Analog Meter Digital Reading using Digital Image Processing

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Abstract

The modern ways in which the health of most old industrial systems is identified is through continuous monitoring of the various supporting devices that are mostly analog systems. These analog systems need to be kept under a continuous watch to make sure that there are no unnecessary surges in the system. This process requires a lot of trained manpower that needs to observe the meters at repeated intervals and ensure that there is no imminent danger to the power plant. This paper outlines an algorithm that can automatically identify the pointer gauge readings using images captured by a camera. This will help in providing a record of the readings for future reference by deploying an automatic approach based on computer vision and digital image processing.

If we consider real world problems, like that of a Nuclear Power plant, where converting Analog systems to Digital Systems requires a lot of capital and change in infrastructure, an Analog Meter Reader is the most viable solution. This Analog Meter Reader replaces the conventional Human-Analog interface with an Analog-Digital interface that uses computer vision and gray-scaling techniques to convert the set of analog system images fed into the system into a digital value, thus converting an Analog system into a Digital system without changing the current systems in place. The system uses Circle and Edge Detection image processing techniques that are used for identifying and observing the current position of the needle in the meter and gives an output directly to the user interface where threshold values can be manipulated. For this project and with the given apparatus, we are able to achieve an accuracy of about 60%, however, with better equipment we can achieve higher accuracies.

Keywords—*Monitoring, Analog Systems, Computer Vision, Digital Image Processing.*

I. INTRODUCTION (*ANALOG METER DIGITAL READING)*

Analog meters are instruments that are used to measure quantities such as current, voltage, signal power, frequency and resistance. The basic operation includes measurement of current in amperes, resistance in ohms, and potential in volts. Analog multi meters can also be used to find electrical problems in the equipments. Once these Analog systems are set up for huge scale projects like Nuclear Power Plants, the overall cost of replacing an entire unit of Analog meters and replacing them with fast and efficient digital meters is very high and generally takes a lot of restructuring. In order to eliminate the problem of extra costs of replacing traditional systems, training manpower, erring human needs and the inefficiency of Analog Meters, Digital Image Processing using grayscaling techniques and Circle, Line and Edge Detection algorithms that make use of the facilities of OpenCV, Raspberry Piand an external camera module is a viable solution to the above mentioned problems. This Analog Meter Reader replaces the conventional Human-Analog interface with an Analog-Digital interface to convert the set of images fed into the system into a digital value, thus converting an Analog system into a Digital system without changing the current systems in place. This project uses fundamentals of Raspberry Pi, Python and OpenCV in unison to capture the images of the meters in the Industrial Systems using a camera and send these images to a Data Acquisition System, in this case a Raspberry Pi 3, in order to convert the images to a grayscale format in order to distinguish the colors and parts of the image. Once this is achieved, sine and cosine functions can be used to calculate the angle between the initial reading of the meter and the point to where the needle is currently placed located on the dial.

Further, the paper has been organized in the following way; Section 2 consists of the motivation for the proposed system and the reason why this project was incepted. Section 3 consists of the literature

ISSN: 2005-4238 IJAST

survey and followed by Section 4 which talks about the inference from each survey. Section 5 consists of the proposed work which includes the design of the overall system and current hardware and software that is being used for this project. Section 6 consists of the implementation of the system and the output results for each segment. Section 7 shows the results that are obtained after performing tests on the system and Section 8 concludes the paper by giving the necessary closure to the paper.

II. MOTIVATION FOR THE PROPOSED SYSTEM

A. The PGCIL Power Plant

The idea of the project came from the problems that are faced in the PGCIL Power Plant in Jabalpur where they had problems in training and regulating man power to monitor the systems of the power plant. The impetus for this project is to provide a better technology for computing the values of industrial meters in trying to identify thresholds for analog meters with radial (or similar shaped) dials, so as to provide a real-time solution to the shortcomings and the current process of monitoring traditional industrial meters. In the Chernobyl disaster of 1986, a human error which was a breach of predefined protocols, led to 4000 deaths and an everlasting radiation in the Pripyat region of Russia.np. Power Plants, Manufacturing Plants, Electricity Grids, etc where current monitoring systems exist but depend on human involvement, manipulation, calculation and guidance. In systems where regulation of physical quantities like Current, Voltage and Power that exist in the ranges of Kilo Volts and Giga Watts is highly critical, a smart system that sends values of the above mentioned quantities, to a Data Acquisition System and gives a prompt if the threshold values are crossed is the most viable solution to upgrading the current systems that are being used every day.

B. Existing System

The existing systems include physical human observations along with partial automation for the already existing systems in place. This method is not fully efficient because it may lead to wrong observations by the human.

III. LITERATURE SURVEY

[1] Machine Vision Based automatic detection method of indicating values of a pointer gauge.

This paper highlights the defects of the current recognition systems that are in place and uses "Region Growing" to locate the dial region and its center. This paper is essential for this project because the method of identification of the center and the circumference of the dial can be found out using the fundamentals mentioned in this paper. The above could be made more effective with an IoT interface in order to make the whole system more mobile.

[2] Segmentation free approaches of computer vision for automation calibration of digital and analog instruments.

"Segmentation" is a Computer Vision algorithm that is the process of partitioning a digital image into multiple segments in order to simplify and/or change the representation of the image into something simpler, however when segmentation is used, a lot of essential grayscale information goes to waste and hence, in order to accurately "calibrate" the instruments, we need the greyscale information and thus, other techniques like "Template Matching" are used in order to solve this problem.

[3] An automatic recognition method of pointer instrument based on improved Hough transform

This paper implements automatic recognition of pointer instruments using an advanced "Hough Transform". A Hough Transform is a mathematical concept that is used in image processing in order to extract features from an image and find imperfect instances of objects within a certain class of shapes. This method is used in the OpenCV library for cv2.HoughCircles in the method attribute in order to define the type of Hough Transform. The advantage of such a system is the ability of the algorithm to work in low light conditions. According to the angle method, the pointer reading is obtained using a linear relationship between the initial scale and the angle of the instruments' pointer.

[4] ViDAQ: A computer vision based remote data acquisition system for reading multi-dial gauges

This prototype of a Visual Data Acquisition System aims to eliminate the idea of a Human Machine Interface and to replace it with a Visual Data Acquisition System in order to remove a human interface between the Machine and systems on board. It also deploys a EYE-on-Human Machine Interface that requires a human to keep an eye on the interface of the ViDAQ. This system involves overall monitoring of the system and includes a Human Factor Engineering System.

[5] Research on automatic reading recognition of index instruments based on computer vision.

This paper talks about the automatic reading recognition of index instruments according to the precision demand of the calibration system. The "Total Least Squares Method" is used to find the center of the panel and an "Improved angle method" and the "Distance Method" is proposed to recognize the gauge reading.

[6] Analog dial gauge reader for handheld devices.

This paper talks an algorithm that can read the analog gauges using a handheld device to identify the reading of the analog meter. It uses a "Polar Representation Technique" of the dial gauge image to identify the needle and the start position of the dial.

IV. Inference From The Survey

According to [1], the algorithm used to detect the various parameters of the gauge like the center of the gauge and the outline of the gauge is "Region Growing". However, a better implementation of the above system could include a remotely operated system
The main focus of [2], is to avoid using the Segmentation algorithm which causes the loss of the grayscaling information and rather implement "Template Matching" in order to find the parameters of the gauge.
According to [3], the Hough Transform algorithm is used to perform the HoughCirclesP function from the OpenCV library and is the most viable solution for our project because of the numerous advantages it has over the other forms of implementation.
According to [4], the main objective of the project was to establish an EYE-on-Human Machine Interface in order to eliminate the existance of human actions on the machines that are being analysed through the ViDAQ. A better analogy would be to try and circumvent the EYE-on-Human Machine Interface and use an externa camera to analyse, collect and process the information at one go.
According to [5], the "Total Least Squared Method" can be used to find the center of the gauge and it's other parameters with extreme precision and is usually used for calibration.
According to [6], handheld devices like PDAs can be used to find the reading of the analog gauge. The algorithm used for this is the Polar Representation Technique that uses polar data to identify the position of the needle and the center of the gauge.

From the above comprehensive literature survey it is observed that a combination of the Hough Transform algorithm and a remotely accessible system that can be implemented on a system like a Raspberry Pi is the best of both worlds for such an application. The advantages of Hough Transform include:

- Pixels lying on one line need not be contiguous

- It works well in low light conditions

Even though the quality of the final output depends on the input image, it is the most sophisticated algorithm for such computer vision applications.

V. PROPOSED WORK

The proposed system should be able to identify analog meters in an image and convert the reading in the image into the necessary digital reading by using the concepts of OpenCV and Digital Image Processing. The systems works by using the computer vision system- OpenCV that is coded in Python and is supported on the Raspberry Pi. The Raspberry Pi is connected to a camera through its USB port and accesses the OpenCV libraries for converting the value from an analog value to a digital value.

The cosine and sine functions are used in the Hough Transform to calculate the angles subtended by the needle.

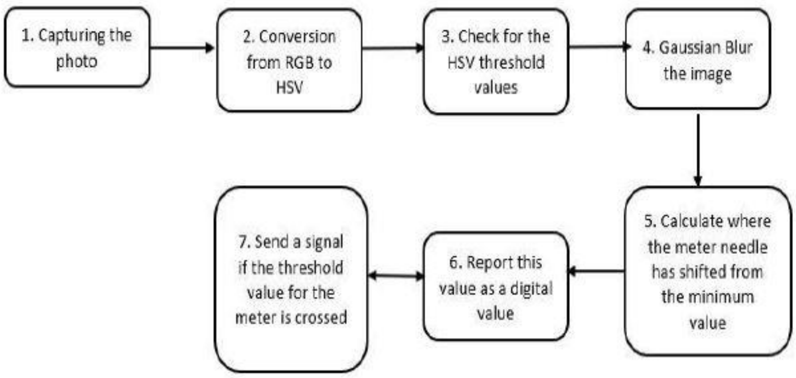

Figure 1.1: The flowchart signifying each step of the process

The above flow chart gives more details about the proposed system. Open CV 3.3.0 and Python 3 will be used in order to make sure that the system works efficiently. Defined below are the modules that we will be using for our project:

The current system uses the following hardware modules:

1. Raspberry Pi 3

   The Raspberry Pi as shown in Fig 1.2 is an affordable single board computer that allows its users to deploy computer like abilities for diverse applications. For this project, the Raspberry Pi is used in order to fully deploy the system and make the algorithm run on the system.

Figure 1.2: The Raspberry Pi

2. Logitech Camera C270 Camera

   The Logitech C270 camera as shown in fig 1.3 is used to capture the image of the meter and convert it to a format that is readable by the algorithm.

Figure 1.3: The Camera Module

3. Monitor and other peripherals

   A monitor and other peripherals are needed in order to remotely control the system. These peripherals are connected to the Raspberry Pi and the it performs the necessary operations using the algorithm and displays it onto the main display, thus giving us the required values.

4. Python and OpenCV modules

   Python and OpenCV modules are useful to run the entire system in unison. The OpenCV code is written in Python and deployed by the system Command Prompt. The results are derived by multiple iteration of the python command in the cmd window.

VI. IMPLEMENTATION

The implementation of the project has 3 basic steps as shown in Fig 2.1, Fig 2.2 and Fig 2.3:

- Input gauge image:

Figure 2.1: The photo sent as an input to the processor

- Calibrated Image:

Figure 2.2: The calibrated image

- Gauge Lines Image:

Figure 2.3: The needle being identified by the algorithm

The system will perform the above transformations using OpenCV library functions and Python configuration files.

VII. Results

In the trails shown in Table 1, the trial number 1 consists of testing the algorithm only, that is, running a high-quality image through the system without the use of system apparatus, in order to test if the algorithm works properly.

Trial Number 2 and 3 consist of using the entire apparatus and testing the systems multiple times. For every 5 readings, the system gives successful readings 2 to 3 times, thus indicating the fact that with a better processing system and a high resolution and better quality camera, the system could perform with very high accuracy for longer durations of time, under no supervision after the entire configuration is complete according to system requirements.

Trial Number	Meter Type	Meter reading	Observed reading	Result
1.1	AEM Meter (8-18V)	14.8 V	14.79 V	Success
1.2	AEM Meter(8-18V)	14.8 V	14.79 V	Success
1.3	AEM Meter (8-18V)	14.8 V	14.79 V	Success
1.4	AEM Meter (8-18V)	14.8 V	14.79 V	Success
1.5	AEM Meter (8-18V)	14.8 V	14.79 V	Success
2.1	Tyre Gauge Meter	35 psi	32 psi	Failed
2.2	Tyre Gauge Meter	35 psi	35 psi	Success
2.3	Tyre Gauge Meter	35 psi	35 psi	Success
2.4	Tyre Gauge Meter	35 psi	35 psi	Success
2.5	Tyre Gauge Meter	35 psi	34 psi	Failed
3.1	Tyre Gauge Meter	12 psi	14 psi	Failed
3.2	Tyre Gauge Meter	12 psi	12 psi	Success
3.3	Tyre Gauge Meter	12 psi	12 psi	Success
3.4	Tyre Gauge Meter	12 psi	12 psi	Success
3.5	Tyre Gauge Meter	12 psi	11 psi	Failed

Table 1: Trials that were conducted for the project.

VIII. CONCLUSION

ISSN: 2005-4238 IJAST

This project gives an insight about how in order to convert from a fully analog system to a digital system, there does not have to be complete revamp of existing systems. The camera module and the RaspberryPi systems can be used in unison with OpenCV and NumPy libraries in order to fully calculate the digital value of the analog system. Moreover, the existing system need not be changed in order for this system to be made a part of the current system, thus ensuring a cheap alternative to replacing the entire analog system with a digital one. Moreover, according to our test results, if better individual modules were used, that is, better processors and a camera with a higher resolution and better quality, the system would be able to perform much better and with very high accuracy with respect to this system.

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