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An efficient Image Processing Technique to Measure and Align Vehicle Wheel Cylinder with Cloud Management System

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Abstract

The measurement and alignment of vehicle wheel cylinders (motorcycle wheel hub) is an important and more challenging task for manufacturing companies. Currently in most of the local industries this measurement system is manual, and technicians are using screw gauges and vernier calipers for the measurement of cylinder diameters. There are some issues associated with the manual system to measure the different cylinder diameters of the wheel hub. Some very common issues are time consuming, human error can impact the accuracy of measurements, least count values are changed in different tools, which are used in measurements, and it requires more concentration for converting the decimal places and one of a very important issue is the alignment of centroids for different diameters of wheel cylinder. This centroid problem would never be fixed in a manual system, and it creates a big issue for the alignment of the wheel as well, that causes wobble in the wheel. The automated sensor-based system can resolve these issues and especially centroid issues with accurate measurements of cylinder diameters, but this system is very costly. The proposed system provides a state-of-the-art solution to measure the diameters of the cylinder with the accurate alignment of centroids. The work presented here consists of two modules— an automated vehicle wheel hub measurement and alignment system (VWMAS) using image processing techniques and cloud management. The proposed system is a low cost and effective technique, which resolves the issue of centroid with accurate measurement of diameters of different circles found in the hub with the accuracy (95%) and precision (100%).

Keyword: motorcycle, automated, vehicle wheel, centroid, bubbling, screw gauge, vernier caliper, measurement, diameter, accuracy, precision

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1. Introduction

Motorcycle industry in Pakistan is now one of the fastest growing industries. In the financial year 2020 record motorcycle production and sales is recorded in Pakistan [1-4].

As per the published report of Association of Pakistan Motorcycle Assemblers (APMA), there are around seventy-two motorcycle companies who are registered and actively participating in manufacturing, import and assembling of the motorcycles. Karachi is one of the most important centers to manufacture and produce different physical parts of two-wheel vehicles but the production cost in Karachi is very high compared to the other cities [1]. In late 90s, one of the significant motorcycle companies started the assembly and manufacturing of two-wheel vehicles in Pakistan through a mutual venture with the Yamaha, a world-renowned Japanese company and then other companies opted for the same model. Fateh Hero is one of a leading motorcycle company who produced an average of 21,778.500 Units from Jun 2006 to 2017 in Pakistan. The published data of Fateh Hero during the mentioned period is given here in table 1 [5].

Table 1: Motorcycle Production Rate

Duration (Years)	Production (Unit)
2006	34018.00
2007	25798.00
2008	22519.00
2009	21038.00
2010	35010.00
2011	41972.00
2012	38834.00
2013	20466.00
2014	11525.00
2015	8607.00
2016	2958.00
2017	3012.00

Few years back, different parts of motorcycles were imported and then assembled in local industries but now most of the parts are produced and assembled in the local industries in Pakistan. Some very common locally produced and developed motorcycle parts are listed here and shown in figure1.

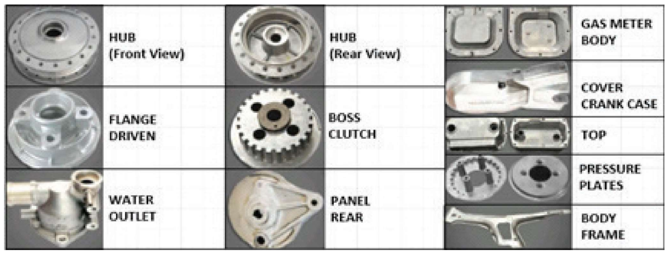


Figure 1: Parts Manufacturing in Local Industries

In most of the industry, the physical inspections and measurements of parts is carried out manually. Numbers of technicians are trained and they use basic tools to measure the components as per the standard engineering drawings. This way of measurement requires more time and there is a higher chance of human error, which can affect the overall accuracy and precision of the components performance.

The work presented here is divided into two key modules, first is related to the automated motorcycle wheel hub measurements and alignment of centroids, which is an important part used to mount the front and rear wheels of motorcycle accurately, secondly the cloud management system, which helps the management to monitor and track the records of good and bad cylinder measurements. In this paper, an automated measurement of wheel HUB is presented by using image processing technique.

2. Related Work

Various authors have published a number of research papers related to motorcycle parts design and manufacturing. This domain is now more attractive and challenging for the industries as well for the researchers. Some key contributions from the researchers are listed here: Ahmed et al. [6], Hussain et al. [7], Niazi et al. [8], Batra [9], Vasuvanich et al [10], Sayeed et al [11], Taneja et al. [12] and Nabi et al. [13], have reported about diverse methodologies, that can increase the volume of trade in the region of Asia. Authors of [14-15] discussed the image contour extraction using pixel-based comparison method. Authors of [16-19] discussed the background subtraction and image enhancement techniques. Authors of [20] describe the method of large-scale image retrieval, which is efficient in time with better efficiency. In [21], authors discussed a 3-D layout estimation technique in a more efficient way. Authors of [22] elaborate the efficient way to image denoising from the image. This way is really help to understand the methods to reduce noise from the captured image. It improves the efficiency of proposed technique.

3. Proposed Method

A. Model Development

The presented work is divided into two key modules, first is related to the automated motorcycle wheel hub measurements and alignment of its centroids, which is an important part use to mount the front and rear wheels of motorcycle wheels/tire accurately. Second module of the cloud management system will help the management to monitor and track the records of good and bad cylinder measurements of component (HUB).

a. Automated Motorcycle Wheel HUB Measurement and Alignment

This is the first module of the proposed system. Motorcycle wheel hub is an important part of motorcycle to mount the wheel as shown in figure2. In most of the companies, the measurements of wheel hub are based on manual system. Technicians are uses screw gauge and vernier calipers to measure the inner diameters of circular cylinders.

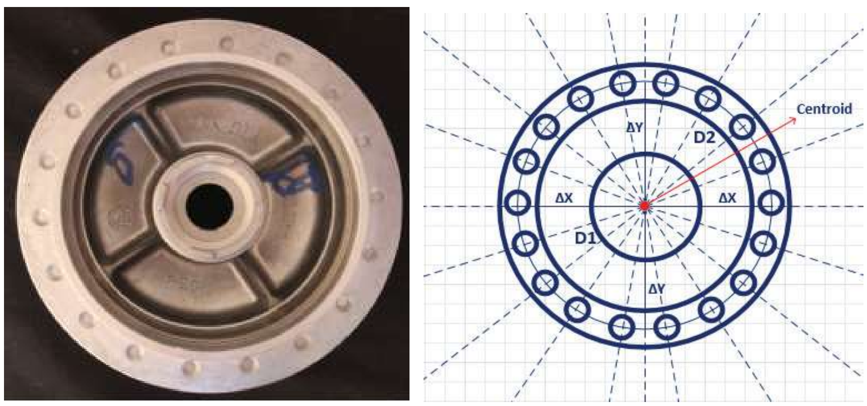


Figure 2: Hub Rear View

As per the standard engineering drawing, the measurements are as follows:

$$D_1 = \text{Diameter of small circle} = (35-0.5) \leq D_1 \leq (35+0.025)$$
$$D_2 = \text{Diameter of large circle} = 110 \leq D_1 \leq (110+0.20)$$

As far as the alignments of centroids are concerned, it is not possible in the manual system to analyze and measure accurately [23-26]. This is very critical and big issue for the industries. Using the techniques developed in the proposed system, the measurements of diameters and issues of centroid are solved with a very high accuracy and precision.

The system, which is developed in Image Processing Research Laboratory (IPRL) [27] is consists of a wooden base with black colored background. A 'v-shaped' space is created on wooden base to fix the position of wheel hub. A camera was mounted on tripod stand on the top of hub rear face to capture the image. This captured hub rear face then measured and analyzed using the developed application program. The developed application generated the reports about the measurements of diameters and the position of centers of all circles, which needs to be properly aligned. When all the measurements and centroid are well aligned as per the standard values, green LED will be ON, which indicates the tested wheel hub is 'good', otherwise it will be 'bad' and red LED will be ON. A Raspberry pi module is programmed and used for these indications of good and bad cylinders. The complete hardware set up is shown in figure3.

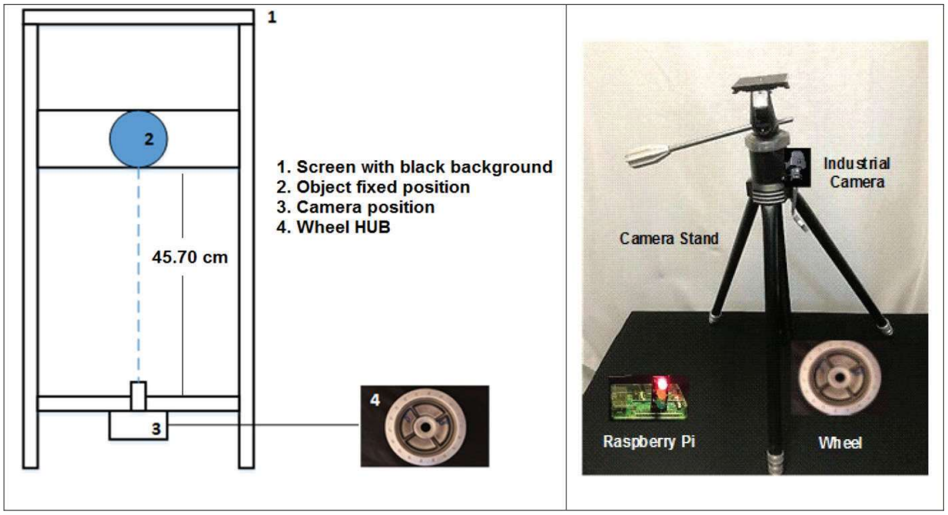


Figure 3: Hardware Set-up

To resolve the issue of centroid multiple radii were calculated for small and large circles in the captured image. All these radii for small and large circles were calculated from a common center red point as shown in figure 3. The system ensures that all the measurement of radii for small circle is equal in magnitude and same for the larger circle. The centroid issue has been resolved using this automated wheel hub measurement and alignment system. The system is capable of identifying the good and bad hubs. Good hub means the drum having valid measurement of the diameter with a well aligned centroid while the bad hub refers to the drum having invalid measurement of diameters or non-aligned centroid [28-33]. All the measurements of diameters are measured and recorded in centimeters (cm) in the system.

b. Cloud Management

This is the second module of the developed system, which is related to the cloud management and monitoring of complete environment [34-38]. All the measurements conducted by the technicians are directly stored in the cloud database[39-40]. Technician just place the wheel hub at the specified positions in hardware set-up and capture the image of rear face of hub by viewing the live streaming on the camera which is connected to the wifi network. The application program read the image and measured the values of diameters from the circular shaped cylinders and validates the centroid of all circles. The decisions about the good and bad measurement are shown using the red and green LEDs controlled by Arduino processor.

Administrator can view all the detail of stored measurement along with the detail of technician IDs, technician shift timing (data is filtered by the day, month and year), status of good and bad cylinder measurements and can generate the reports as well. The complete system flow diagram is shown in figure4.

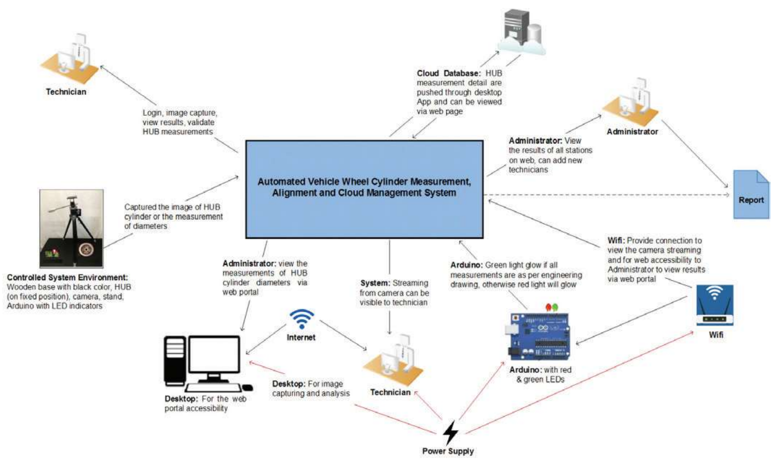


Figure 4: Proposed System FlowDiagram

c. System Application - Explanation of system functions

A desktop application is developed for the technician who can capture the images of the wheel hub (rear face), process the captured image using image processing techniques and results of measurements can be viewed in real time. The admin can view and change the detail of measurements using web portal. The Technician and The admin interfaces in developed application are shown in figure 5.

Figure 5: Technician (LH) and Admin (RH) Interface in Application

In the following figure 6, image processing techniques and the steps involved to measure the diameters and to find centroid of circles are shown.

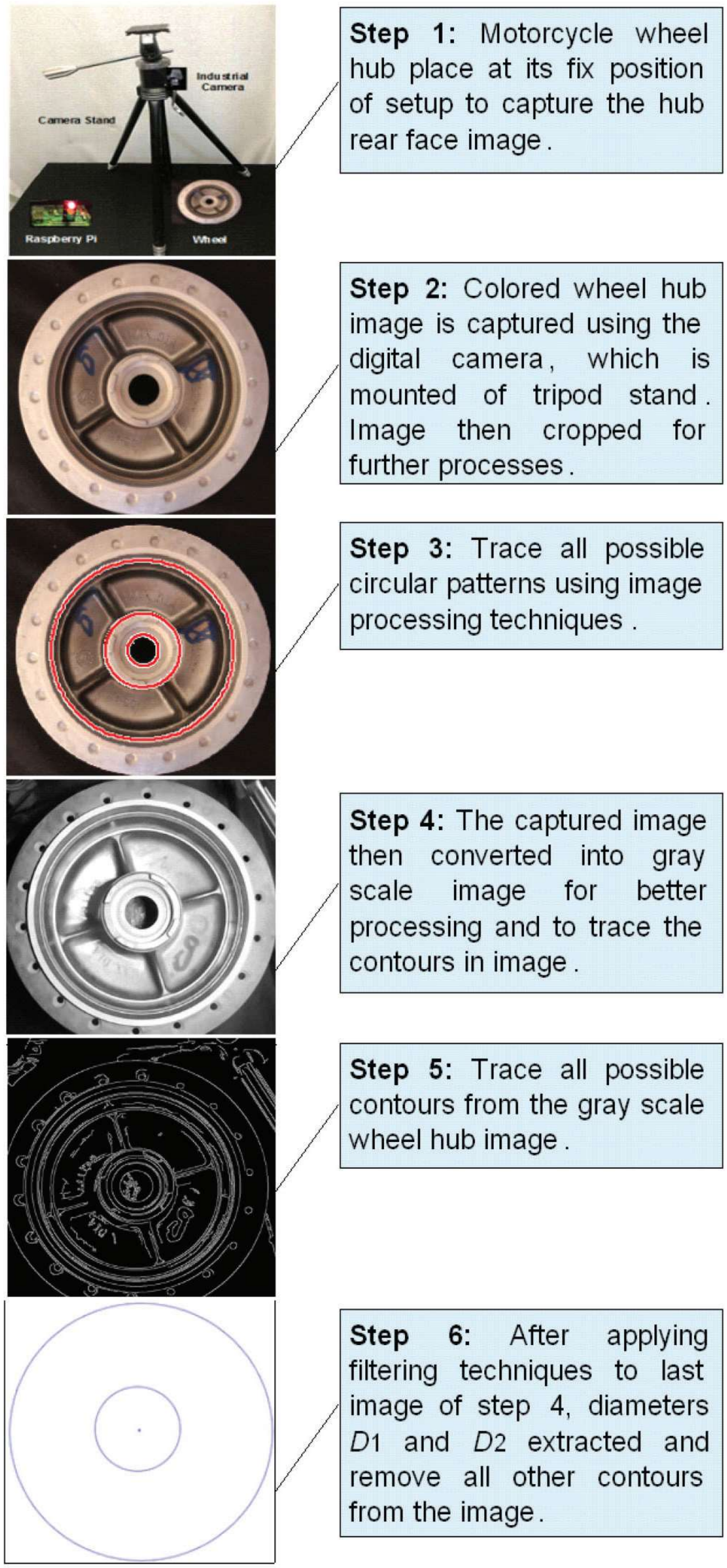


Figure 6: Steps of Proposed Technique

Fast Finding and Fitting (FFF) Algorithm:

Fast Finding and Fitting (FFF) algorithm was used for multiple circles detection. This algorithm uses Hough transformation.

The Hough Transform (HT):

Hough Transformations along with their extensions are commonly used in multiple circles detection. HT is still one of the most effective techniques because of its high capabilities to remove the noise from the images.

Circle detection using Fast Finding and Fitting (FFF) algorithm is uses the mechanism of the genetic algorithm. The FFF is very efficient and accurate as compared to the other algorithms[41].

Pseudo Code

The pseudo code of the proposed system is given as below:

1. Input the image
2. Apply HT transformation and extract all possible vertical symmetrical axis
3. Locate the pixels of circular shape
4. Measure the diameters of smaller and larger circles and locate the centers of circles to resolve centroid issues.

4. Experimental Results

Table 1 shows the measurement of wheel Hub diameters for both small and large circles. During the manual observations of diameter, two critical values were found for wheel hub 6 and wheel hub 7. For wheel hub 6, the manual value was rejected but in case of system generated values, it was accepted it was found that the wheel hub no. 6 was correct but there was a mistake to observed value via manual system. As for as wheel hub 7 is concerned, manual value was accepted but it was at the maximum allowed limit, which is a critical condition. In case of system generated value, wheel hub 7 was strongly accepted. Wheel hub 6 has centroid issue and it was observed through the proposed technique.

Table 2. Manual and System Generated Readings

S. No	Manual Readings of small circle D_1 (cm)	System Readings of small circle D'_1 (cm)	Manual Readings of large circle D_2(cm)	System Readings of large circle D'_2(cm)
Wheel Hub1	34.93	34.93	110.08	110.03
Wheel Hub 2	34.94	34.93	110.16	110.11
Wheel Hub 3	34.93	34.94	110.06	110.14
Wheel Hub 4	34.93	34.92	110.10	110.18
Wheel Hub 5	34.93	34.93	110.18	110.31
Wheel Hub 6	34.92	34.93	110.22	110.16
Wheel Hub 7	34.92	34.92	110.20	110.13
Wheel Hub 8	34.93	34.93	110.06	110.12
Wheel Hub 9	34.94	34.93	110.16	110.28
Wheel Hub 10	34.94	34.93	110.16	110.22

Table 2 shows the observations of small and large circle diameters and the change between two manual and system generated values. It is very clear in observation that deviations between manual and system generated values are very small and within the range. So all system generated values are highly accepted.

Table 3. Observations of Small and Large Circles

Observation of Small Circle with difference of Manual and System Generated Values			Observation of Large Circle with difference of Manual and System Generated Values		
Manual Readings D_1 (cm)	System Readings D'_1 (cm)	Deviation of Diameters $\Delta D_1=D_1-D'_1$	Manual Readings D_2 (cm)	System Readings D'_2 (cm)	Deviation of Diameters $\Delta D_2=D_2-D'_2$
34.93	34.93	0.00	110.08	110.05	0.03
34.94	34.93	0.01	110.16	110.11	0.05
34.93	34.94	-0.01	110.06	110.04	0.02
34.93	34.92	0.01	110.10	110.18	-0.08
34.93	34.93	0.00	110.18	110.11	0.07
34.92	34.93	-0.01	110.22	110.16	0.06
34.92	34.92	0.00	110.20	110.13	0.07
34.93	34.93	0.00	110.06	110.12	-0.06
34.94	34.93	0.01	110.16	110.18	-0.02
34.94	34.93	0.01	110.16	110.18	-0.02

Table 3 shows the accuracy, precision, sensitivity and specificity of the proposed automated wheel hub measurement systems. In our test run, 40 samples have been tested using edge detection techniques. For edge detection technique, 38 samples of drum were correctly recognized as true Positive. Table 4 shows the facts recorded during test runs for edge detection systems.

Table 4. Key parameters and performance of system

Parameter	Edge Detection	Parameter	Performance (%)
Number of true positive (TP)	38	Accuracy= $\frac{(TP+TN)}{(TP+FP+FN+TN)}$	95
Number of true negative (TN)	0	Precision= $\frac{TP}{(TP+FP)}$	100
Number of false positive (FP)	0	Senitivity= $\frac{TP}{(TP+FN)}$	95
Number of false negative (FN)	2	Specificity= $\frac{TN}{(FP+TN)}$	0

A. Data Consistency

The data consistency of the system can be analyzed using statistical technique. The coefficient of variationfor manual and system generated values is used to analyze the data consistency.

a. *Coefficient of Variation for Small Circle*

Coefficient of Variation$= \frac{\sigma}{\mu} \times 100$ .... (1)

σ = Standard Deviation = $\sqrt{\frac{\Sigma(x_i - \mu)^2}{N}}$................ (2)

μ = Mean = $\frac{\Sigma x_i}{N}$ .... (3)

After solving the parameters, we have

Coefficient of Variation (Manual)$= \frac{\sigma}{\mu} \times 100 = \frac{0.007}{34.931} \times 100 = 0.020\%$............ (4)

Coefficient of Variation (System)$= \frac{\sigma}{\mu} \times 100 = \frac{0.00538}{34.929} \times 100 = 0.015\%$............ (5)

The result shows the system generated values are more consistent as compare to manual values.

b. *Coefficient of Variation for Large Circle*

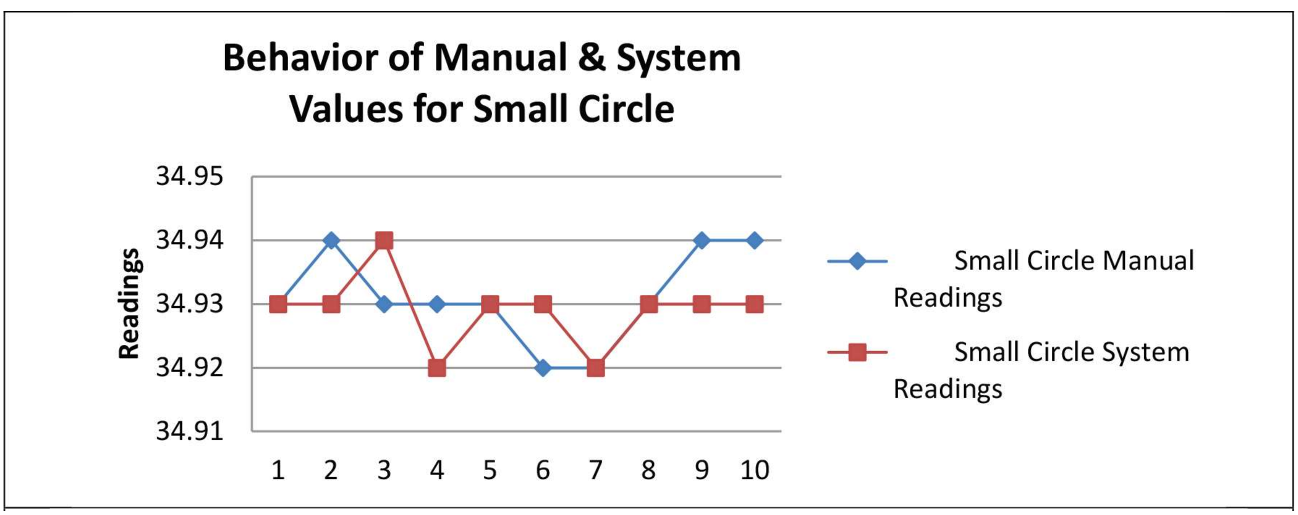
Coefficient of Variation (Manual)$= \frac{\sigma}{\mu} \times 100 = \frac{0.00050}{110.138} \times 100 = 0.00050\%$............ (6)

Coefficient of Variation (System)$= \frac{\sigma}{\mu} \times 100 = \frac{0.00044}{110.126} \times 100 = 0.00044\%$............ (7)

The result shows the system generated values are more consistent as compare to manual values.

c. *Graphical Representation of Manual and System Values*

A graphical representation of manual and system generated values are shown in figure7.



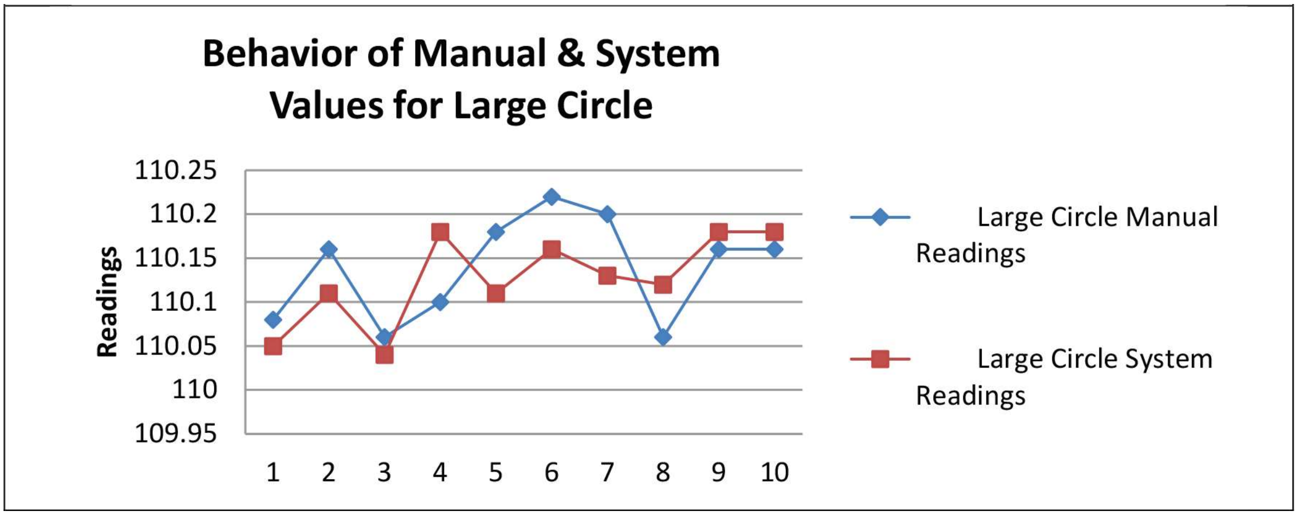


Figure7: Behavior of Manual and System Values for Small and Large Circles

5. Conclusion

The measurement done by proposed system is more accurate as compare to the manual system. The throughput of automated system is higher compared to the manual system. The proposed system has an acceptable range of accuracy, which shows the performance of the proposed system. As in Pakistan, a very large number of motorcycle companies are working so this automated measurement system can be extended for other components of vehicle parts of motorcycles as well.

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