AUTOMATED CALIBRATION OF ANALOG INSTRUMENTS

THESIS

Submitted by

PRAKASH S

EE19M010

for the award of the degree of

MASTER OF TECHNOLOGY

With the guidance of

Dr. Boby George

DEPARTMENT OF ELECTRICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY MADRAS

CHENNAI-600036

JUNE 2021

THESIS CERTIFICATE

This is to certify that the thesis entitled "AUTOMATED CALIBRATION OF ANALOG INSTRUMENTS" submitted by PRAKASH S to the Indian Institute of Technology Madras for the award of the degree of Master of Technology is a bona fide record of research work carried out by him under my supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

Prof. Boby George
Project Guide
Professor
Department of Electrical Engineering
Indian Institute of Technology Madras
Chennai – 600 036.

Place: Chennai
Date: 15 June 2021

ACKNOWLEDGEMENTS

It gives me a sense of happiness and satisfaction to write a few words to acknowledge people who guided and supported me in accomplishing the project work.

I would like to express my heartfelt gratitude to my project guide, Prof. Boby George, for giving me an opportunity to do project work under him. This work would not have been possible without his boundless guidance and strong support. His innovative thinking, enthusiasm, dedication towards work and welcoming attitude have encouraged and inspired me. His observations and comments were accurate and instrumental in improving my work. I always look forward to learn from him and imbibe the spirit of ingenious thinking and dedication.

I would like to express my gratitude to Prof. Ravinder David Koilpillai, Head of the Electrical Engineering Department, who has always been supportive in providing necessary encouragement for the students. I am very much thankful to Mrs. V. Rekha and Mr. Manigandan from the Measurements and Instrumentation Laboratory for their support by providing the necessary materials and equipments whenever needed. I am grateful to all the staff of Electrical Engineering Department for being very helpful whenever I approached them.

I am very thankful to the Indian Airforce for providing me an inspiring opportunity to do my post-graduation from an esteemed institute like IIT Madras.

I am very much thankful to my friends and colleagues who guided me through the project work and made my time at the laboratory a memorable one.

Above all, I am grateful to my wife and daughter for their struggles and sacrifices towards my well-being. Their love and encouragement are the foundation of all my achievements

ABSTRACT

Indian Air Force proposed the project to develop an alternate solution for existing calibration procedure of analog instruments. Analog and some digital instruments are not equipped with computer interfaces. They are not benefitted from the advantages of automatic calibration. In these cases, manual test methods are applied where the technician must manually read and record the value shown in Device Under Calibration (DUC). He must adjust manually the calibrator so that the DUC presents some particular reading.

The human work in repetitive tasks is very prone to errors. If by some reason like fatigue, he or she makes a mistake in, one or more values, the Calibration process and its credibility can be compromised. In order to avoid this sort of problems and to increase productivity and speed in calibration, the greater the level of automation the better.

A computer vision-based method is proposed to automatically calibrate Analog instruments. The computer automatically instructs and controls the calibrator to output a chosen value. Computer vision based approach is used to obtain the reading of the instrument, calculates the error with which the instrument being calibrated. The calibration report is also automatically generated. The complete system of automatic calibration is controlled through a single window in the computer screen.

Lab View software installed PC is the command control and data processing unit. Master calibrator is automatically controlled by this PC to generate required parameters and output to the analog instruments. Image sensor which is basically a USB camera capture the indicated values of the analog instruments and send it to the PC Image capture control signals are generated by PC to camera and camera in turn sends images back to the PC. Here also a two way communication is established The PC stores images in a specified folder and Lab View access this for image processing to find out indicated value.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

IAF	Indian Air Force
PWM	Pulse Width Modulation
DUC	Device Under Calibration
PC	Personal Computer
VI	Virtual Instrument
ROI	Region Of Interest
USB	Unified Serial Bus
JPG	Joint Photographic Group
BRD	Base Repair Depot

LIST OF SYMBOLS

R	Resistance
cos	Cosine
sin	Sine
tan	Tangent
Ɵ	Theta
Φ	Phi
V	Voltage

CHAPTER 1

INTRODUCTION

In measurement technology and metrology, calibration is the comparison of measurement values delivered by a device under test with those of a calibration standard of known accuracy. Such a standard could be another measurement device of known accuracy, a device generating the quantity to be measured such as a voltage, a sound tone, or a physical artifact, such as a meter ruler. The calibration standard is normally traceable to a national or international standard held by a metrology body.

Computer-based automatic systems play nowadays an important role in the calibration of measurement Instruments. They promote the accuracy, repeatability, and cost reduction of a repetitive, monotonous, and many times complex task.

The calibration of analog or digital measurement instruments not equipped with computer interfaces does not benefit from the advantages of automatic calibration. In these cases, manual test methods are applied where the calibration technician must manually read the value of the reading of the instrument being calibrated, or must adjust manually the calibrator so that the instrument being calibrated presents some particular reading. These are very time consuming, and results are subject to human errors. As a consequence, the calibration of these instruments is, in many cases, less frequent than it is desirable. The system presented in this paper allows the implementation of completely automated calibration procedures for analog instruments, which are not equipped with computer interfaces.

1.1 BACKGROUND AND LITERATURE SURVEY

Indian Air Force (IAF) has vast inventory of legacy and modern instruments. These instruments need to be calibrated at specific time interval. IAF is on constant search for a system that increase calibration productivity. This work is about a computational system to automate the entire calibration process for analog instruments. The computer vision system proposed is to be used to read the display of analogue instruments that do not have communication interfaces to computers. The proposed system accelerates the data acquisition process and makes it less prone to errors. Consequently, it contributes to improve calibration and reduce costs, increasing the number of instruments with quality assured measurements.

LabVIEW Based Advanced Instrumentation Systems by S. Sumathi, P. Surekha was studied to get basic programming skills in LabView. The related works are reviewed for getting insight into implementation of the project idea. Several methods have been developed to determine the angle of pointer of an analog instrument. The method proposed by Lima et al. [1] needed the meter to be perfectly horizontally lined up with the camera which would be troublesome for users. Kim et al. described about the automatic recognition of analog and digital meters installed in a nuclear power plant. Ocampo-Vega et al. [2] used the centroid and tip coordinates of the pointer of a water meter to form a straight line and calculated the pointer angle between the x-axis and the line that was created by joining the tip and the centroid of the pointer. Zhang and Li [3] developed a preprocessing method to automatically read a water meter, where Fourier transform was used to correct a tilted dial image of a water meter . The above methods needed Region of Interest (ROI) to be drawn by the user which fails the idea of complete automation of calibration of analog instruments

1.2 OBJECTIVE

Objective of the project is to demonstrate automated calibration of analog instruments. The computer automatically instructs and controls the calibrator to output a chosen value. Machine vision-based approach is used to obtain the reading of the instrument, calculates the error with which the instrument being calibrated. The calibration report is also automatically generated. The complete system of automatic calibration is controlled through a single window in the computer screen.

1.3 MOTIVATION

Indian Air Force has vast inventory of legacy and modern instruments. These instruments need to be calibrated at specific time interval. IAF is on constant search for a system that increase calibration productivity. This work is about a computational system to automate the entire calibration process for analog instruments. The computer vision system proposed is to be used to read the display of analogue instruments that do not have communication interfaces to computers. The proposed system accelerates the data acquisition process and makes it less prone to errors. Consequently, it contributes to improve calibration and reduce costs, increasing the number of instruments with quality assured measurements.

CHAPTER 2

AUTOMATED CALIBRATION OF ANALOG INSTRUMENTS

In order to obtain the reading of an analog instrument, it is necessary to determine the position of the pointer over the scale. The automatic determination of the analog instrument indication requires the use of computer vision techniques. This thesis describes a computer vision technique that obtains the reading of an analog instrument from the image of its display.

The system was designed to perform the calibration of instruments that measure electrical quantities like voltage, current, power, and impedance. LabView software application is used to develop the system. A user-friendly interface enables any person with a minimal training to perform the calibration procedures. This system can be used in calibration laboratories side by side with other automatic calibration system. It brings an added workload capacity in the calibration of old, low-cost, or hand-held instruments that do not have a digital communication interface. These types of instruments represent today more than half of the instruments that are send to calibration laboratories for periodic calibration as required for their normal operation.

2.1 PROPOSED METHOD

Lab View software installed PC is the command, control and data processing unit. Master calibrator is automatically controlled by this PC to generate required parameters and output to the analog instruments. The calibrator also sends its status and parameter output digitally to the PC; hence it’s a two-way communication. Image sensor which is basically a USB camera capture the indicated values of the analog instruments and send it to the PC Image capture control signals are generated by PC to camera and camera in turn sends images back to the PC. Here also a two way communication is established The PC stores images in a specified folder and Lab View access this for image processing to find out indicated value.

2.2 ANALOG METER DISPLAYS

Analog form of display uses the deflection of an indicator needle to indicate the level of the measurement being made. In order to obtain the reading of an analog instrument, it is necessary to determine the position of the pointer in the scale.

Fig. 2. 1 Analog meter displays

2.3 AUTOMATIC METER DISPLAY READING

In order to obtain the reading of an analog instrument, it is necessary to determine the position of the pointer in the scale. The automatic determination of the instrument indication, from images of the display, requires the use of computer vision techniques.

A block diagram the automatic calibration process is show below:

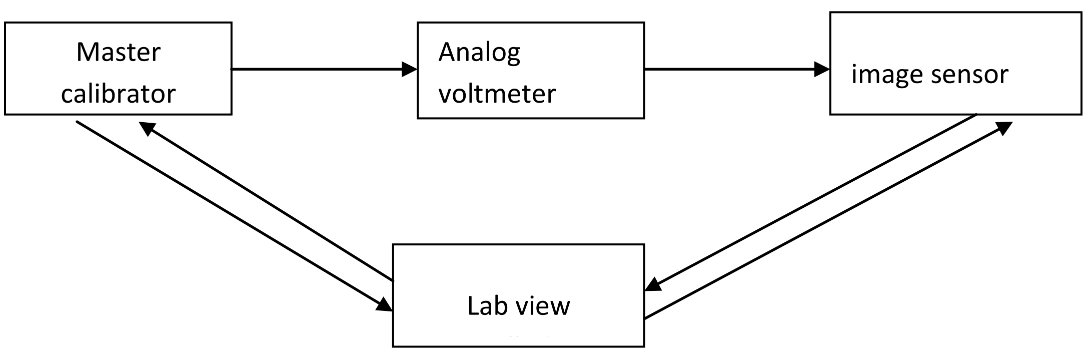


Fig. 2. 2 Block diagram the automatic calibration process

LabView software installed PC is the command control and data processing unit. Master calibrator is automatically controlled by this PC to generate required parameters and output to the analog instruments. The calibrator also sends its status and parameter output digitally to the PC; hence it’s a two-way communication. Image sensor which is basically a USB camera capture the indicated values of the analog instruments and send it to the PC. Image capture control signals are generated by PC to camera and camera in turn sends images back to the PC.

Here also a two-way communication is established. The PC stores images in a specified folder and LabView access this for image processing to find out indicated value.

2.4 THE COMPUTER VISION SYSTEM

The main module of the entire project is machine vision-based image processing. Block diagram of the image processing module is shown below:

The images captured by the camera are stored in a specified folder inside the PC. On initiation Lab View load these images and start executing the program. The images are initially corrected for any alignment errors. For image alignment of the analog instrument under test, it is matched with a template image. This template image is previously loaded to the Lab View and invoked when the same type of instrument is selected for calibration. The coordinates of the perfectly aligned template image and the test instrument is matched to find any alignment error and correction feedback is applied to the instrument under test.

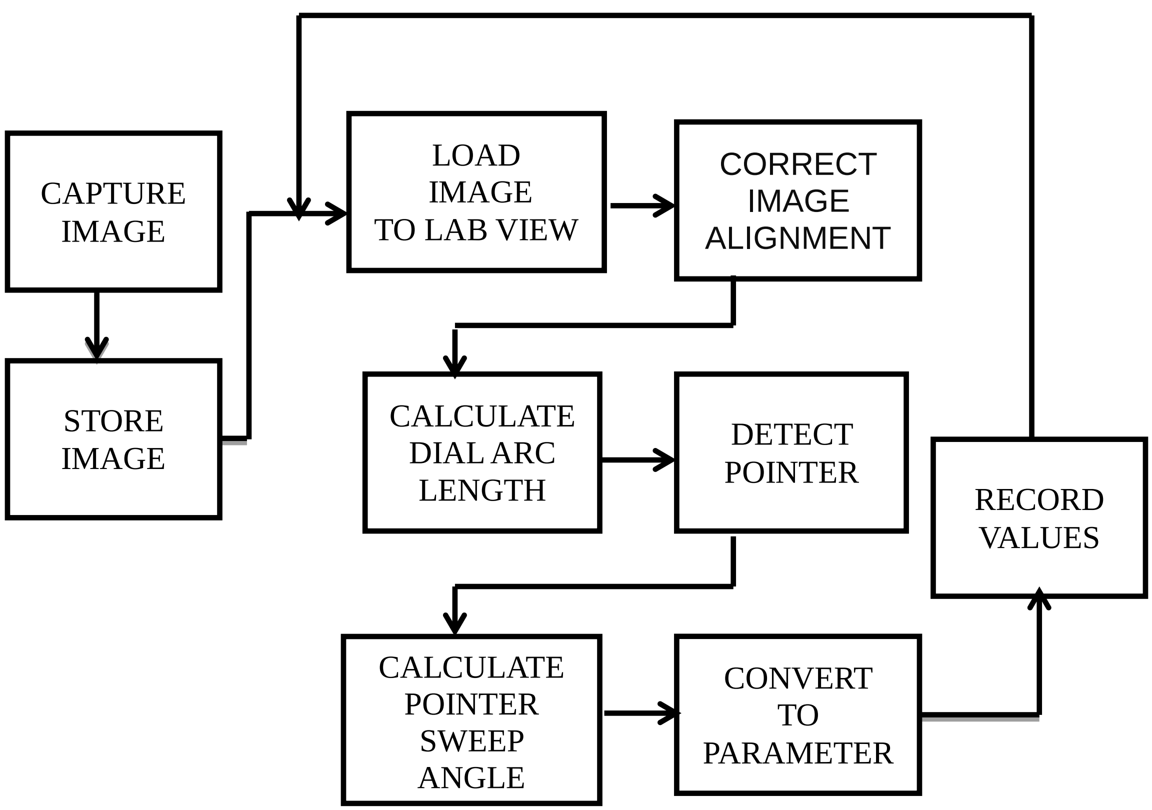


Fig. 2. 3 Block diagram of machine vision process

The corrected image then goes to next step which is full scale arc detection. Full scale arc detection works on the principle of detecting distinct variation of intensity of dial arc start and end region. The coordinates of this specific intensity variation points are taken as start and end points of the arc.

The next step is detection of pointer needle location. Lab View is programmed to look for the pointer template anywhere in the region of interest as the pointer needle is continuously moving. This is also called needle tracking and Lab View returns the coordinate position of the needle.

Trigonometric relationship corresponding to intersecting lines is used for finding the needle sweep angle. The last step in this image processing is the calculation of the indicated value. With the knowledge of full-scale value, full scale angle and pointer sweep angle, indicated value can be calculated with the equation shown in the slide. The calculated values by image processing are recorded in an array and the process is repeated automatically for the next available image.

2.4.1 IMAGE ALIGNMENT

For image alignment of the analog instrument under test, it is matched with a template image. This template image is previously loaded to the lab view and invoked when the same type of instrument is selected for calibration.

The coordinates of the perfectly aligned template image and the test instrument is matched to find any alignment error and correction feedback is applied to the instrument under test.

Steps involved in image alignment:

(a) A horizontally aligned image of the meter under test is selected as reference image.

(b) A prominent part of this image is selected as template for matching with other input images

(c) Template matching is used to locate regions of a grayscale image that match a predetermined template. Pattern Matching can find template matches regardless of poor lighting, blur, noise, shifting of the template, and rotation of the template.

(d) Set Coordinate System: This function is used to build a coordinate system based on the location and orientation of a reference feature.

(e) The edge detection steps for finding meter region and needle position will also get translated according to shifted or rotated image.

$$\begin{aligned} x' &= \cos\theta\ x + \sin\theta\ y, \\ y' &= -\sin\theta\ x + \cos\theta\ y, \end{aligned} \tag{2.1}$$

2.4.2 PATTERN MATCHING

Pattern matching is a method for finding regions in a grayscale image that match a reference image pattern. If the initial image source is a color image, the image needs to be converted to grayscale first in order to use pattern matching. The pattern matching VI uses a reference or template image to find like images within a new image regardless of location, rotation, or scaling of the template.

Pattern matching is often used to locate the positions of a fiducial mark, or unique characteristic features, of an object in an image. You can use the positions to compute length, angles, and other measurements. As a result, pattern matching has been widely used in various applications such as alignment, gauging, and inspection. Pattern matching has an advantage over particle analysis or edge detection because the pattern search does not rely on distinct brightness of the imaged object compared with the image background.

2.4.3 EDGE DETECTION

Edge detection is used to find locations in the digital image where the image brightness changes abruptly along a line of pixels. These abrupt changes usually define the edge of an object in an image. By using the edge detection, boundaries of an object can be identified. Once the boundary of an object is located, the size as well as other features of the object can be determined.

Note that the type of ROI used for edge detection is defined as a line in the image display. To use the edge detection algorithm, color image should be converted to either a grayscale or a binary image in advance.

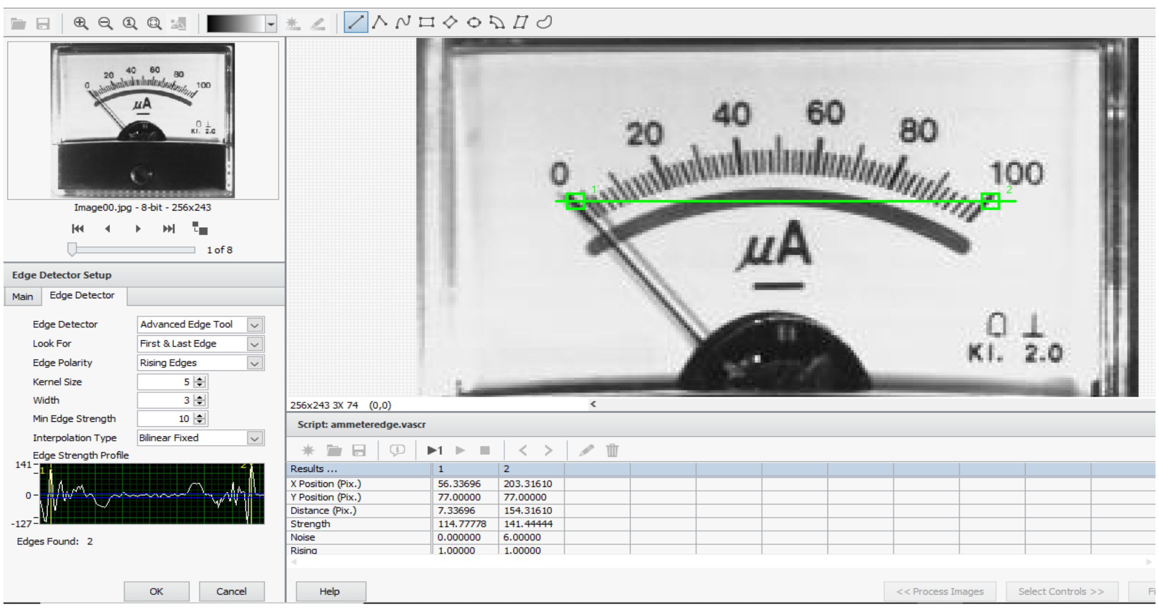


Fig. 2. 4 Screenshot of Edge Detection in NI Vision Assistant

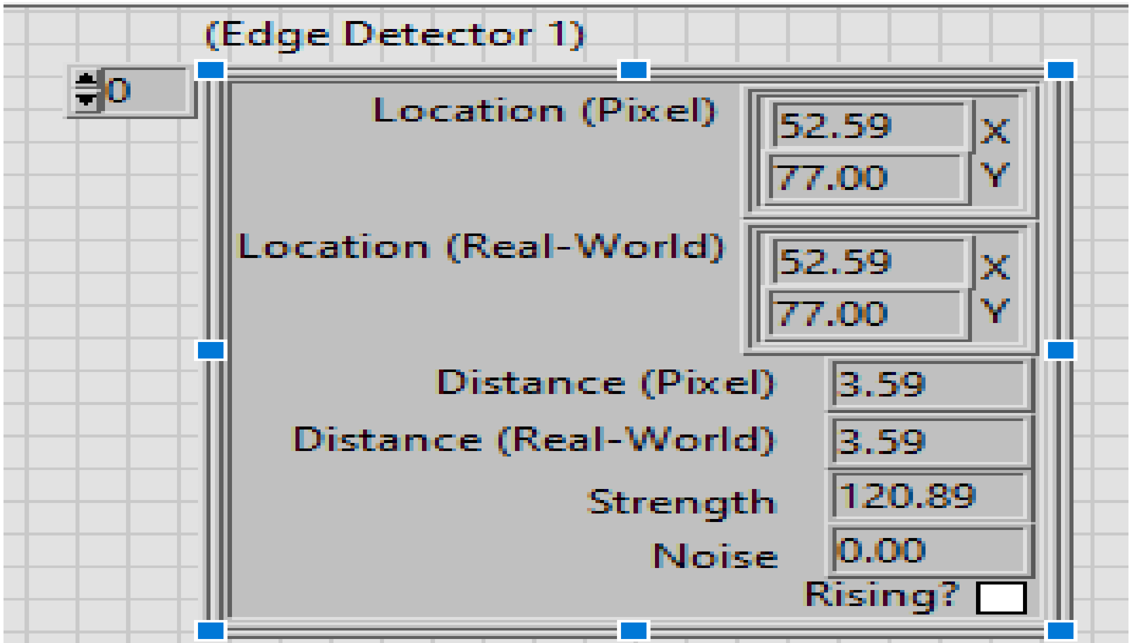


Fig. 2. 5 Block diagram of LabView front panel. Edges of starting and end point of scale are detected in (X,Y) coordinates in pixel values.

2.5 STEPS FOR CALCULATION OF NEEDLE POSITION

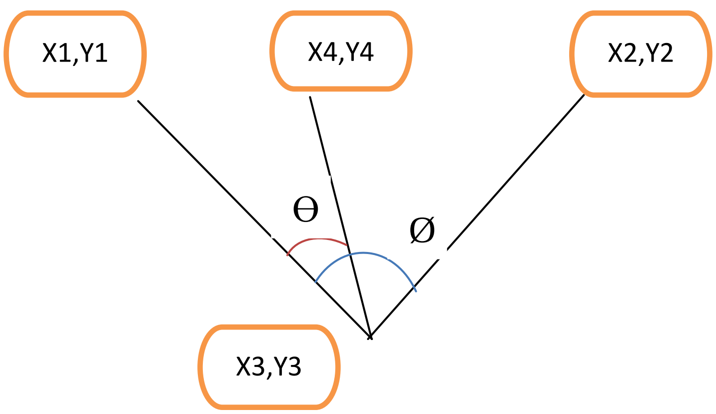


Fig. 2. 6 Line geometry connecting co-ordinates of the scale arc limits and pointer needle.

Steps involved in finding indicated value by the needle:

(a) Find out coordinate points (X1,Y1) and (X2,Y2) by edge detection method.

(b) Find out coordinate points (X4,Y4) with template matching

(c) With known angle Ø of the given meter find the coordinate points of needle vertex by the following calculation.

$$X3 = (X1+X2)/2 \quad (2.3)$$

$$Y3 = [(Y1+Y2)-(X2-X1) \times \cot(Ø/2)] / 2 \quad (2.4)$$

(d) Find the angle ϴ subtended by points (X1,Y1),(X4,Y4) and point of intersection at (X3,Y3) by below equation.

$$\text{Slop of first line } m1 = \frac{Y3-Y1}{X3-X1} \quad (2.5)$$

$$\text{Slop of first line } m2 = \frac{Y3-Y4}{X3-X4} \quad (2.6)$$

$$\text{Angle } ϴ = \text{Tan}^{-1}\left(\frac{m2-m1}{1+m1m2}\right) \quad (2.7)$$

(e) Find the angle subtended by needle

$$\text{Indicated value} = \frac{\text{Fullscale value}}{Ø} \text{x}ϴ \quad (2.8)$$

$$\text{Angle } ϴ = \text{Tan}^{-1}\left(\frac{m2-m1}{1+m1m2}\right) \quad (2.9)$$

(f) Find the value indicated by needle

$$\text{Indicated value} = \frac{\text{Fullscale value}}{Ø} \text{x}ϴ \quad (2.10)$$

2.6 AUTOMATIC CALIBRATOR CONTROL.

At present all modern digital calibrators are equipped with digital communication interface. As these calibrators are highly expensive and not required for a simulation study, Arduino Uno board is selected to simulate the behavior of a calibrator. Arduino uno is a micro controller board which can be programmed to the requirement of the user. Arduino Uno can be programmed to control through Lab View interface to generate required variable voltages as per the control applied through Lab View. PWM signal Voltages 0V and 3V are generated from Arduino board on application of command signals from Lab View. This PWM signal is filtered through an RC filter circuit and applied to analog meter to simulate behavior of calibrator.

2.7 AUTOMATIC REPORT GENERATION

Automatic report generation is done using LabView output to Microsoft Excel. The voltage generated from Arduino board is given to analog voltmeter and the readings are obtained as explained earlier in image processing module. The two values, one directly from calibrator to PC and another, read by image processing are compared in the Lab View, report generation module to find the error associated with meter under calibration. Report which is in excel format is also stored in a specified folder which can be printed or mailed as per convenience.

CHAPTER 3

SCHEME IMPLEMENTATION

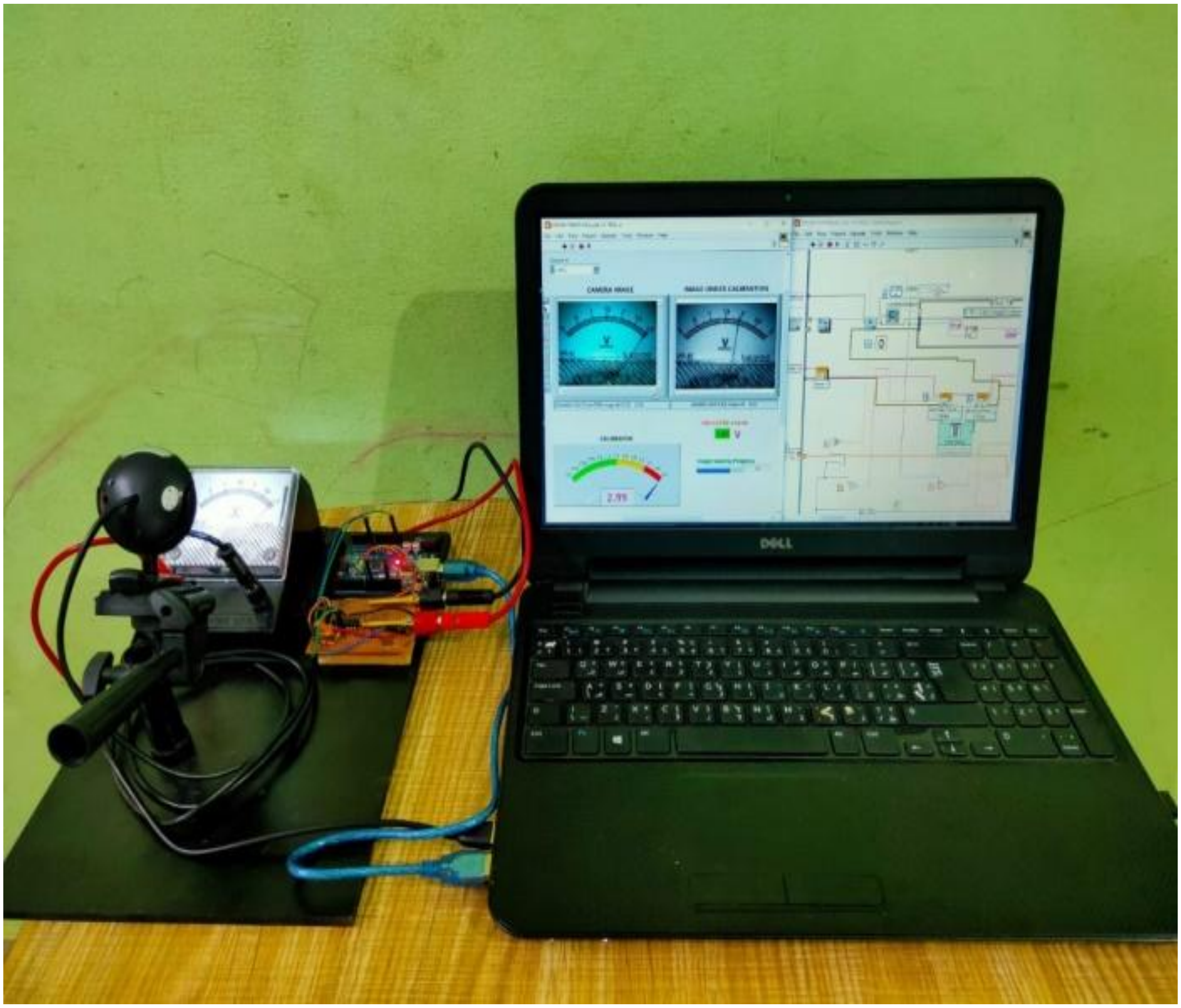


Fig. 3. 1 Automatic calibration test bench setup

3.1 IMAGE CAPTURE

Analogue voltmeter image is captured with a USB camera connected to the LabView installed PC. The camera is installed on a tripod to facilitate 3D rotational adjustment to focus over the analog meter under calibration. Image capture signals are generated by the LabView program to the USB camera and USB camera in turn return the analog meter images back to the PC.

Fig. 3. 2 USB camera setup

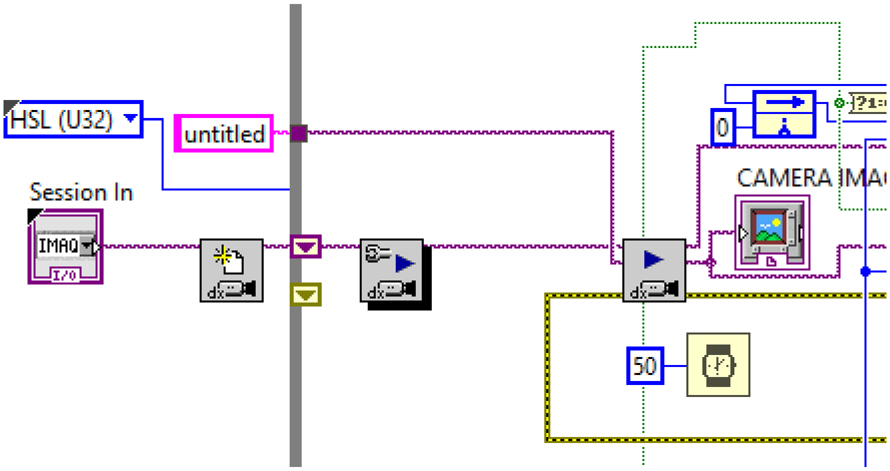


Fig. 3. 3 Screenshot of image capture Sub-VI

3.2 IMAGE STORAGE

Images are stored in a specified folder inside the PC with auto numbering enabled. On initiation of image capture signals the USB camera returns captured images to the LabView program. LabView is programmed to give auto numbering starting from Image1.jpg.Numbering will continue to increment till there is image available from USB camera. Snippet view of the LabView Image storage program is shown below.

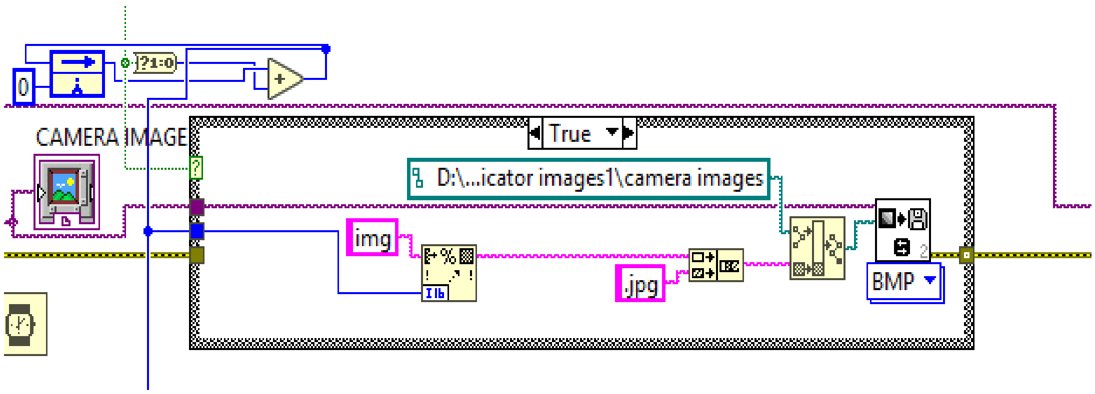


Fig. 3. 4 Screenshot of image numbering and storage Sub-VI

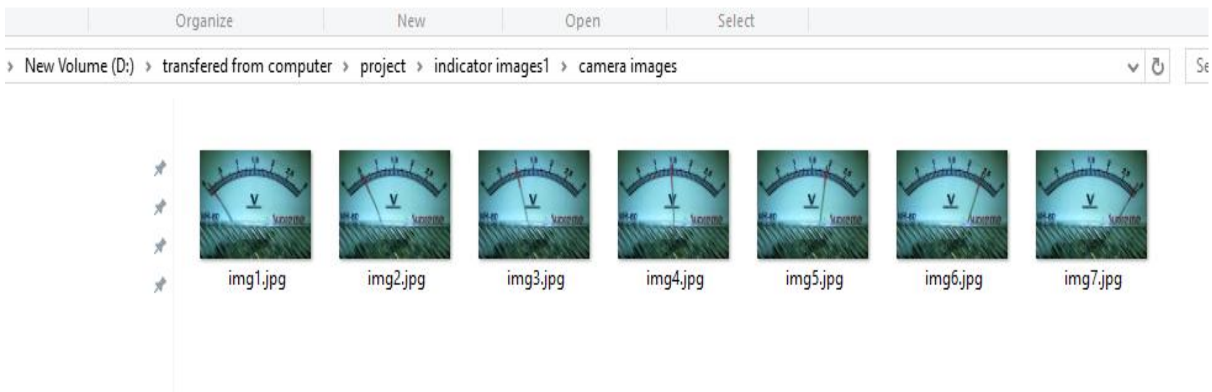


Fig. 3. 5 Screenshot of images stored in PC

3.3 IMAGE LOADING INTO LABVIEW CALIBRATION PROGRAM

On completion of input from calibrator to the analog DUC and capture of needle position images by the USB camera LabView automatically load these images one by one to the Calibration Program Module. The Calibration program consist of Image alignment, full scale arc detection, needle position tracking and mathematical calculation sub programs.

3.4 IMAGE ALIGNMENT SUB MODULE

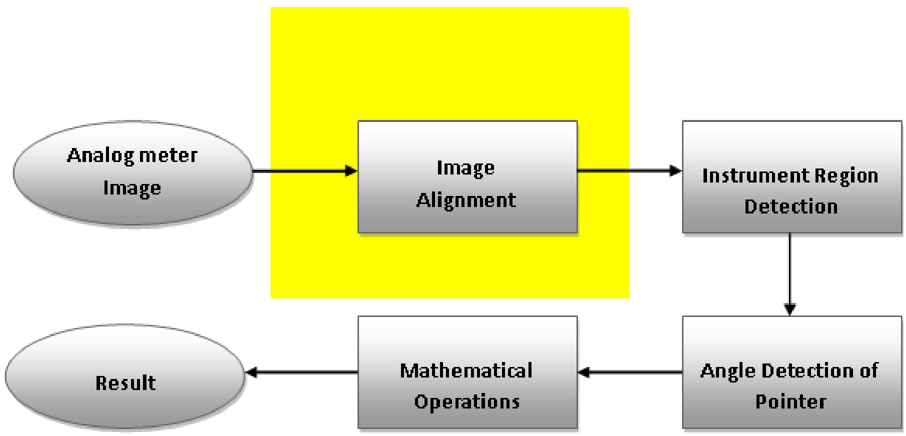


Fig. 3. 6 Block diagram showing image alignment step in Machine vision

Correction for transitional and angular displacement of the image has been applied through image alignment step.

A horizontally aligned image of the meter under test is selected as reference image.

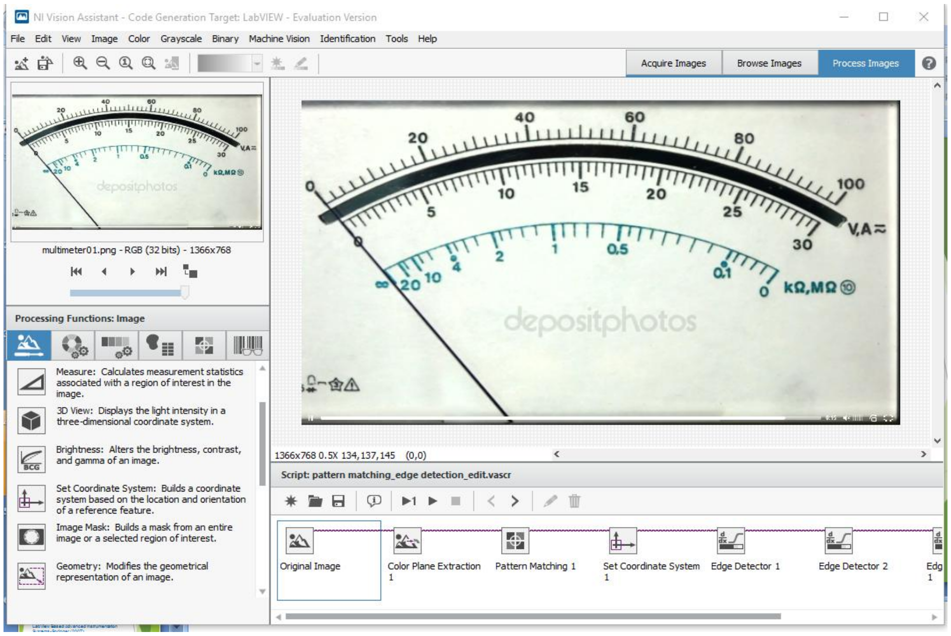


Fig. 3. 7 Screenshot of Horizontally aligned image loaded in Vision Assistant

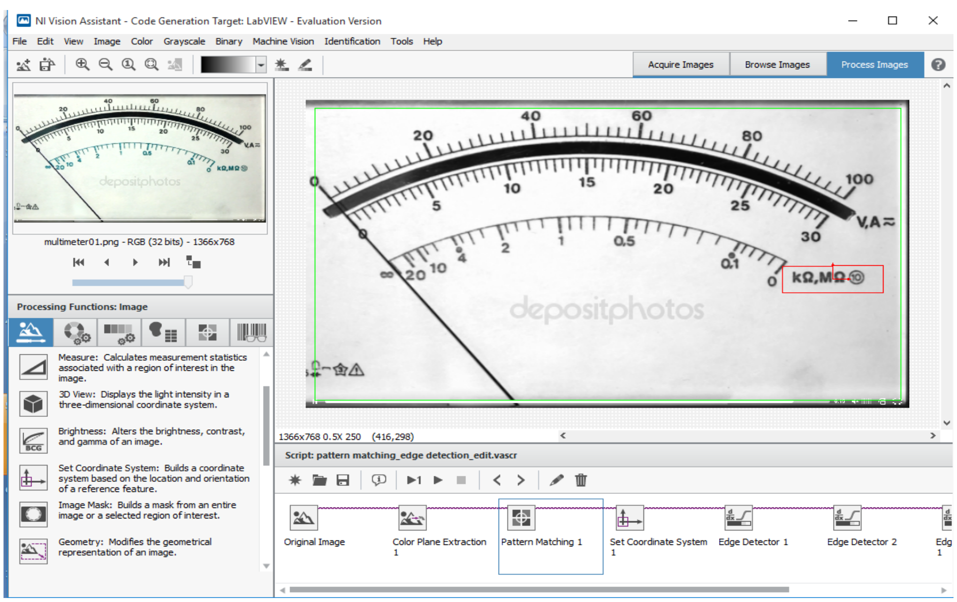


Fig. 3. 8 A prominent part of this image is selected as template for matching with other input images

Template matching is used to locate regions of an image that match a predetermined template. Pattern Matching can find template matches regardless of poor lighting, blur, noise, shifting of the template, and rotation of the template.

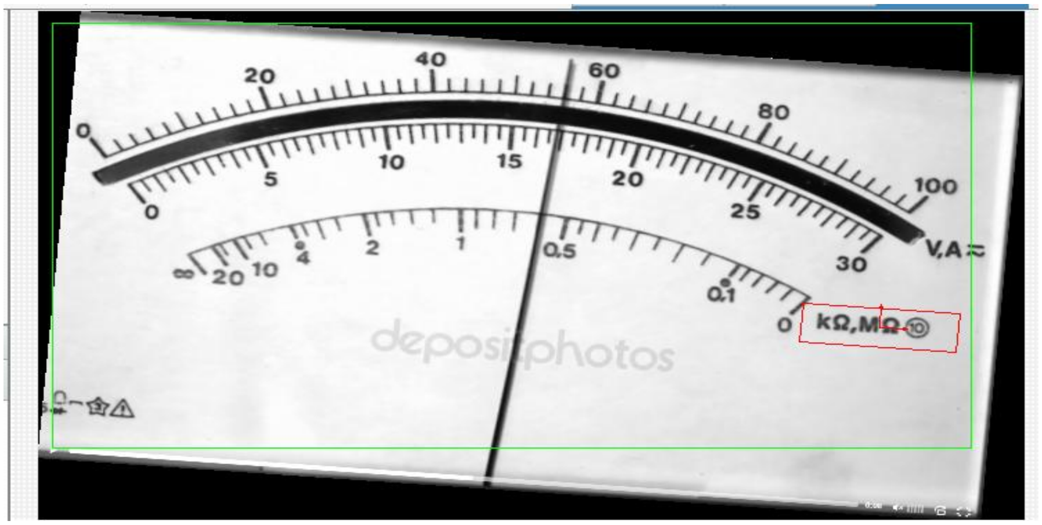


Fig. 3. 9 Screenshot of rotated image template area identified in Vision Assistant using template matching

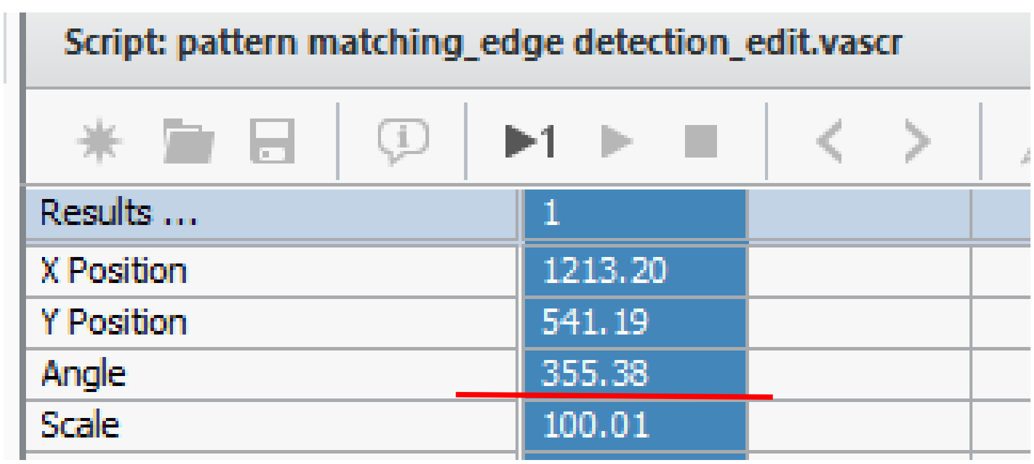


Fig. 3. 10 Screenshot of results of template matching

Set Coordinate System: This function is used to build a coordinate system based on the location and orientation of a reference feature.

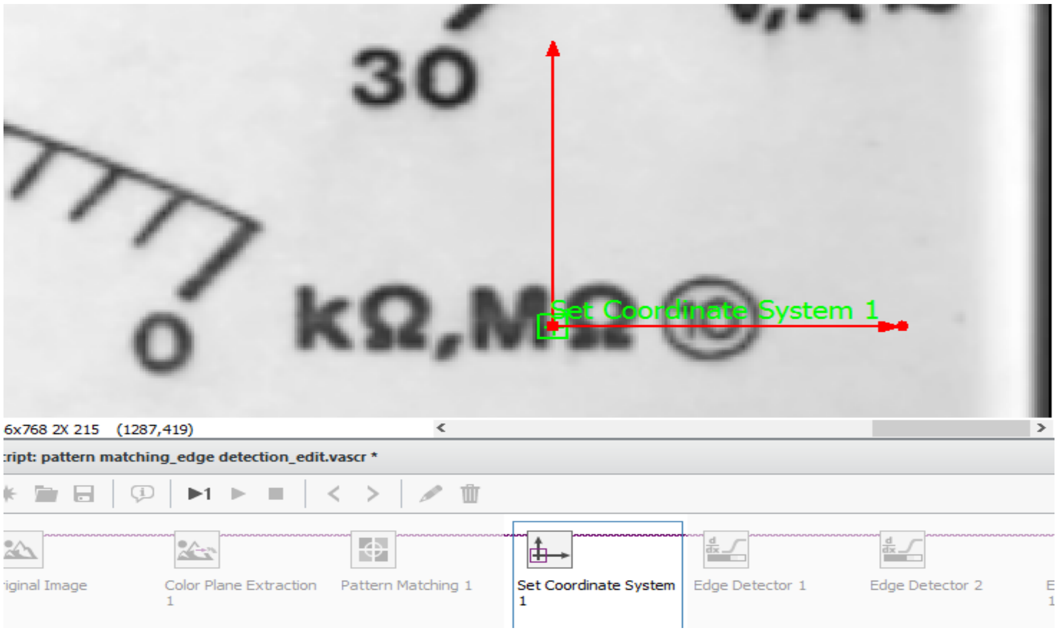
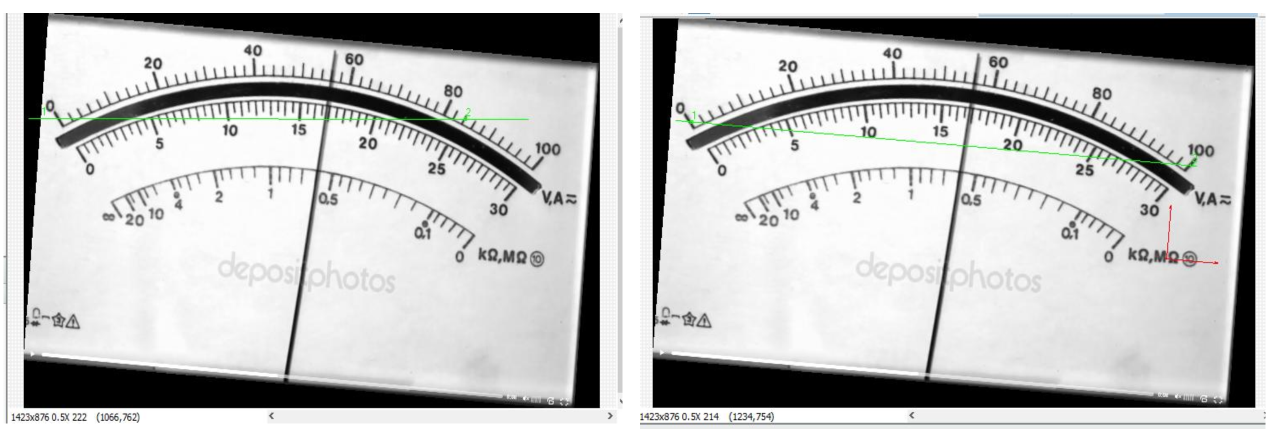


Fig. 3. 11 Screenshot of co-ordinate setup

The edge detection steps for finding meter region and needle position will also get translated according to shifted or rotated image.



Edge detection step without alignment correction

Edge detection step with alignment correction

Fig. 3. 12 Screenshot of edge detection error correction on rotated image using coordinate correction

Coordinate correction- with known translation (shift in x and y coordinates) and rotation (of the meter under test image coordinates w.r.t. reference image coordinates) coordinate correction is applied to the image according to the formula:

$$\begin{aligned} x' &= \cos\theta\, x + \sin\theta\, y, \\ y' &= -\sin\theta\, x + \cos\theta\, y, \end{aligned} \tag{3.1}$$

Where θ is the angle of rotation of the coordinates in radians.

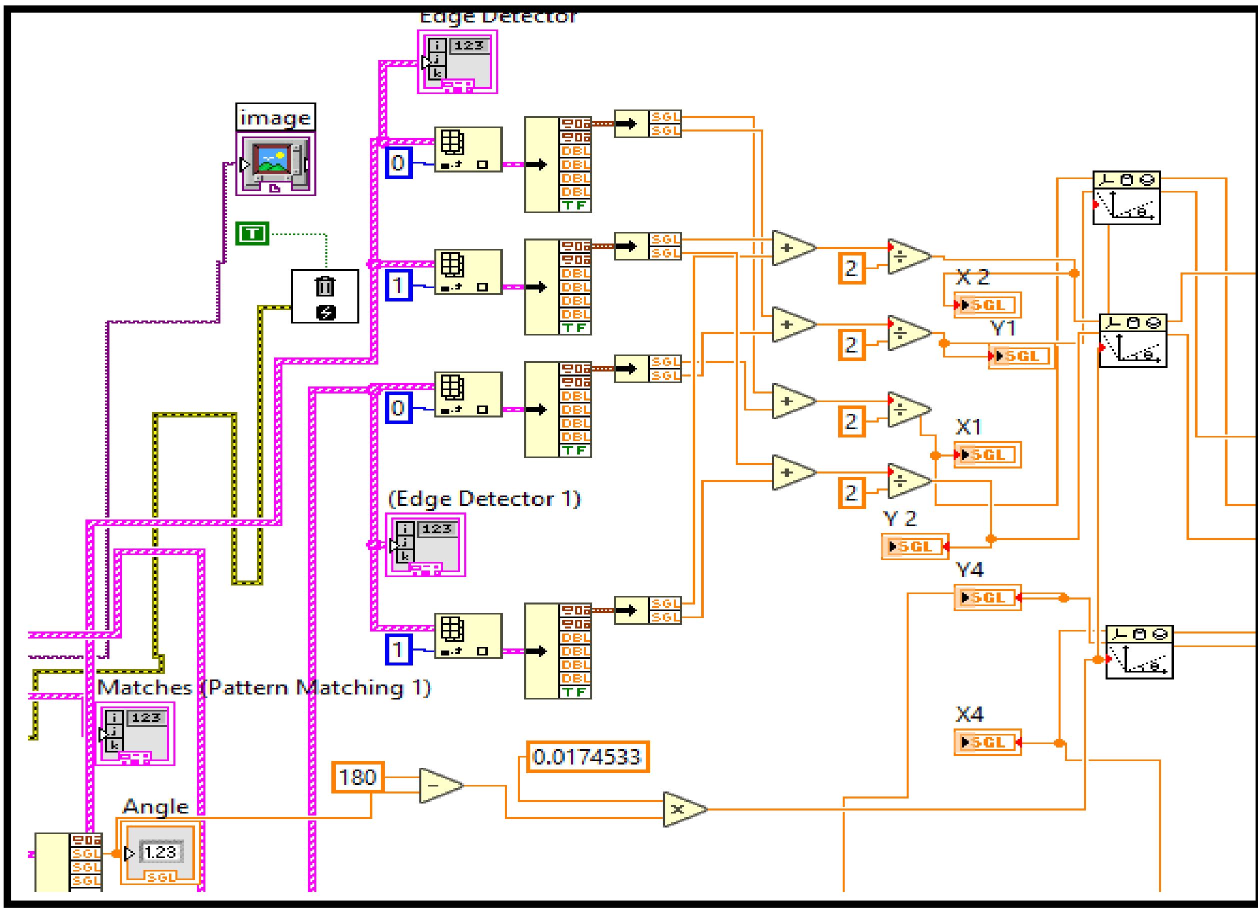


Fig. 3. 13 Screenshot coordinate setup using LabView Sub-VI

3.5 FULL SCALE ARC DETECTION

Full scale arc detection works on the principle of edge detection. Edge detection is used to find locations in the digital image where the image brightness changes abruptly along a line of pixels. These abrupt changes usually define the edge of an object in an image. By using the edge detection, boundaries of an object can be identified.

Here full-scale arc starting and end region marks distinctive change in image brightness along ROI line. The result shows X and Y position coordinate values for dial arc start and end points. In the Fig 1.15 coordinate position reading up to 3 significant digits are considered.

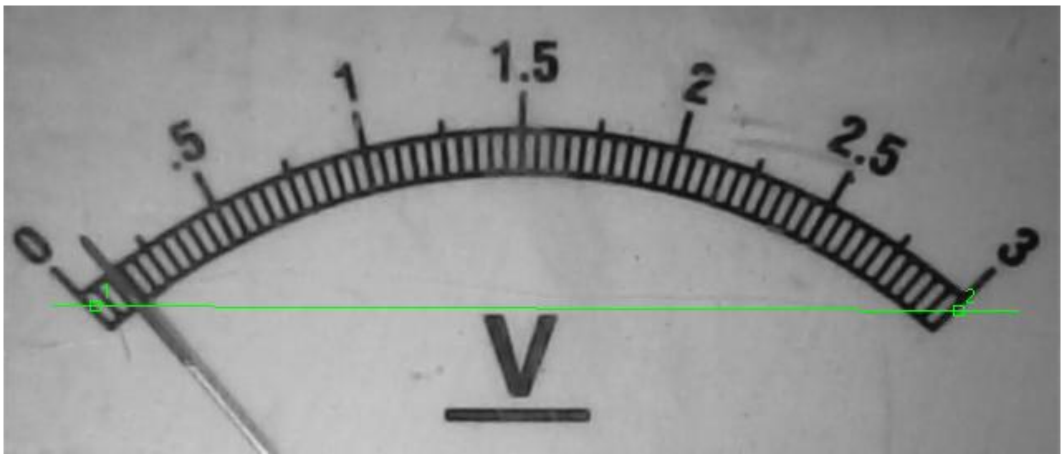


Fig. 3. 14 Screenshot of edge detection in LabView

Results ...	1	2
X Position (Pix.)	55.55995	577.62756
Y Position (Pix.)	182.92249	185.52861
X Position (pixels)	1.38782	7.58300
Y Position (pixels)	2.74756	2.73911
Distance (Pix.)	25.56007	547.63343
Distance (pixels)	0.32188	6.51707

Fig. 3. 15 Screenshot of results of edge detection (Table 1 is coordinates of meter arc starting point and Table 2 is arc end coordinate points)

3.6 NEEDLE POSITION TRACKING

LabView program is trained to identify the needle template and the program search for needle position anywhere in the region of interest and return the coordinate position of the needle.

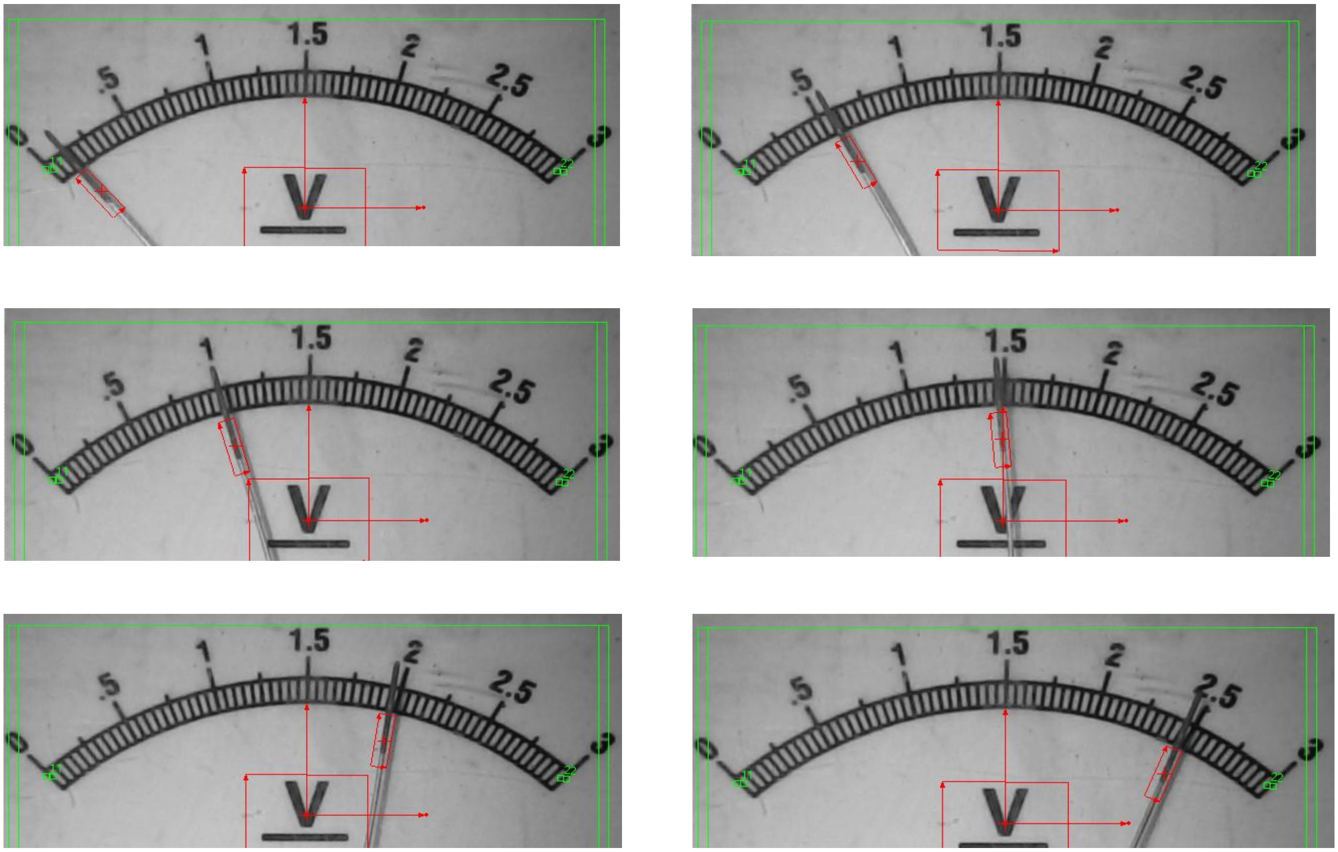


Fig. 3.15 Fig. 3. 16 Screenshot needle tracking done at different needle pointer positions

Results ...	1
X Position	470.57953
Y Position	173.83632
X Position (pixels)	6.33399
Y Position (pixels)	2.57765
Angle	337.66638
Angle (World)	338.47781

Fig. 3. 17 Screenshot of results obtained on needle tracking is in the X and Y pixel coordinates of the current needle position

3.7 MATHEMATICAL CALCULATIONS

Trigonometric relationship corresponding to intersecting lines is used for finding the needle sweep angle. The last step in this image processing is the calculation of the indicated value. With the knowledge of full-scale value, full scale angle and pointer sweep angle, indicated value can be calculated. The calculated values by image processing are recorded in an array and the process is repeated automatically for the next available image.

Steps involved in finding indicated value by the needle:

(g) Find out coordinate points (X1,Y1) and (X2,Y2) by edge detection method.

(h) Find out coordinate points (X4,Y4) with template matching

(i) With known angle Ø of the given meter find the coordinate points of needle vertex by the following calculation.

$$X3 = (X1+X2)/2 \tag{3.2}$$

$$Y3 = [(Y1+Y2)-(X2-X1) \times \cot(Ø/2)] / 2 \tag{3.3}$$

(j) Find the angle Ɵ subtended by points (X1,Y1),(X4,Y4) and point of intersection at (X3,Y3) by below equation.

$$\text{Slop of first line } m1= \frac{Y3-Y1}{X3-X1} \tag{3.4}$$

$$\text{Slop of first line } m2= \frac{Y3-Y4}{X3-X4} \tag{3.5}$$

$$\text{Angle } Ɵ= \text{Tan}^{-1} \left(\frac{m2-m1}{1+m1m2}\right) \tag{3.6}$$

(k) Find the value indicated by needle

$$\text{Indicated value} = \frac{\text{Fullscale value}}{Ø} x Ɵ \tag{3.7}$$

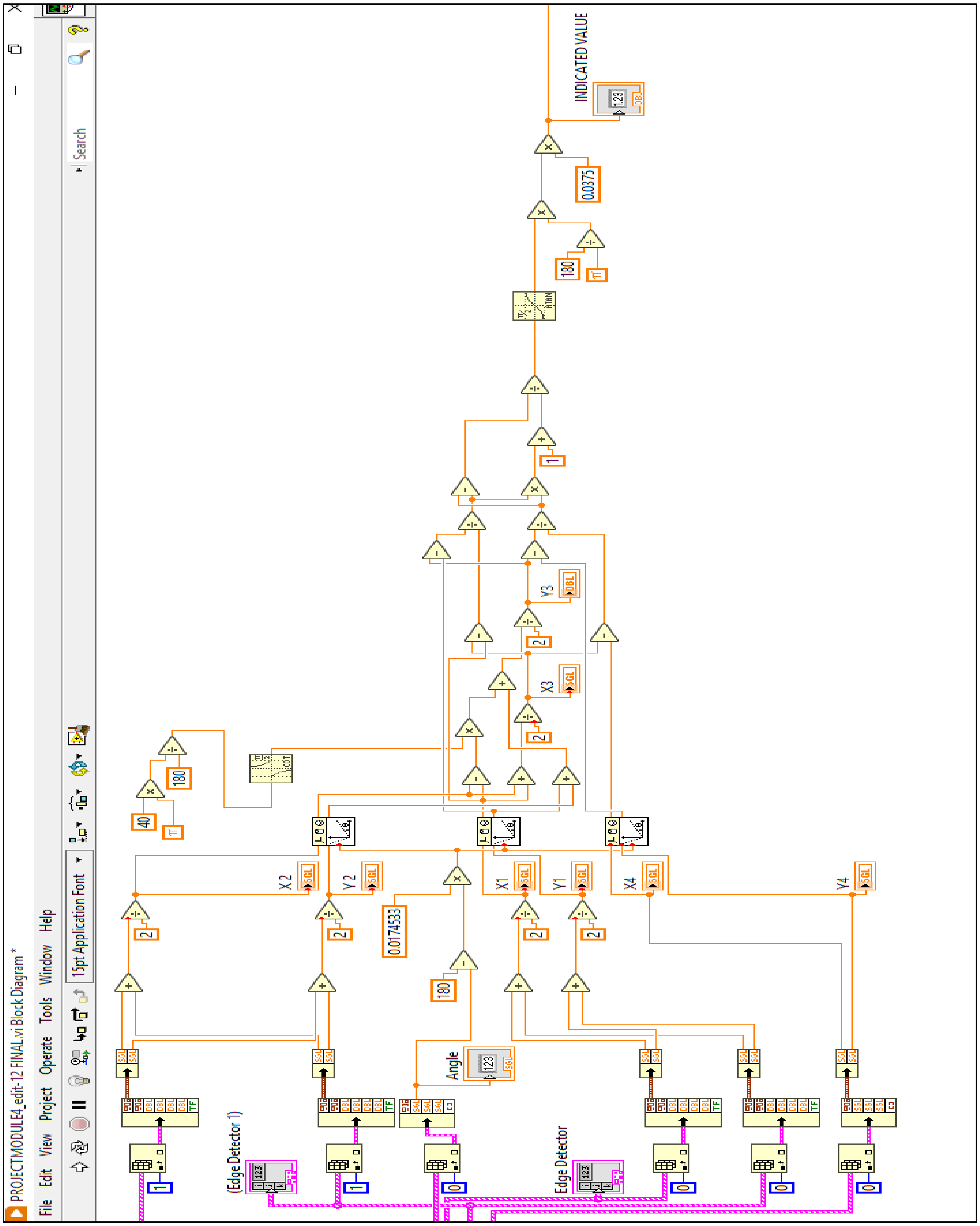


Fig. 3. 18 Screenshot of mathematical calculations implemented on LabView Sub-VI

3.8 CALIBRATOR CONTROL SIMULATION

Arduino Uno board is selected to simulate the behavior of a calibrator. Arduino uno is a micro controller board which can be programmed to the requirement of the user. Arduino Uno can be programmed to control through Lab View interface to generate required variable voltages as per the control applied through Lab View. PWM Voltages between 0V and 3V are generated from Arduino board on application of command signals from Lab View.

The Arduino IDE has a built in function "analogWrite()" which can be used to generate a PWM signal. The frequency of this generated signal for most pins will be about 490Hz and we can give the value from 0-255 using this function.

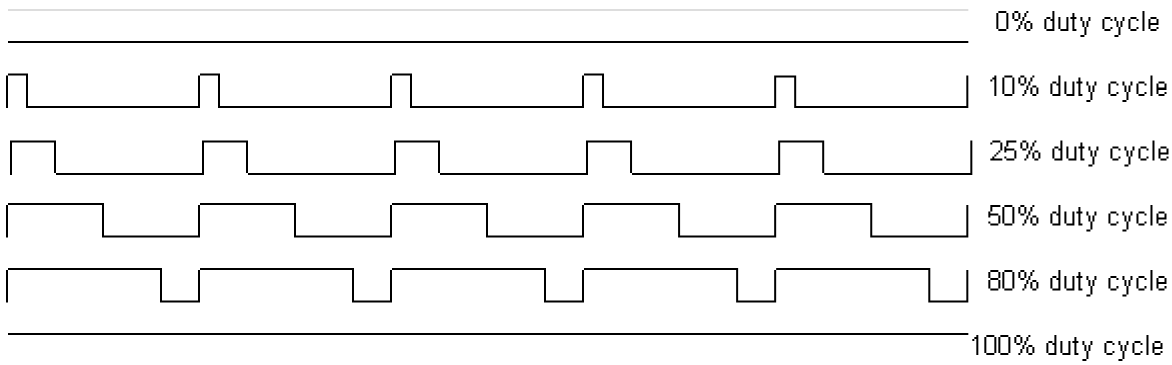


Fig. 3. 19 PWM Waveform

Arduino Uno integration with LabView is done through LINX software. LINX is an open source project by Digilent and is designed to make it easy to develop embedded applications using LabVIEW. LINX provides easy to use LabVIEW VIs for interacting with common embedded platforms like Arduino.

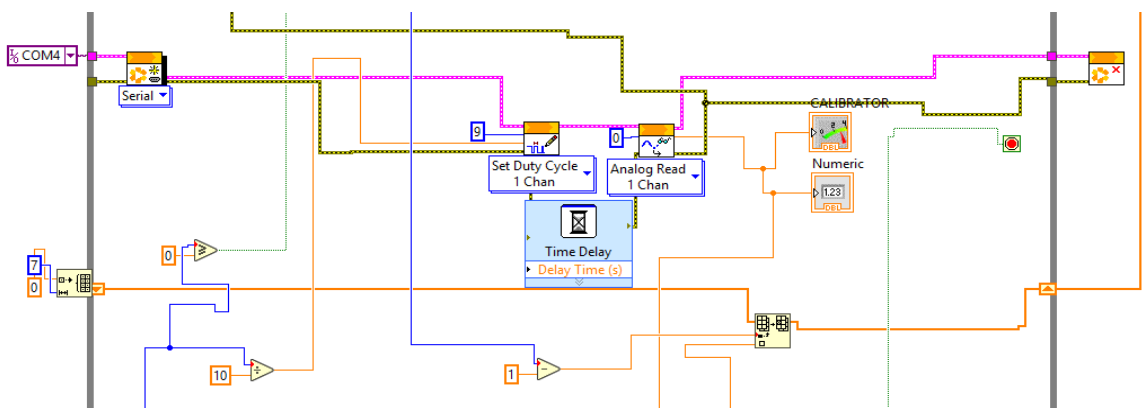


Fig. 3. 20 VI sub module for Arduino Uno PWM generation

PWM signal generated by Arduino board is filtered using RC active filter circuit

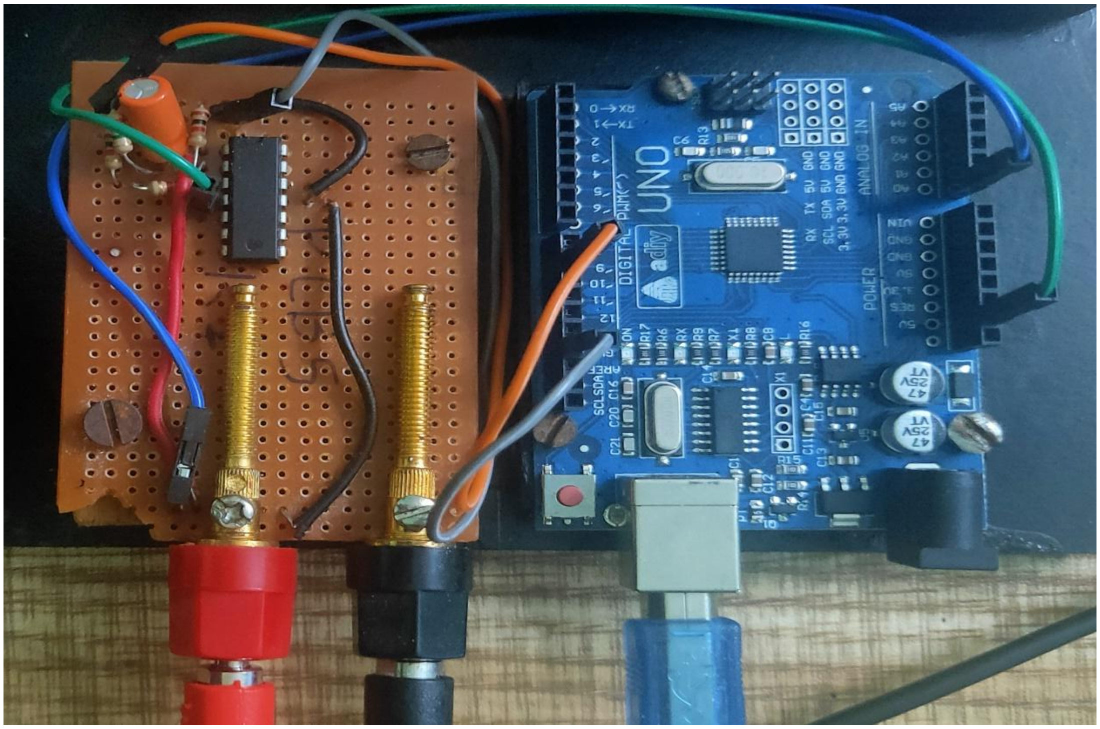


Fig. 3. 21 Master calibrator simulation circuit

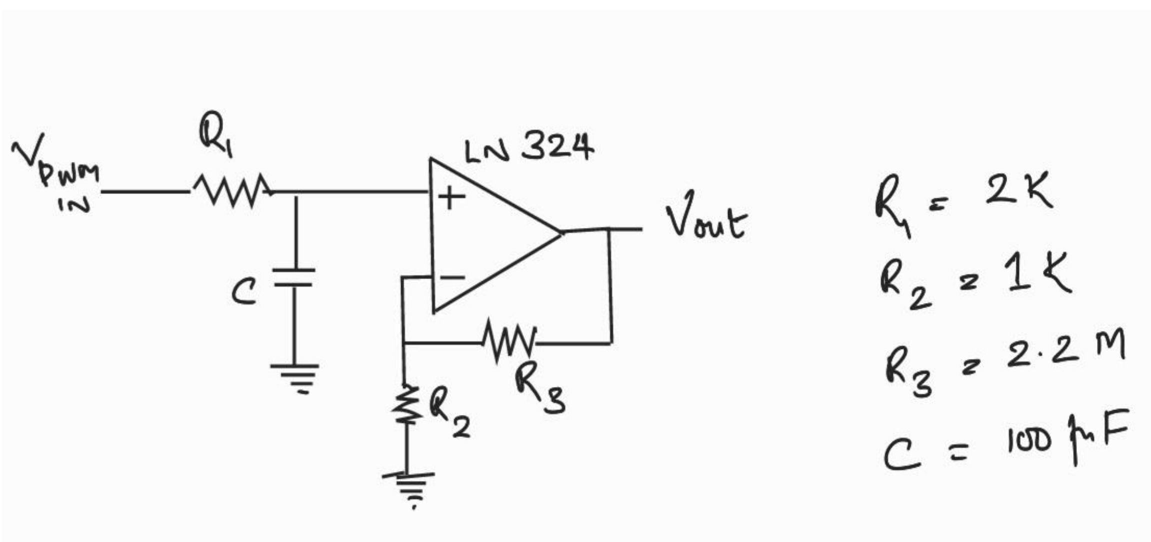


Fig. 3. 22 RC filter with active buffer circuit (Ref:
http://www.ecircuitcenter.com/Circuits/opfil1/opfil1.htm

3.9 LABVIEW FRONT CONTROL PANEL

The Figure below shows the lab view front panel from where all control signals are generated. Left top is camera selection window. Below that a window shows live camera view of the instrument. Left bottom is the calibrator voltage output indication. On application of voltage to analog instrument the image is captured and entered into the image processing module and also shown in the right image window. The values calculated by the program are indicated in the small window below along with calibration progress bar.

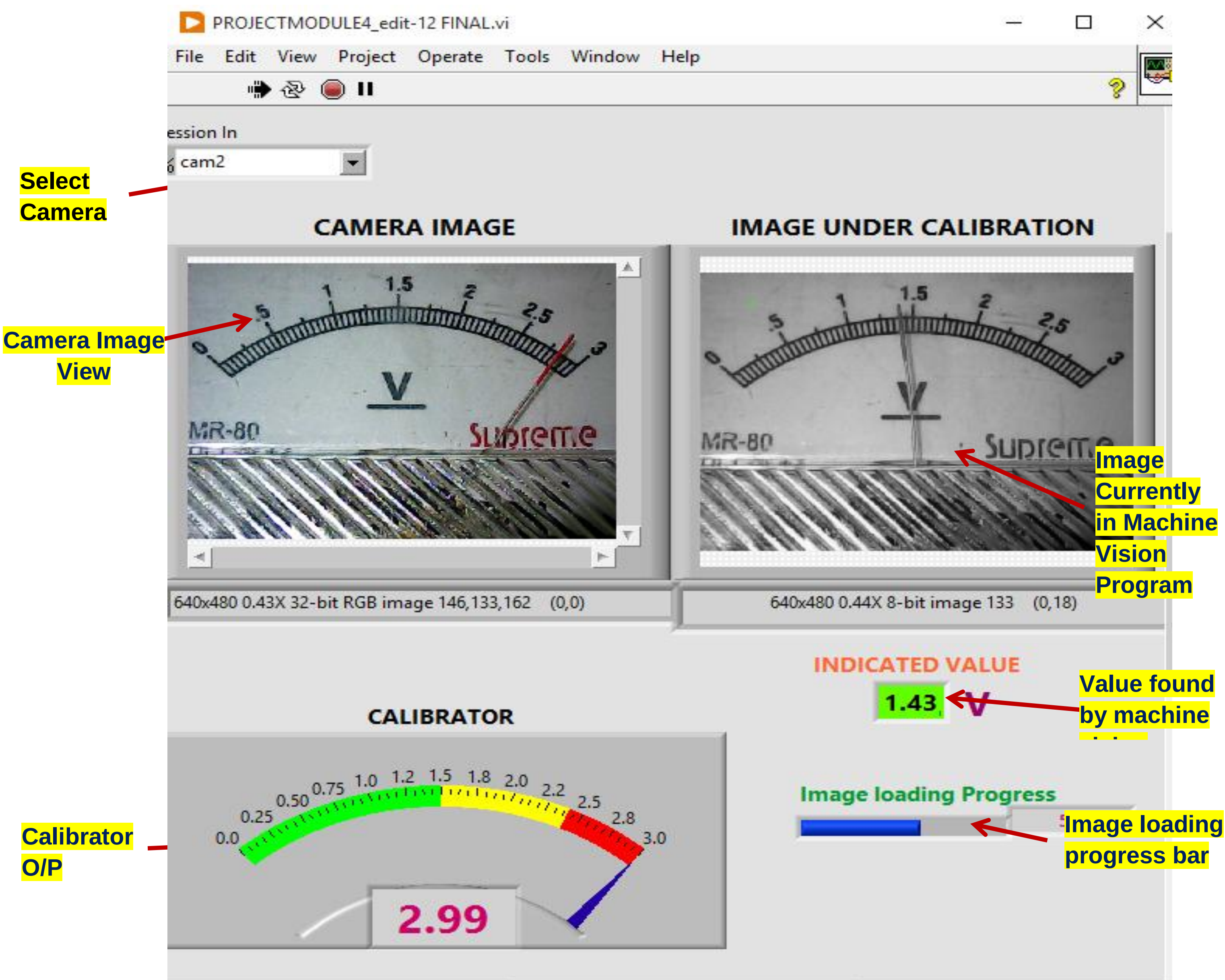


Fig. 3. 23 Front Control Panel

3.10 AUTOMATIC REPORT GENERATION

Automatic report generation is done using LabView output to Microsoft Excel. Sub VI for implementing the above process is shown below:

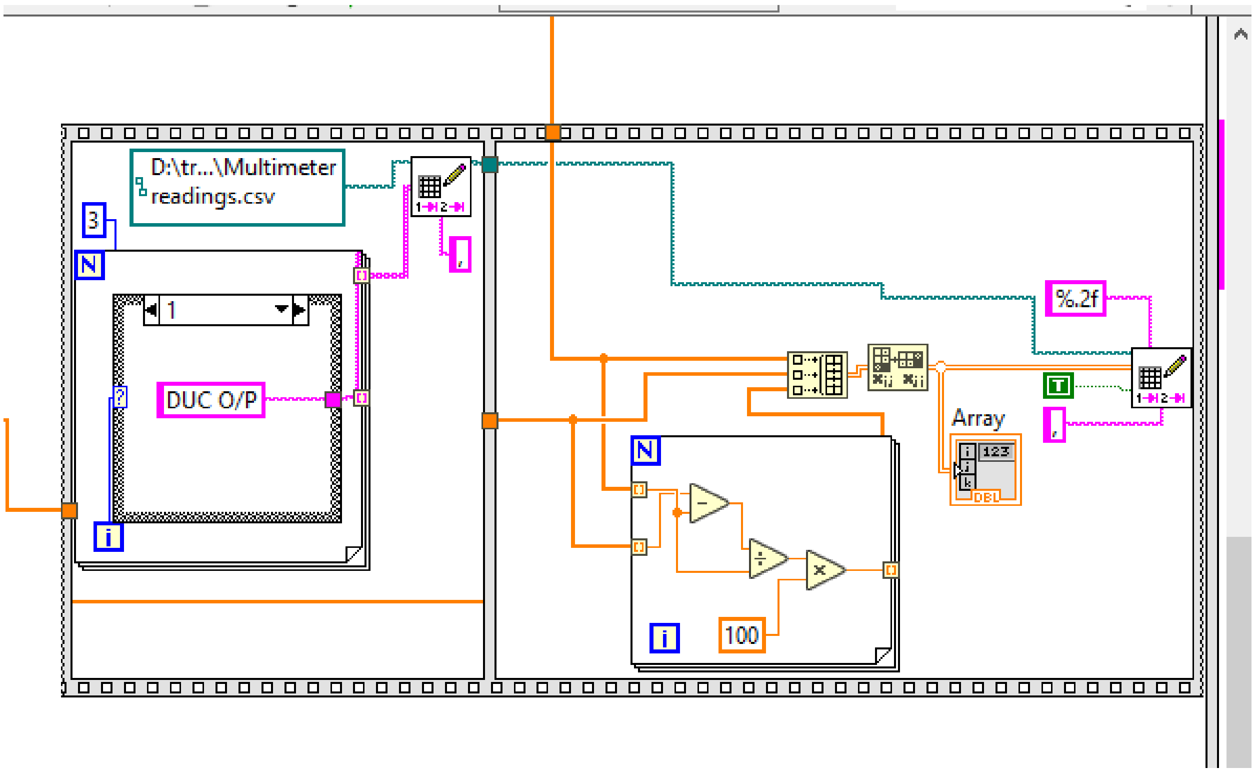


Fig. 3. 24 Automatic report generation Sub-VI

CHAPTER 4

RESULTS AND INFERENCES

Important results of the study conducted are presented here. Indicated values are recorded for three experiments. First one with Horizontally aligned image second with 5 degree clockwise rotated image and third experiment with 5-degree anti-clockwise rotated image.

4.1. EXPERIMENT 1

Experiment was carried out with a 0-3 Volts voltmeter reading filtered PWM output from Arduino uno board. The indicated value read by image processing and read by visual inspection from the output of the analog voltmeter was compared and results are tabulated in table.

Value read by Visual Inspection	Value read by Machine Vision	% of Accuracy
0.15V	0.15V	100
0.55V	0.56V	98.1
1.00V	1.01V	99.0
1.90V	1.91V	99.4
2.35V	2.36V	99.5
2.85V	2.86V	99.6

4.2 EXPERIMENT 2

The experiment as above carried out with analog voltmeter tilted to right to find the effect of meter Vs camera misalignment error. The indicated value read by image processing and read by visual inspection from the output of the analog voltmeter was compared and results are tabulated in table.

Value read by Visual Inspection	Value read by Machine Vision	% of Accuracy
0.15V	0.14V	93.3
0.55V	0.55V	100
1.00V	0.99V	99.0
1.90V	1.88V	98.9
2.35V	2.32V	98.7
2.85V	2.84V	99.6

4.3 EXPERIMENT 3

The experiment as above carried out with analog voltmeter tilted to left to find the effect of meter Vs camera misalignment error. The indicated value read by image processing and read by visual inspection from the output of the analog voltmeter was compared and results are tabulated in table.

Value read by Visual Inspection	Value read by Machine Vision	% of Accuracy
0.15V	0.16V	93.3
0.55V	0.57V	96.3
1.00V	1.02V	98.0
1.90V	1.91V	99.4
2.35V	2.37V	99.1
2.85V	2.86V	99.6s

4.4 INFERENCES

Comparing the experiment results of machine vision-based calculation to the readings obtained by human eye a higher level of accuracy of is obtained. The results hold the similar accuracy even in case the meter is slightly misaligned with respect to the camera position. With analog meter under calibration having reading uncertainty of +/- 0.025V the readings obtained by machine vision can be estimated to nearest uncertainty value. This will avoid mistaken uncertainty evaluation due to a more precise machine vision reading, if the uncertainty due to image resolution is taken instead of the uncertainty due to instrument scale resolution, like in conventional calibration.

4.5 CONCLUSION

LabView installed PC based automatic calibration of analog instruments was attempted in this thesis work. By using computer vision techniques, the pointer's position in the scale of analog instruments is determined. The project clearly demonstrates accurate and fast calibration of analog instruments which otherwise could not benefit from the advantages of automatic calibration.

CHAPTER 5

SUMMARY AND FUTURE SCOPE

5.1 SUMMARY

The calibration of analog or digital measurement instruments not equipped with computer interfaces does not benefit from the advantages of automatic calibration. In these cases, manual test methods are applied where the calibration technician must manually read the value of the reading of the instrument being calibrated, or must adjust manually the calibrator so that the instrument being calibrated presents some particular reading. These are very time consuming, and results are subject to human errors. As a consequence, the calibration of these instruments is, in many cases, less frequent than it is desirable.

The system presented in this paper allows the implementation of completely automated calibration procedures, even in the cases of instruments not equipped with computer interfaces. The computer automatically instructs the calibrator to output a chosen value, obtains the reading of the instrument, calculates the error with which the instrument being calibrated performed the measurement and compares the value with the limit specified by the manufacturer. The calibration procedure often consists of repeating this routine for different values. The calibration report also generated automatically.

5.2 FUTURE SCOPE

Being shown the possibility of automating analog tester calibration, the challenges for implementing the same in Indian Air force are to be studied. Like all other modernization in IAF collection of data base for all available analog instruments is the first task.

A survey of calibrators available for integration has been already carried out here in the 5 Base Repair Depot (BRD) Calibration Lab of Indian Air Force. Integration of this calibrators and trial on analog instruments are to be carried out in 5 BRD AF for validation of results.

On successful validation of the results project can be rolled out in Indian Air Force.

.

5.3 REFERENCES

[1] de Lima D. L., Pereira G. A. S., de Vasconcelos F. H.: A Computer Vision System to Read Meter Displays. 16th IMEKO TC4 Symposium Exploring New Frontiers of Instrumentation and Methods

[2] Ocampo-Vega, R.; Sanchez-Ante, G.; Falcón-Morales, L.E. Automatic reading of electro-mechanical utility meters. In Proceedings of the 12th Mexican International Conference on Artificial Intelligence, Mexico City, Mexico, 24–30 November 2013; pp. 164–170.

[3] Zhang, Z.; Li, Y. Research on the pre-processing method of automatic reading water meter system. In Proceedings of the International Conference on Artificial Intelligence and Computational Intelligence, Shanghai, China, 7–8 November 2009; pp. 549–553.

[4] Andria G., Cavone G., Fabbiano L., Giaquinto N., and M. Savin: Automatic Calibration System for Digital Instruments without built-in Communication Interface. XIX IMEKO World Congress Fundamental and Applied Metrology, September 6−11, 2009, Lisbon, Portugal.

[5] Pociecha D. M.: Development of the automatic stand for the measurement devices calibration using advanced image processing, MSc dissertation, Wrocław University of Technology, 2014.

[6] Alegria F. C., and Serra A. C.: Automatic Calibration of Analog and Digital Measuring Instruments Using Computer Vision, IEEE Trans. on Instrumentation and Measurements, vol. 49, no. 1, 2000.

[7] Dominik Pociecha, The histogram-enhanced Hough transform applied to automated readout of analogue gauge meters using digital image processing, Measurement Automation Monitoring, Nov. 2015, vol. 61, no. 11.