process of dilation enlarges the edges of the objects in a picture. The structural element used for dilation is defined by its shape and size by the kernal parameter. The number of times that dilation is used is controlled by the iterations option.
- **cv2.erode(dilate, kernal, iterations=1):**  
Erosion is applied to the enlarged image. The morphological process of erosion removes the borders of objects in an image. It is the opposite of dilation. Like cv2.dilate(), the function's parameters are same.
- **cv2.Canny(erosion, Low, High):**  
Apply the Canny edge detection technique to the eroded image. By analyzing gradients in the image and using hysteresis thresholding, the Canny algorithm finds edges. The low and high threshold levels for edge connecting are represented by the Low and High parameters.

### 4) Contour Detecion:

- **cv2.findContours(edges, cv2.RETR\_CCOMP, cv2.CHAIN\_APPROX\_SIMPLE):**  
This function finds the contours in the edge detected image.
- **cv2.RETR\_CCOMP:**  
It is the contour retrieval method that retrieves all the contours and arranges them into a two-level hierarchy (external and internal contours).
- **cv2.CHAIN\_APPROX\_SIMPLE:**  
It is a technique for approximating contours that saves

only the ends of horizontal, vertical, and diagonal segments while compressing the rest.

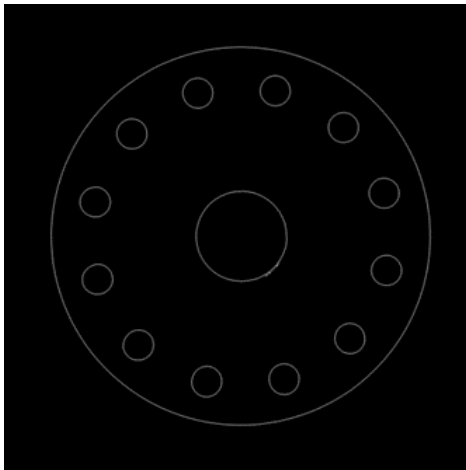


Fig. 4. Canny Edge Detected Image

5) *Circle Detection*: **cv2.minEnclosingCircle(cnt)**: This function takes the contours as the input and finds the minimum enclosing circle for each of the contours by calculating the center and radius of the smallest circle that encloses the contours.

6) *Measurement*: The proposed method for dimensional inspection of parts involves the following steps.

- 1) Firstly, an image of the reference part is provided, and its dimensions are recorded as the reference. This image serves as a baseline for comparison.
- 2) Next, the mm-to-pixel ratio is established for each feature of the reference part. To accomplish this, the user clicks on each feature, such as circles, in the reference image to define the corresponding mm size. These mm to pixel ratios are then saved for future use. In our case, we have manually saved the values first.

In order to account for variations and allow for flexibility in measurements, a pixel area range is defined for each feature. Some padding is added to the original value to create a reasonable range that accommodates minor variations. This range ensures that measurements within a certain tolerance are considered acceptable.

- 3) When an image of the part to be measured is provided, the method compares each feature of the part to the corresponding feature in the reference image. By matching features, the mm to pixel ratio is determined for each feature of the part. This ratio is then used to perform the necessary calculations for dimensional inspection.

By establishing the mm to pixel ratio based on the reference part and comparing features between the reference and measured parts, this method enables accurate dimensional inspection. It provides a systematic approach to handle variations in measurements and ensures reliable results for assessing the dimensions of parts under inspection.

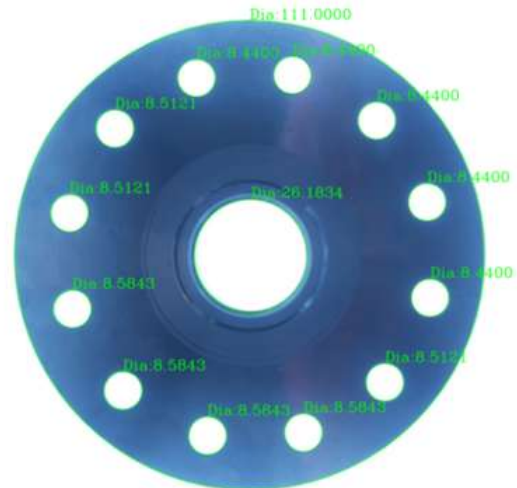


Fig. 5. Output of the Algorithm

### C. Comparison between OpenCV and DipLib

We found OpenCV more suitable for our task for the following reasons:

1) *Image Processing Capabilities*: OpenCV offers a wide range of image processing functions that are well-suited for measuring dimensions. It provides tools for image filtering, edge detection, contour detection, and geometric transformations, which are fundamental for extracting relevant features and performing accurate measurements.

2) *Feature Extraction*: OpenCV includes algorithms for feature extraction, such as corner detection, blob detection, and line detection. These features can be used to identify key points on the parts and extract meaningful information for dimensional analysis.

3) *Geometric Transformations*: OpenCV provides functions for perspective transformation, homography estimation, and camera calibration. These capabilities are valuable for compensating for perspective distortions and performing accurate measurements in real-world scenarios.

4) *Community and Support*: OpenCV has a large and active community with extensive documentation, tutorials, and online resources. It is widely adopted in various industries and research fields, which means there is a wealth of knowledge and support available. This community can be instrumental in helping you overcome challenges and find specific solutions related to measuring dimensions using a camera.

## IV. EXPERIMENTAL SETUP

The setup consists of mainly three parts - one is the metallic frame, the second is the microprocessor and the third is the touchscreen on which we will display the Graphical User Interface.

### A. Metallic Frame

The design of the metallic frame is similar to that of a 3D printer. It consists of a 9x9 inch base plate which is basically a diffuser that is used to spread light evenly over the surface. The test part is placed over this plate. Under the plate, is a matrix of thin LED lights that illuminates the base plate.

There are four columns that extend upward and at the top there is an fixture on which the camera is mounted. The fixture is 3D printed, the columns can extend up to a height of 8 inches so that the device provides the flexibility to enlarge its view-port for large or extensive parts.

The following images show the hardware parts and their assembly:

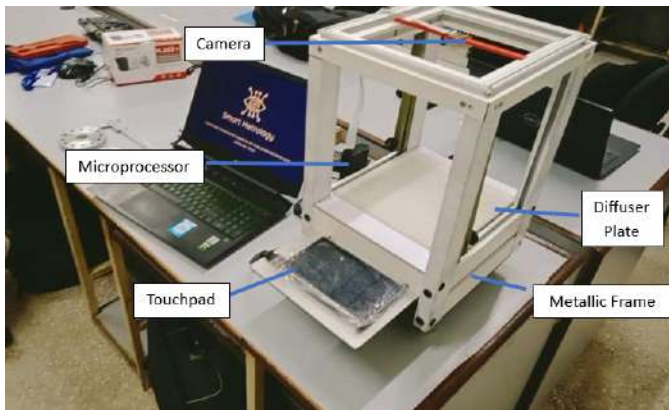


Fig. 6. Major Components of Experimental Setup

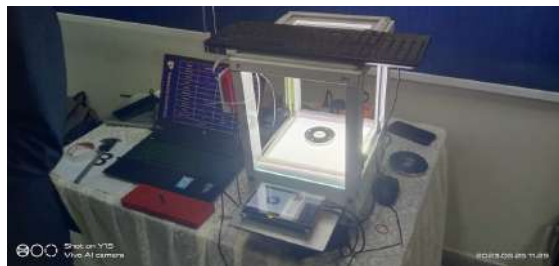


Fig. 7. Test part placed under inspection

### B. Microprocessor

The microprocessor acts as a channel for transferring information between the camera and the human input. Raspberry Pi 4B with 4GB RAM is used to operate the camera and run the GUI.

### C. Graphical User Interface (GUI)

An easy and user-friendly GUI was built. It consists of touch buttons that use simple English language like "Next", "Save" and "Back". The GUI also provides the option to save every record so that it can be referred to later on. For each part, there is a separate icon that shows the image of that part.



Fig. 8. Main Menu of the GUI

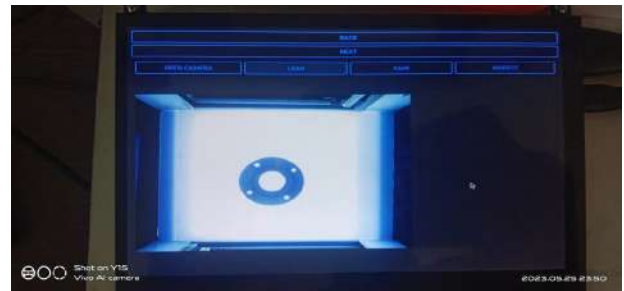


Fig. 9. Inspection options of the GUI

## V. RESULTS

For carrying our the experiments, two flanges were taken. One which had all accurate holes and the other flange which had two defective holes. Inpsection process was performed and its results are shown as below:



Fig. 10. Inspection of the Defective part

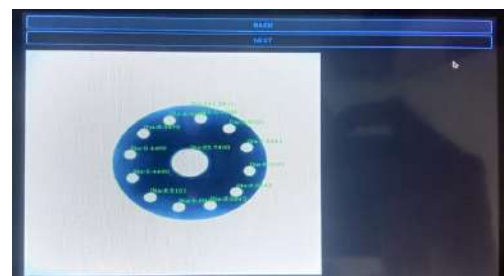


Fig. 11. Inspection of the Accurate Part

In our experimental results, we were able to achieve an average accuracy of  $\pm 0.2mm$ . However, the accuracy went as low as  $\pm 0.03$  and as high as  $\pm 0.3mm$ .

## VI. CONCLUSIONS

- 1) Successful inspection process with 0.2mm accuracy displayed on GUI.
- 2) Parts inspected in 10-15 seconds, faster than manual measurement with a vernier caliper.
- 3) Camera resolution and settings affect accuracy; improved image quality can yield to 0.1 mm precision.

## VII. RECOMMENDATIONS AND DISCUSSIONS

We observed that lightning conditions in the surrounding affected the results of the inspection. It is better to have a controlled environment of light as most mechanical parts are silver in color and they produce a large amount of glare. To improve this condition, we can place wooden blackboards on all four faces of the frame. In this way, we can limit the amount of light falling on it.

Aside from that, we can provide flexibility in terms of camera position by making a slider for it. It can be motorized so that according to the part and its features we can obtain the images at varied camera angles to capture features from all sides.

The current design does not support depth measurement. For it, we can place camera's on each side so that it can provide us with height information of the part.

## VIII. ACKNOWLEDGMENT

We extend our gratitude to our faculty supervisor, Dr. Riaz Ahmad Mufti, for his guidance and feedback throughout this project. We also want to thank our class fellow, Ahmad Hasan Khan, for helping us develop our hardware structure.

## IX. REFERENCES

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- [1] Akbar, Habibullah, and Anton Satria Prabuwo. "Webcam based system for press part industrial inspection." *International Journal of Computer Science and Network Security* 8.10 (2008): 170-177
- [2] Du, Hongru, et al. "A method of dimension measurement for spur gear based on machine vision." *2011 International Conference on Multimedia and Signal Processing*. Vol. 1. IEEE, 2011
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# Thesis

*by* Kamran Shafi

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- [6] Jia, Xiyuan, et al. "A machine vision-based method of high-precision measurement of the size of workpiece." Seventh International Symposium on Precision Mechanical Measurements. Vol. 9903. SPIE, 2016
- [7] Moon, C. W. "Error analysis for dimensional measurement using computer vision techniques." 1988. IMTC-88. 5th IEEE Instrumentation and Measurement Technology Conference. IEEE, 1988

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- **dip.EdgeObjectsRemove:**  
Small connected regions that may not be a part of the primary object are removed from the area surrounding the image boundary.

3) *Noise Removal:* **dip.Opening and dip.Closing:** Removes noise from the binary image by opening and closing operations. Opening is a process of erosion and dilation that eliminates small foreground areas while leaving the bigger object's general size and shape intact. Closing, which fills in tiny cracks and crevices in the foreground, is dilatation followed by erosion.

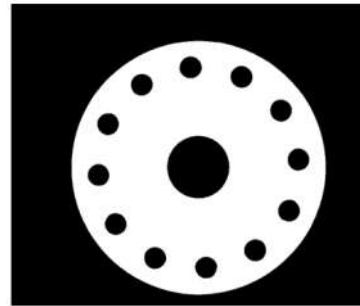


Fig. 2. Thresholded Image

#### 4) Measurement:

- **dip.Label:**  
Label the binary image's connected elements. It gives each connected region (object) in the image a special identifier.
- **dip.MeasurementTool.Measure():**  
It measures the area of each of the labeled region in terms of pixels and converts the pixels into mm as set by `img.SetPixelSize`. It also measures the circularity of the labeled regions which determines how close the region is to a circle.

5) *Calculations of Dimensions:* The formula for calculating the diameter of each contour is given by:

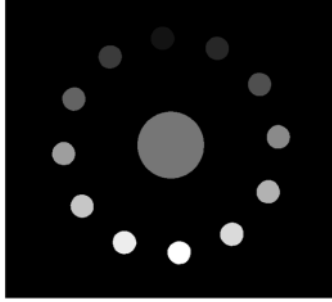


Fig. 3. Each Feature is Color Labelled

$$Diameter = 2 \times \frac{ObjectArea}{\pi} \quad (1)$$

In code form, the size and circularity of each feature is given by:

	Size	Circularity
	(mm <sup>2</sup> )	
1	57.24	0.008481
2	56.61	0.007530
3	56.08	0.01039
4	56.17	0.008318
5	55.49	0.01078
6	461.7	0.002227
7	56.47	0.01043
8	55.24	0.01117
9	55.99	0.01156
10	55.06	0.008574
11	56.47	0.01194
12	55.98	0.009362
13	55.39	0.01336

The diameters in mm are given below:

```

110.38464191462222
8.55494178354087
8.502478448178252
8.458369660182038
8.46601676999589
8.40886051675724
26.019082288258545
8.491495346302687
8.388062369918618
8.451511763966563
8.373435919441341
8.491495346302687
8.449920811601118
8.401266564372307

```

## B. Using OpenCV

### 1) Reading and Pre-processing of the Image:

- **cv2.imread:**  
Reads the image in a BGR format.
- **cv2.cvtColor(image, cv2.COLOR\_BGR2GRAY):**  
Converts the BGR image to grayscale.

This step performed produces the same result as shown in Fig. 1 using the DipLib library.

### 2) Thresholding and Image Blurring:

- **cv2.GaussianBlur:**  
Apply Gaussian blur to the image in grayscale. Using a Gaussian kernel to convolve the image, the widely used blurring technique known as "Gaussian blur" lessens image noise and smoothes off the edges.
- **cv2.threshold(binary+otsu)[1]**  
Apply Otsu's thresholding technique on the blurred image to perform thresholding. The ideal threshold value is automatically determined by Otsu's approach based on the image histogram. The maximum value to be assigned to pixels over the threshold is 255, and the thresholding method is specified by the variables cv2.THRESH\_BINARY+cv2.THRESH\_OTSU. The function gives back a tuple, and [1] gets the image that was thresholded.

### 3) Morphological Operations and Edge Detection:

- **cv2.dilate(thresh, kernal, iterations=1):**  
Utilises a kernel to apply dilation on the thresholded picture. The morphological process of dilation enlarges the edges of the objects in a picture. The structural element used for dilation is defined by its shape and size by the kernal parameter. The number of times that dilation is used is controlled by the iterations option.
- **cv2.erode(dilate, kernal, iterations=1):**  
Erosion is applied to the enlarged image. The morphological process of erosion removes the borders of objects in an image. It is the opposite of dilation. Like cv2.dilate(), the function's parameters are same.
- **cv2.Canny(erode, Low, High):**  
Apply the Canny edge detection technique to the eroded image. By analyzing gradients in the image and using hysteresis thresholding, the Canny algorithm finds edges. The low and high threshold levels for edge connecting are represented by the Low and High parameters.

### 4) Contour Detecion:

- **cv2.findContours(edges, cv2.RETR\_CCOMP, cv2.CHAIN\_APPROX\_SIMPLE):**  
This function finds the contours in the edge detected image.
- **cv2.RETR\_CCOMP:**  
It is the contour retrieval method that retrieves all the contours and arranges them into a two-level hierarchy (external and internal contours).
- **cv2.CHAIN\_APPROX\_SIMPLE:**  
It is a technique for approximating contours that saves

only the ends of horizontal, vertical, and diagonal segments while compressing the rest.

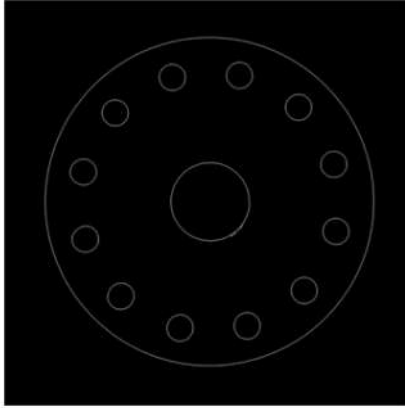


Fig. 4. Canny Edge Detected Image

5) *Circle Detection*: `cv2.minEnclosingCircle(cnt)`: This function takes the contours as the input and finds the minimum enclosing circle for each of the contours by calculating the center and radius of the smallest circle that encloses the contours.

6) *Measurement*: The proposed method for dimensional inspection of parts involves the following steps.

- 1) Firstly, an image of the reference part is provided, and its dimensions are recorded as the reference. This image serves as a baseline for comparison.
- 2) Next, the mm-to-pixel ratio is established for each feature of the reference part. To accomplish this, the user clicks on each feature, such as circles, in the reference image to define the corresponding mm size. These mm to pixel ratios are then saved for future use. In our case, we have manually saved the values first.  
In order to account for variations and allow for flexibility in measurements, a pixel area range is defined for each feature. Some padding is added to the original value to create a reasonable range that accommodates minor variations. This range ensures that measurements within a certain tolerance are considered acceptable.
- 3) When an image of the part to be measured is provided, the method compares each feature of the part to the corresponding feature in the reference image. By matching features, the mm to pixel ratio is determined for each feature of the part. This ratio is then used to perform the necessary calculations for dimensional inspection.

By establishing the mm to pixel ratio based on the reference part and comparing features between the reference and measured parts, this method enables accurate dimensional inspection. It provides a systematic approach to handle variations in measurements and ensures reliable results for assessing the dimensions of parts under inspection.



Fig. 5. Output of the Algorithm

### C. Comparison between OpenCV and DipLib

We found OpenCV more suitable for our task for the following reasons:

1) *Image Processing Capabilities*: OpenCV offers a wide range of image processing functions that are well-suited for measuring dimensions. It provides tools for image filtering, edge detection, contour detection, and geometric transformations, which are fundamental for extracting relevant features and performing accurate measurements.

2) *Feature Extraction*: OpenCV includes algorithms for feature extraction, such as corner detection, blob detection, and line detection. These features can be used to identify key points on the parts and extract meaningful information for dimensional analysis.

3) *Geometric Transformations*: OpenCV provides functions for perspective transformation, homography estimation, and camera calibration. These capabilities are valuable for compensating for perspective distortions and performing accurate measurements in real-world scenarios.

4) *Community and Support*: OpenCV has a large and active community with extensive documentation, tutorials, and online resources. It is widely adopted in various industries and research fields, which means there is a wealth of knowledge and support available. This community can be instrumental in helping you overcome challenges and find specific solutions related to measuring dimensions using a camera.

## IV. EXPERIMENTAL SETUP

The setup consists of mainly three parts - one is the metallic frame, the second is the microprocessor and the third is the touchscreen on which we will display the Graphical User Interface.



### A. Metallic Frame

The design of the metallic frame is similar to that of a 3D printer. It consists of a 9x9 inch base plate which is basically a diffuser that is used to spread light evenly over the surface. The test part is placed over this plate. Under the plate, is a matrix of thin LED lights that illuminates the base plate.

There are four columns that extend upward and at the top there is an fixture on which the camera is mounted. The fixture is 3D printed. the columns can extend up to a height of 8 inches so that the device provides the flexibility to enlarge its view-port for large or extensive parts.

The following images show the hardware parts and their assembly:

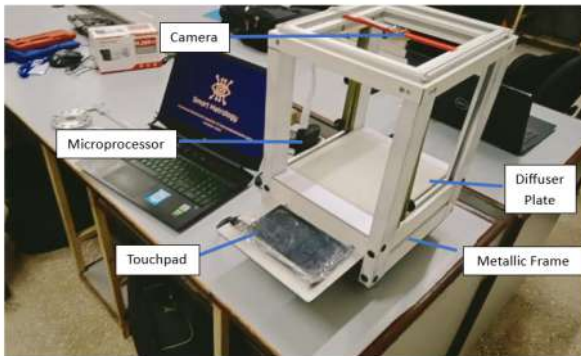


Fig. 6. Major Components of Experimental Setup

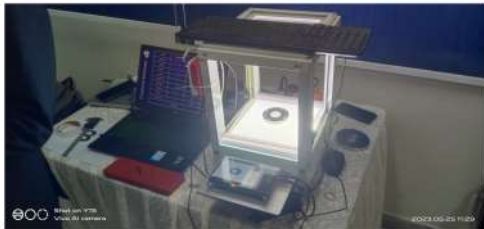


Fig. 7. Test part placed under inspection

### B. Microprocessor

The microprocessor acts as a channel for transferring information between the camera and the human input. Raspberry Pi 4B with 4GB RAM is used to operate the camera and run the GUI.

### C. Graphical User Interface (GUI)

An easy and user-friendly GUI was built. It consists of touch buttons that use simple English language like "Next", "Save" and "Back". The GUI also provides the option to save every record so that it can be referred to later on. For each part, there is a separate icon that shows the image of that part.



Fig. 8. Main Menu of the GUI



Fig. 9. Inspection options of the GUI

## V. RESULTS

For carrying out the experiments, two flanges were taken. One which had all accurate holes and the other flange which had two defective holes. Inspection process was performed and its results are shown as below:



Fig. 10. Inspection of the Defective part

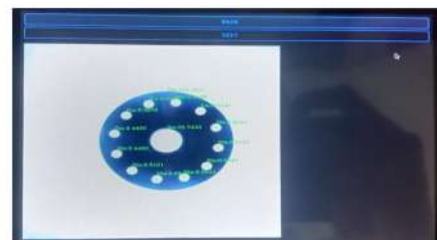


Fig. 11. Inspection of the Accurate Part

In our experimental results, we were able to achieve an average accuracy of  $\pm 0.2mm$ . However, the accuracy went as low as  $\pm 0.03$  and as high as  $\pm 0.3mm$ .

#### VI. CONCLUSIONS

- 1) Successful inspection process with 0.2mm accuracy displayed on GUI.
- 2) Parts inspected in 10-15 seconds, faster than manual measurement with a vernier caliper.
- 3) Camera resolution and settings affect accuracy; improved image quality can yield to 0.1 mm precision.

#### VII. RECOMMENDATIONS AND DISCUSSIONS

We observed that lightning conditions in the surrounding affected the results of the inspection. It is better to have a controlled environment of light as most mechanical parts are silver in color and they produce a large amount of glare. To improve this condition, we can place wooden blackboards on all four faces of the frame. In this way, we can limit the amount of light falling on it.

Aside from that, we can provide flexibility in terms of camera position by making a slider for it. It can be motorized so that according to the part and its features we can obtain the images at varied camera angles to capture features from all sides.

The current design does not support depth measurement. For it, we can place camera's on each side so that it can provide us with height information of the part.

#### VIII. ACKNOWLEDGMENT

We extend our gratitude to our faculty supervisor, Dr. Riaz Ahmad Mufti, for his guidance and feedback throughout this project. We also want to thank our class fellow, Ahmad Hasan Khan, for helping us develop our hardware structure.

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