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QUALITY CONTROL AND ASSURANCE USING IMAGE PROCESSING AND OPENCV

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Abstract- This paper focuses on how to implement an automated defect identification system for infinite uptime devices using computer vision. In other words, we worked on the problem of detecting scratches, dents, and minor irregularities on an IoT device. This IoT device which comes with several sensors like temperature sensor, vibration, sensor, etc. is mounted on a number of mechanical devices and collects the required data. Due to the relatively small size of our dataset, we manually collected and annotated images. Various methods are used for generating more and more images. Here we dealt with an Image data generator which includes zooming, rotations, changing some angles, translation, etc a particular picture. Furthermore, more images were generated using various photoshop software. Because of the surface texture and curvature of sides, detection of dents, scratches can be a challenging task for traditional computer vision methods. The recent advancements in computer vision and the addition of many traditional libraries make it technically feasible to detect the dents and scratches which may not be visible by a naked eye. The project was divided into 3 models. The 1st part aimed to recognize the QR code and extract important data like the date of manufacturing, ID, etc. The 2nd part focuses on detecting the dis-alignment parts of the device and the 3rd part which is the main module detects the scratches, dents, and minor irregularities. OpenCV was used for dealing with the 2nd part, and the algorithm for the 3rd part was designed using Keras-TensorFlow. Results showed that dents, scratches that are not visible with the naked eye were effectively detected with 90% accuracy. Furthermore, we focused on generating more and more datasets for increasing accuracy. Our Study delivers a rigid introduction to image processing along with Image Data Generation techniques and computer vision fundamentals.

Keywords:- Image Processing, OpenCV, Quality Control, Quality Assurance, Keras-Tensorflow

I. INTRODUCTION

The project undertaken was “Quality Control and Assurance”. The solution caters to an IOT device designed and build to read mechanical machines and gather statistics. The device is mounted on the machines to read the vibration. This IoT device plays an important role in achieving target sales and follows maintenance procedures for the machines.

The device comes in a rectangular enclosure with a connecting socket under its belly. The device has a number of sensors like temperature, vibration, and acoustics. This device is compact in size and comes with Wi-Fi and Bluetooth connectivity. The role of this device is to collect various readings and send it to server. These readings are used to determine the uptime, faults of the machines. As a result, we can keep an eye on the progress of the machines. As this device needs to be manufactured and distributed on a large scale, the defects on the rectangular enclosure,including dents, minor scratches, and irregularities that might cost changes in the final reading might often slip through naked eyes. There was a need for an automated system that could keep an eye on the product quality and serve as a filtering process in the final stages of product manufacturing.

Many industries still practiced the traditional method of testing. The product testing is done by a human eye wherein the products are moving on the assembly line at a very fast rate and humans check the shapes, sizes, dents, and other irregularities on the product at a real time. Many times, some of these products having faults are not detected and are missed by these peoples. This way of testing is very time consuming, tedious, and prone to human errors. So, we came up with an automated defect detection system that could efficiently and effectively

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detect these dents, scratches, and help to minimize the claim leakage. Using very high-frequency cameras in the inspection system which captures very high-resolution images of the product when they are moving down the assembly line in very less time without any distortion; as a result, the clear images are obtained which are of high quality for further examination. Images of every product are taken as a set of six images and fed to the algorithm for further processing. The typical image processing task is to compare the faulty images with healthy images. As a result of this accuracy increases and on the other hand, avoids human errors. These processes are also rapid as compared to human testing.

The above requirement was the need that our project would satisfy – "Quality Control and Assurance". In recent years, automated defect detection systems using traditional libraries and algorithms has gained a boost as they are more compelling and feasible as compared to
Human detection systems. Quality control techniques are used during the initial stage of the production phase of manufacturing to detect various dents, scratches, and cracks on the product. Various ways were figured out to build the project but the most voted idea was a combination of existing Image classification algorithms using Keras and traditional Image classification using OpenCV. A mixture of these two technology stacks was found out to cater to the client requirements with scope for improvement. Although human vision is the traditional way used for this purpose.

The project was split into 3 main parts, according to the requirements and algorithm performance. The first part aimed to recognize the QR code and to extract necessary details like the date of manufacturing, ID (to uniquely identify each product). The second part was divided into two parts. The first part focuses on the Dis-aligned connector from the axis and the second part focuses on detecting the dents, scratches on the same part (the front side). The third part aimed to detect the dents, scratches, and other irregularities on the remaining sides. Each part is supposed to generate a binary output which will help in generating the final output also in the form of a binary. Each segment of the project is furthermore split into more individual parts to safeguard the independence of each module. Each module is tested against a couple of algorithms to set a threshold accuracy score. Further, the main aim was to beat this accuracy score using a combination of our algorithm.

Taking this into consideration we used CNNs for classification and detection of the faults.
CNN's is a multilayer neural network, prominent and common deep learning frameworks widely used for image classification due to its accuracy. Neural Networks are used to detect edges, these edges form to detect some straight lines, curvy lines. After that these lines combines to form various shapes like the circles, rectangle, squares and many irregular ones which then combines to form detects like the dents, scratches. The convolutional neural networks are used on a high scale basis for quality control and assurances.

For the first part, we used the pyzbar library which extracts prerequisites (e.g., Date of manufacturing, ID) from the one-dimensional barcodes and two-dimensional QR codes, using the zbar library. Template matching which is used for finding small parts of an image that matches a template image was used for dealing with the second part. We focused on commonly damaged types such as dents, scratches, engrave on the remaining sides of the device. Keras -TensorFlow was introduced to develop the algorithm with a 90% accuracy. We started with a basic CNN model having 3 layers having relu activations functions for the first two and a SoftMax activation function for the last layer. For increasing the dataset, we photoshopped more and more images and introduced dents and scratches at abundant spots. The implementation and results are discussed below.

II. LITERATURE REVIEW

Quality Control using computer vision is currently one of the most active area of research. Many new frameworks have been proposed while many of them are near to actual industrial implementation, but there always remains some scope for improvisation as different assembly lines producing different types of products need optimized and personalised algorithms.

Paper [1] discusses about an analysis framework using coordinate conversion technique and some pattern matching algorithm to facilitate the inspection of cylindrical objects. Pattern matching is the pivot point around which the framework revolves.

Nematullo Rahmatov [2] proposed a model administrating the central processing unit system assembly lines. The model takes the images of the assembly lines as input and flags the abnormalities of defects on the assembly line. This information is transferred to the system administrator via a cyber-physical cloud network. Machine learning is the main technology stack behind this model.Quality Control comprises of both hardware as well as software architecture. In [3] Marco Sasso, Massimo Natalini and Dario Amodio proposed a framework with both the sides of the quality control systems. The software part of the proposed system was dependent on traditional methods such as calibration, image alignment and parameter settings.

In the first chapter of book **"**Industrial Image Processing: Visual Quality Control in Manufacturing**"** written by JonRigelsford [4], an overview of some commonly used filters and transformations is given. The chapter describes image pre-processing and some grayscale transformations, image arithmetic and median. We can find a good description on linear and non-linear filters including morphological filters.

Hema L. Chavan [5] proposed use of dimensional image processing with the help of 2D and 3D images. It is then compared to detect edge defects. To extract features of manufactured product from image of product Principal Component Analysis (PCA) was used. Besides Machine learning we found out that OpenCV was next popular approach. Nursabillilah Mohd Ali [6] presented a model based on OpenCV. The highlights being the consideration of visible white light during inspection as the sensors used were CMOS sensor for image data generation. On the other hand, A. Dias [7] proposed a OpenCV based approach to detect defects on tyres. The images collected by Basler matrix camera were treated by the model. Background Subtraction and Hough transform were two techniques tested to implement the solution. Harry Logan [8] in his paper presented a model detecting physical features of electronic board based on ImageJ and OpenCV. Another identical approach was made by Fa'Iq Raihan [9] for defect detection of PCBs using image subtraction and blob detection techniques of OpenCV. Similar model was developed by TanapongParakontan consisting of LabVIEW programming with OpenCV library. Another model presented by Vidya V [11] used Hue saturation value comparison of defective and healthy targets using open-source computer vision. Many have attempted to developed personalised systems as done by Paulo Heleno[12] who developed a model describing the implementation of INFIBRA, a machine vision system used in quality control of acrylic fibres production. Some interesting solutions which integrate two different domainsas per the industrial requirement as proposed by Jacqueline Schmitt [13] who used a predictive-model based quality inspection using machine learning and edge-cloud computing.

Most of the quality control systems based on Computer Vision are either build on traditional Image Classification or using more advanced, recently developed algorithms. Having image data in hand is also an important factor and directly affects the final output. This common trend depreciates as the image data moves more toward computer-generated rather than real-time images. Although any kind of Image data could cater to our requirement. The extent of change in accuracy score is rather not guaranteed if the image data is artificially generated.

Another important observation was related to the types of algorithms these quality control systems use. Rarely, the combination of old and new is used. This doesn't usually mean the failed alliance but rather depends on the requirement. So does our requirement use the above alliance and also prove it to be trustworthy.

Thus, it can be inferred that OpenCV is quite popular amongst quality control models besides Machine learning approach. A combination of two is rarely seen and that is what we are attempting to do.

III. DETAILS AND METHODOLOGY

The enclosure of the device in inspection is rectangular which doesn't come without saying it has 6 faces. 4 of the lateral faces are plain while one of the faces has a QR code containing ID and other details of the device. The remaining face has a connector socket which is generally referred the under-belly face.

These 3 individual modules are supposed to be treated independently. This can also result in 3 independent algorithms coming together to give the final output.

Assumption: It has been assumed that the input format to this model will be a bunch of 6 images, not necessarily in the order specified above.

An initial batch of 25 images are sent, followed by another batch of 43 images. Before the commencement of the project according to the flow chart, we had to work on generating more and more images. It is industry practice to create synthetic images to train algorithmsin Visual Inspection area when there are no real images available, thiscreates possibility of improving results without any real images inplace and continue training algorithm further when real images are madeavailable. A lot of research and parameters were studied to generate artificial images that were alike. Depending on the research,differentcombinations of offsets and parameters were applied to generate images, resulting in a single batch of 725 images. These would be further multiplied to 6500 images on the requirement. The work stated below is done on the batch of 725 images.

Fig 1. Describes the flow of control of the project. The model is built upon two pivot points. One being the main machine-learning approach. This part is dependent on the traditional 'dogs vs cats' algorithm. This image classification algorithm rather is far more optimised than the original one. The requirement of the project was a catalyst in doing so and multiple layers of same algorithm were put in place to avoid discrepancy and accumulate proper statistics for the model. Initial stages were important to bring the model to the stage that we are in right now. The personalisation on the algorithm was based on the image data and the result the model produced in its each version.

The OpenCV counterpart of the above model is originally based on Pattern matching concept of open-source computer vision. Again, we figured out a lot of scope for optimization of the raw algorithm. Thus, the final version integrates the concept of pattern matching with the requirement of the project (the Connector shift issue). All the binary outputs produced by the model are independent of each other and have individual meanings with respect to the health of the product. Final results were in binary and logical arithmetic between individual binary were taken to determine the overall health of the products in assembly line.

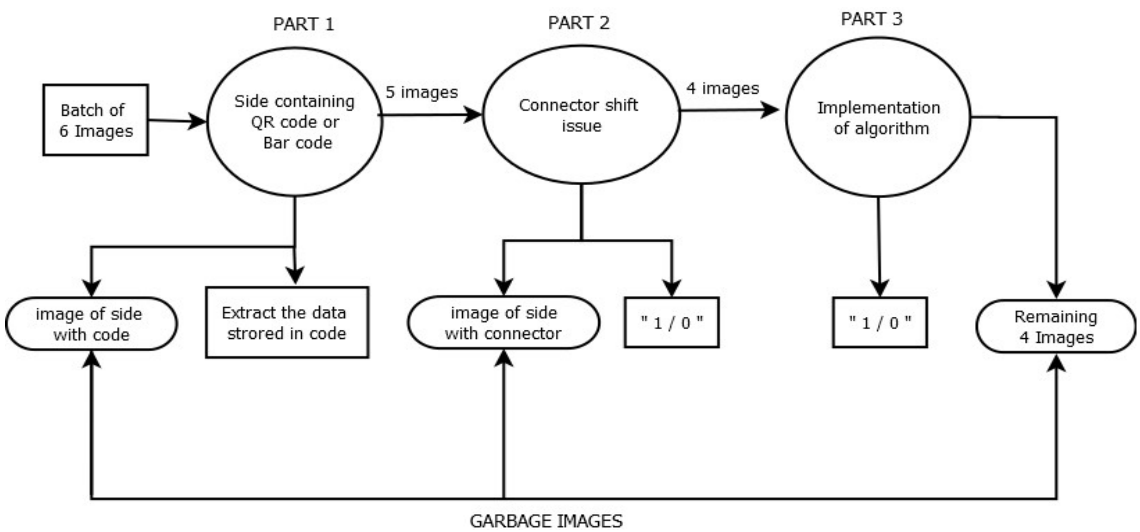

Fig 1: Architecture and Flow of the mode

Module 1:

All the images given as input will pass through this module. The main aim of this module is to detect the face containing the QR code and extracting the necessary information from it.

The design of the module is such that the face containing the QR code will be scrapped out from the input file and will be given to the next module. Thus, a resultant of 5 images will be given to the next module as an input file.

The information extracted from the QR code will be stored in the folder, later to be used as an ID for storing the final status of the device in that particular folder.

Module 2:

This module deals with the face containing the connector socket. There are two possible defects on this face –

1. Dis-aligned Connector from the axis
2. Scratches, dents, and minor irregularities could be present on the face.

Due to these two possibilities, module 2 has been divided into further modules.

Module 2A:

Module 2A is an independent algorithm and finds the dis-alignment of the connector. The algorithm is developed on traditional Image classification i.e., OpenCV. After a month of experimentation and learning, it was found out that "Template Matching" from OpenCV would give maximum accuracy according to the requirement. Also, stating that this conclusion was made on kind of database in hand. There was a lot of scope for change and improvement depending on the database.

Without a doubt, the accuracy was going to reach the sky height due to limited data and pixel-by-pixel matching of the templates. To restrict this, some look-alikes were generated, but with a pinch of irregularities to test the accuracy. The accuracy dropped a bit but was not a reason for any concern as it was expected.

The result of this module would be a single binary digit, either a '1' or a '0'.
'1' represents a healthy device with a healthy and axis-aligned connector, while '0' represents an unhealthy device with a dis-aligned connector. Also, this binary is referred to as the first bit in the final output.

Module 2B:

We can't ignore the fact that the face containing the connector could also have scratches, dents, or minor irregularities which indeed is the main aim of the model.

This module is dedicated to this purpose and is an extension of the main algorithm used in module 3. This algorithm finds scratches and irregularities on the face containing the connector. The output of this module is also a binary bit '1' or '0'. The meaning of the bit stands the same as above.
The final result of Module 2 is a single binary bit – OR of Module 2A and Module 2B.

Module 3:

This module is the main algorithm detecting scratches, dents, and minor irregularities. The algorithm is developed based on Keras-TensorFlow. All 4 images filtered out from module 1, module 2A and module 2B are fed to this module. Now, automatically only those 4 faces which are plain and don't have any QR code or any connector come to module 3 after a 2-layer filtering process.

All these 4 images are tested against the algorithm and flagged as healthy or unhealthy devices.
The output of this module is also a single binary bit '1' or '0'. The bits represent the same as stated above.

Final Output:

Module 2 generates a single binary bit combining two bits from module 2A and module 2B respectively. While Module 3 generates one single binary bit.
With all the possible combinations, the following is the final output.

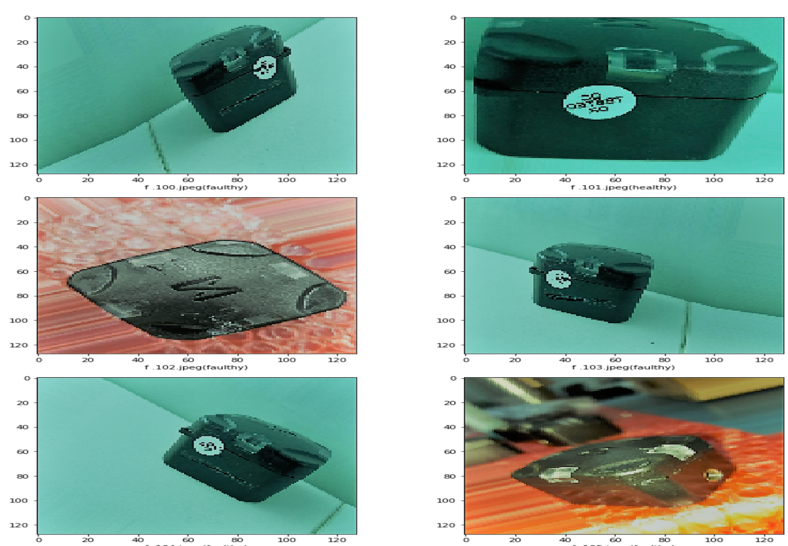

Fig2. Final Output Images

The faulty images are detected with a 90% accuracy .The algorithm also detects the faulty images that were missed by the naked eye . Although our dataset was comparatively small we set the benchmark and our results showed the power and potential of the model . We also came up with a automated solution that can be feasible and can be introduced for quality inspection . We also believe that with a more diverse dataset the accuracy can touch the sky limits ; as it is always said more and more dataset can increase the accuracy .

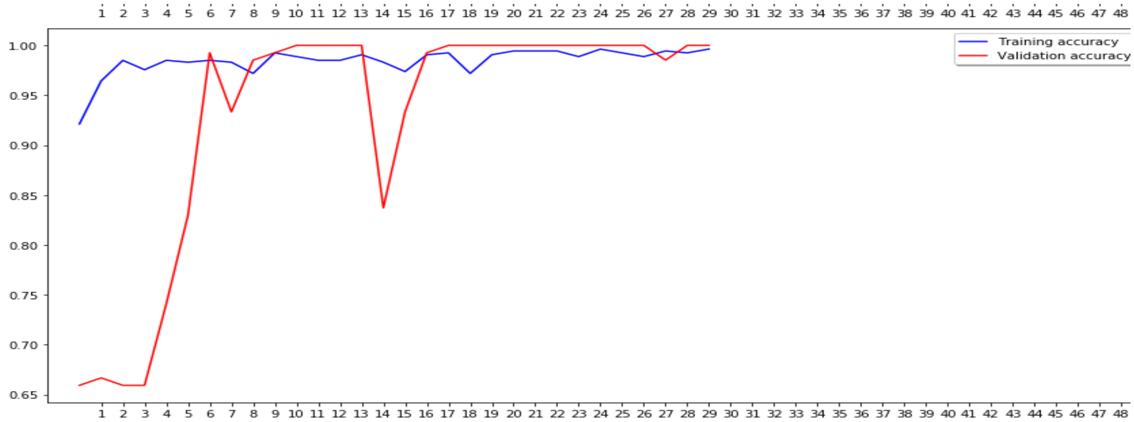

Fig 3. Training Vs Validation Accuracy

TRAINING VS VALIDATION VS TESTING ACCURACY

We divided the world dataset into training, validation and testing with a 80: 10: 10 ratio. Due to lack of real-time images,using various data generation techniques like the Image data generator we clone a 20-25 images of a particular images just by changing some angles, rotating the images, zooming, etc. After that we divided the dataset into 3 parts and each dataset contains 2 separate parts one of faulty images and other of healthy images. [14]The training dataset was used to fit the model. The validation dataset was used to select proper hyperparameters of the system and the testing dataset was used to provide a evaluation of final model.

Output Format

Output	Conclusion
"00"	Defect 1 and 2
"10"	Defect 2 only
"01"	Defect 1 only
"11"	Perfectly Healthy device

Defect 1–Refers to misaligned connector and abnormalities in the connector orientation.

Defect 2- Defect on Lateral Faceswhere the device could have minor irregularities such as dents,patches,minute cracks, etc.

Statistics:

Confusion Matrix	[[5 0] [1 4]]
MCC Score	0.816496580927726
Accuracy Score	0.9
TPR and FPR	[1 0.8] and [0.2 0]

IV. CONCLUSION

For most of the modules, the goal is achieved and the accuracy score goal is satisfied and better than many pre-existing algorithms.

Module 1 has reached the expectations and satisfies the requirements. The data extracted can be used during industry implementation.Module 2 is up o the mark and caters to the requirement. Due to less data, the accuracy score is arguable and so is the result of the module. According to the data, this module reaches the goal.Module 3 also has scope for improvement, but the accuracy score will hardly change as it has reached the saturation point.

All the requirements and goals were reached and all milestones were completed. The final output is in the form of 2 binary bits and represents all the requirements of the problem statement.

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