Walchand College Of Engineering, Sangli.

(An Autonomous Institute)

Department
Of
Computer Science and Engineering

A Project Report

On

Predictive maintenance of Mould in Manufacturing Industry

Submitted by

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CERTIFICATE

This is to certify that the Project Report entitled, **"PREDICTIVE MAINTENANCE OF MOULD IN MANUFACTURING INDUSTRY"**submitted by Mr. Abhishek Bhagate, Mr. Parth Navle, Mr. Anupam Shandilya, Mr. Shubham Choudhari, Mr. Gaurav Arora, to Walchand College of Engineering ,Sangli, India, is a record of bonafide Project work carried out by him/her under my/our supervision and guidance and is worthy of consideration for the award of the degree of Bachelor of Technology in Computer Science & Engineering of the Institute.

Dr. B. F. Momin	**Mr. A B C**	**Dr.S.H.Bhandari**
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Declaration

I hereby declare that work presented in this project report titled **"PREDICTIVE MAINTENANCE OF MOULD IN MANUFACTURING INDUSTRY"** submitted by me in the partial fulfillment of the requirement of the award of the degree of **Bachelor of Technology (B.Tech)** Submitted in the **Department of Computer Science & Engineering, Walchand College of Engineering, Sangli**, is an authentic record of my project work carried out under the guidance of (Guide(s) name and affiliation).

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Abstract

The industry has undergone various technological revolutions throughout history, and these were mainly aimed to increase productivity and efficiency. Industry 4.0, a term used for the fourth industrial revolution, describes transformation of traditional manufacturing in industry to automated industrial practices using modern smart technologies such as IoT, AI, cloud computing, data mining, etc and thus enabling a more efficient and optimized production process. There can be various anomalies that occur in industrial processes which if not rectified in a timely manner can result in huge losses. Fault and Anomaly detection involve analysing the data gathered from sources such as system-equipped sensors or cameras and predicting if it deviates from the normal behaviour thus showing some form of anomaly. The proposed system is intended to predict faults and detect any anomaly that may occur in injection moulding systems. This system will equip the production line with fault-monitoring solution and not only make it more robust and reliable but also help proactively predict faults and anomalies and act on them, thus saving huge costs in repairs and halted production lines.

The proposed system uses various technologies like Computer Vision and AI/ML to make this fault-monitoring system possible. It is developed using vision cameras from Cognex corporation. These cameras are used to capture images of the moulding machine which are then fed to an ML model which can then analyze them to predict if there's any fault in the system. The cameras come built-in with various vision tools that can be used to train the models on baseline images and use them for fault prediction in a live production environment. A major advantage of choosing this approach of working with Cognex cameras and the built-in tools provided by them is the accuracy and flexibility that we get. The various tools provided by Cognex software such as the in-sight explorer software allows us to use them as per our requirements to achieve the maximum accuracy. The trained model can also be easily modified to accommodate any changes in the production line such as different machinery, products, environmental conditions, etc.

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1 Introduction

Industry 4.0 is a term coined for the fourth industrial revolution that involves transformation of traditional manufacturing in industry to automated industrial practices using modern smart technologies such as IoT, AI, cloud computing, data mining, etc and thus enabling a more efficient and optimized production process. The recent advancements in the fields of artificial intelligence (AI) and machine learning (ML) have affected several research fields, leading to improvements that could not have been possible with conventional optimization techniques

There can be various anomalies that occur in industrial processes which if not rectified in a timely manner can result in huge losses. Fault and Anomaly detection involve analysing the data gathered from sources such as system-equipped sensors or cameras and predicting if it deviates from the normal behaviour thus showing some form of anomaly.

There are various methods that can be employed for this purpose. One of the simple methods involves **knowledge-based predictions** wherein experts use their past experiences to co-relate and identify anomalies in productions. A better and more scalable method is **Big data driven predictions** wherein we use the past trends and data of normal behaviour of systems and analyse the current real-time data to predict if the process deviates from the usual behaviour of the system by more than an acceptable threshold. An advantage of the latter method is it exploits the big data generated through various sensors and being able to predict in real-time without the delays introduced by human interventions. It also can adapt to the dynamically changing nature of industrial quality monitoring problems. This sector has seen massive growth with the emergence of industry 4.0 which aims at providing automation of traditional manufacturing and industrial practices, using modern smart technology and the recent innovations in technologies such as IoT and cloud computing. These advances have connected physical machines with the digital world using various sensors equipped with them. This generates huge amounts of data on the real-time behaviour of machines which can help us in monitoring their functioning and making informed decisions on human intervention to rectify any anomaly or fault in the machines. Usually, it yields the best results when a combination of both approaches is used. For eg. Some experience may help in sensor selection which are known to affect the functioning machines in a significant way and thus lead to better accuracy.

There are many challenges in this fault detection field as well. A common challenge is generating the data for training of the model which will automatically monitor and look for any anomalies. This includes selection of proper combination of sensors which would increase accuracy and cleaning and normalising the dataset as required to train the model. Another challenge is to consistently maintain the environmental variables such as lighting or ambient temperatures. Any deviation beyond a given threshold in such factors would lead to increase in error rates of prediction and require frequent recalibration or re-training of the model.

The proposed system is intended to predict faults and detect any anomaly that may occur in injection moulding systems using various technologies described above. There can be various issues that occur with mould manufacturing machines like stuck parts, wear-out of insides of the mould with usage, surface delamination due to contamination. These faults often turn out to be very costly and lead to massive financial losses and slowdown of production. As an example, a key to the high productivity achieved in injection moulding is the use of a blast of air or injector pins to remove the part from the mould at the end of each mould cycle. The chance of the part failing to be ejected from the mould is very small but the potential damage that can occur in this situation is large. If the part has not been ejected from the mould, then, when the mould closes at the beginning of the next moulding cycle, the core pins and other fine features of the mould may be damaged and the replacement can be very costly and halt production for the time period of replacement. It was also observed and concluded that humans can't easily detect faults with good accuracy in a fast-paced production line. Thus, we need machine vision to detect faults with speed and good accuracy.

1.1 Overview and Problem Statement

Industry 4.0 was an evolution from previous generations of industry norms to enhance productivity and efficiency. It transformed the traditional manufacturing industry to enable a more efficient and optimized production process. In most of the modern industry, the fast-paced production line must be kept running all the time to ensure optimum efficiency and maximum profitability ratio. One cannot afford to sustain regular outages in such production environments. But the various uncontrollable parameters can lead to disturbances in the production process and sometimes even cause major problems which cannot be ignored. We need to proactively act and monitor for such scenarios so as to minimize the loss and negative impact caused by these parameters over the production process.

This is especially an area of concern in the moulding industry where various faults may occur due to uncontrollable factors and cause huge losses. Injection moulding companies have traditionally used various methods to guard against these faults and damages. A common approach was to simply assign additional operators to monitor moulding machines. This approach, however, requires that an operator be assigned to each moulding machine which leads to substantial increase in labour costs. On top of that, this approach may not be scalable with the increase in speed of the production line or as the number of machines increases. We propose a system that can continuously monitor the moulding machines and detect any anomaly or deviation from the normal production process. The system exploits modern advances in technologies such as AI/ML and computer vision to accurately predict any deviations and anomalies in the moulding machines. The modern industry 4.0 is usually equipped with various sensors and cameras which generate all the logs which describe how the production process is going on. We leverage this data using the above-mentioned technologies to predict faults and anomalies. Once these are detected, an operator can be alerted or any programmed corrective measure can be taken place. This approach is much more robust and scalable than using a human operator to monitor the production process. It can also turn out to be more cost-effective and accurate in the long run leading to more efficient production lines and minimization of faulty products or outages in the production.

To summarize, we propose to develop a system capable of detecting faults and anomalies in Industry 4.0, more specifically, in the mould manufacturing industry, using Computer Vision and AI/ML on datasets generated from cameras and equipped sensors.

1.2 Motivation

The traditional manufacturing industry has usually relied on manual inspection to detect any abnormal behaviours or faults in the system. Not only is this approach highly unscalable but also inefficient and inaccurate.

The proposed system automatically monitors the moulding machines for any faults or anomalies in the production process. The moulding machines companies face various challenges such as repairs when moulding machines are damaged due to prolonged usage without proper protective measures and loss of revenue due to halted production lines which in many cases can add up to a significant amount. With our system, the moulding machines industry can thus establish a more robust, fault-tolerant, reliable production line with an accurate fault detection system in place. This can help them save costs in above-mentioned scenarios and thus optimize their workflow.

1.3 Contributions of this work

The project started with general research works in the area of fault detection in industrial machinery and equipment with regards to industry 4.0 systems. The findings show that there are various methods that can be employed for this purpose. The common approach leading to the best results are the ones involving use of data generated by machine sensors and analysing them using AI/ML technologies.

The proposed system is developed using vision cameras from Cognex corporation. It is the world's leading provider of vision systems, software, sensors, and industrial barcode readers used in manufacturing automation. These cameras are used to capture images of the moulding machine. These images are then fed to an ML model which can then analyze them to predict if there's any fault in the system. The cameras come in-built with various vision tools that can be used to train the models on baseline images and use them for fault prediction in a live production environment.

The approach used here, first requires us to configure the trigger points of the camera systems which are nothing but the point in time when the Cognex cameras are programmed to capture images and run analysis on these images. The cameras are then trained on the baseline images, that is, the images captured in normal production lines without any anomalies. There are various tools to choose from while training the system on these images. Once the model is trained, then we can deploy it into the production line for live process monitoring and alerting whenever a fault is detected.

A major advantage of choosing this approach of working with Cognex cameras and the built-in tools provided by them is the accuracy and flexibility that we get. The various tools provided by Cognex software such as the in-sight explorer software allow us to use them as per our requirements to achieve the maximum accuracy. The trained model can also be easily modified to accommodate any changes in the production line such as different machinery, products, environmental conditions, etc.

2 Background and Related Work

- **Injection molding**

  Injection molding is a method to obtain molded products by injecting plastic materials molten by heat into a mold, and then cooling and solidifying them.The method is suitable for the mass production of products with complicated shapes, and takes a large part in the area of plastic processing.

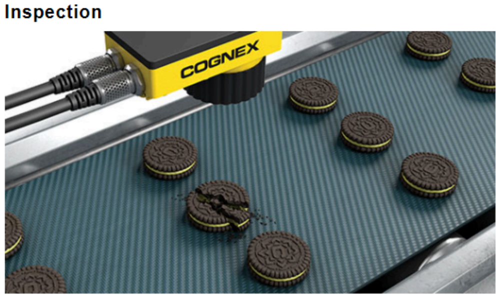
- **Defect inspection** is very important in these injection molding processes, because it can **reduce the risk and cost of providing defective products to customers**. The manufacturer does a final defect inspection before delivery to the consumer. Many small and medium-sized enterprises often do **quality checks manually. Such manual inspection is prone to human errors.**

- Among these studies, research on building a **smart factory using the Internet of Things (IoT) is actively under way.** Its purpose is to make smart factories, factory equipment, and sensors (IoT) collect and **analyze data in real-time**, and see (observability) all situations of factories at a glance. A smart factory refers to a factory that can control itself. IoT-based machines extend the boundaries of smart factories to demonstrate new possibilities for manufacturing.

- **In-Sight Explorer Software**

  - **Ease-of-use** is built into the heart of In-Sight vision systems starting with easy-to-use but powerful vision tools and In-Sight Explorer software interface.
  - A spreadsheet view makes the user experience very simple for maximum control over your optical inspection applications.
  - The In-Sight Explorer software also includes an **EasyBuilder configuration environment for deploying** reliable applications quickly, with no programming required.
  - For 2D imaging

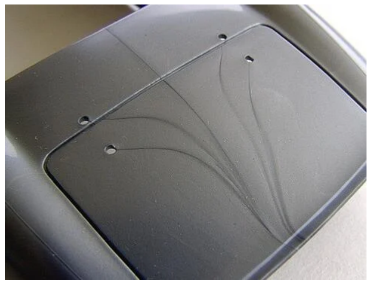
Inspection



Inspect for assembly errors, surface defects, damaged parts and missing features. Identify the orientation, shape and position of objects and features.

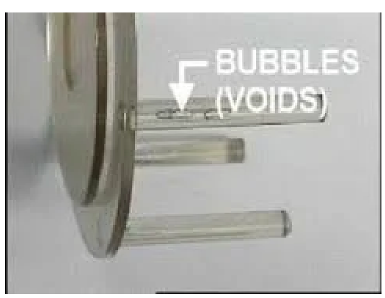
Issues with molds:

- Flow Lines:
    - consequence of the physical path and cooling profile of the molten plastic as it flows into the injection mold tooling cavity.

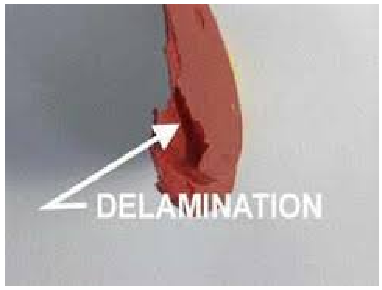


- Sink Marks
    - Sink marks are small craters or depressions that develop in thicker areas of the injection molded prototype when shrinkage occurs in the inner portions of the finished product.
    - 

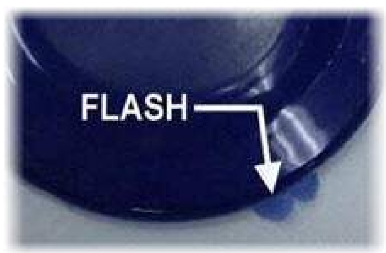
- Vacuum Voids
    - Vacuum voids are pockets of air trapped within or close to the surface of an injection molded prototype.



- Surface Delamination
    - Surface delamination is a condition where thin surface layers appear on the part due to a contaminant material. These layers appear like coatings and can usually be peeled off (i.e. “delaminate”).



- Flash
    - Flash is a molding defect that occurs when some molten plastic escapes from the mold cavity. Typical routes for escape are through the parting line or ejector pin locations. This extrusion cools and remains attached to the finished product.



Related Work

Various studies have been implemented to understand shrinkage and to control the dimensions of injection molding.

1. Kramschuster, A.; Cavitt, R.; Ermer, D.; Chen, Z.; Turng, L.-S. . [CrossRef] applied an experimental design to conduct quantitative studies of the shrinkage and warping of fine-porosity in existing injection molds

2. Kwon, K.; Isayev, A.I.; Kim, K.H. [CrossRef] studied anisotropic contraction in injection molding of amorphous polymers considering the pressure-volume-temperature equation of state, molecular orientation, and elastic recovery

3. Kurt et al [CrossRef] investigated the effect of packing pressure, melting temperature, and cooling time on shrinkage of injection molds.

4. Santis et al. [CrossRef] explored the effects of suppression, time, and geometric constraints on the contraction of semi-crystalline polymers with strain gauges.

5. Chen SC et al. [CrossRef] applied gas back pressure to reduce the shrinkage of parts during injection molding

6. Wang et al. [CrossRef] used artificial neural network (ANN) simulations to evaluate the effectiveness of molding parameters on molding shrinkage.

7. Abdul, R.; Guo, G.; Chen, J.C.; Yoo, J.J.-W. Shrinkage prediction of injection molded high density polyethylene parts with taguchi/artificial neural network hybrid experimental design. Int. J. Interact. Des. Manuf. (IJIDeM) 2019, 14, 345–357. [CrossRef]

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3 Proposed Method/Algorithm

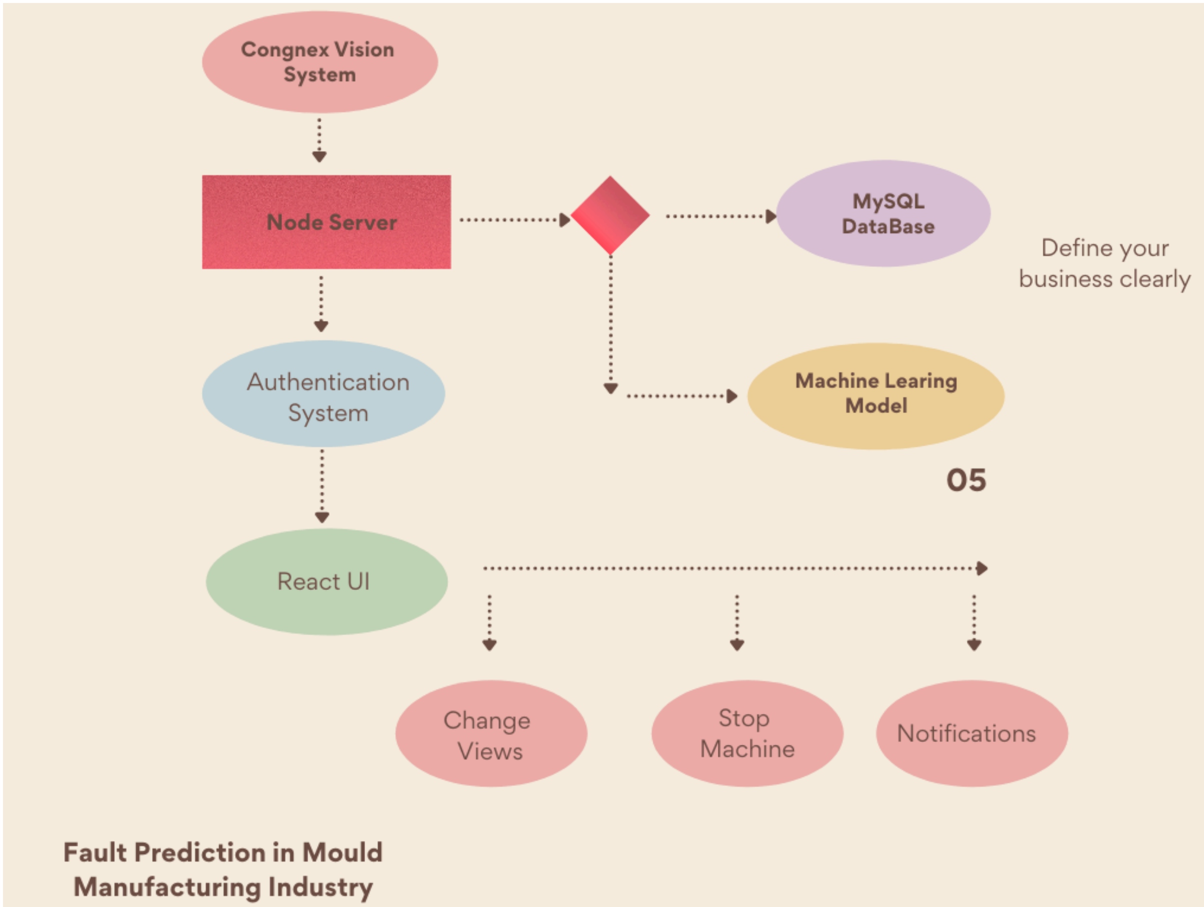
3.1 Problem Definition

Developing a system capable of detecting faults and anomalies and predicting remaining useful life in Industry 4.0 systems using Computer Vision and AI/ML on datasets generated from cameras and equipped sensors

3.2 Proposed Idea/System

A Cognex Vision system capable of monitoring industrial machines and equipment and detecting any form of faults or anomaly in its behaviour using computer vision. This automatic monitoring system will ensure that the equipment functions without any anomalies and alerts the industry operators if any faults occur in the production process. The machines will be monitored using cameras and other sensors as required and the data generated by them would be fed to a trained model which will then analyze the data against normal data to predict if there is any fault or anomalous behaviour in the machines.

3.3 System Architecture

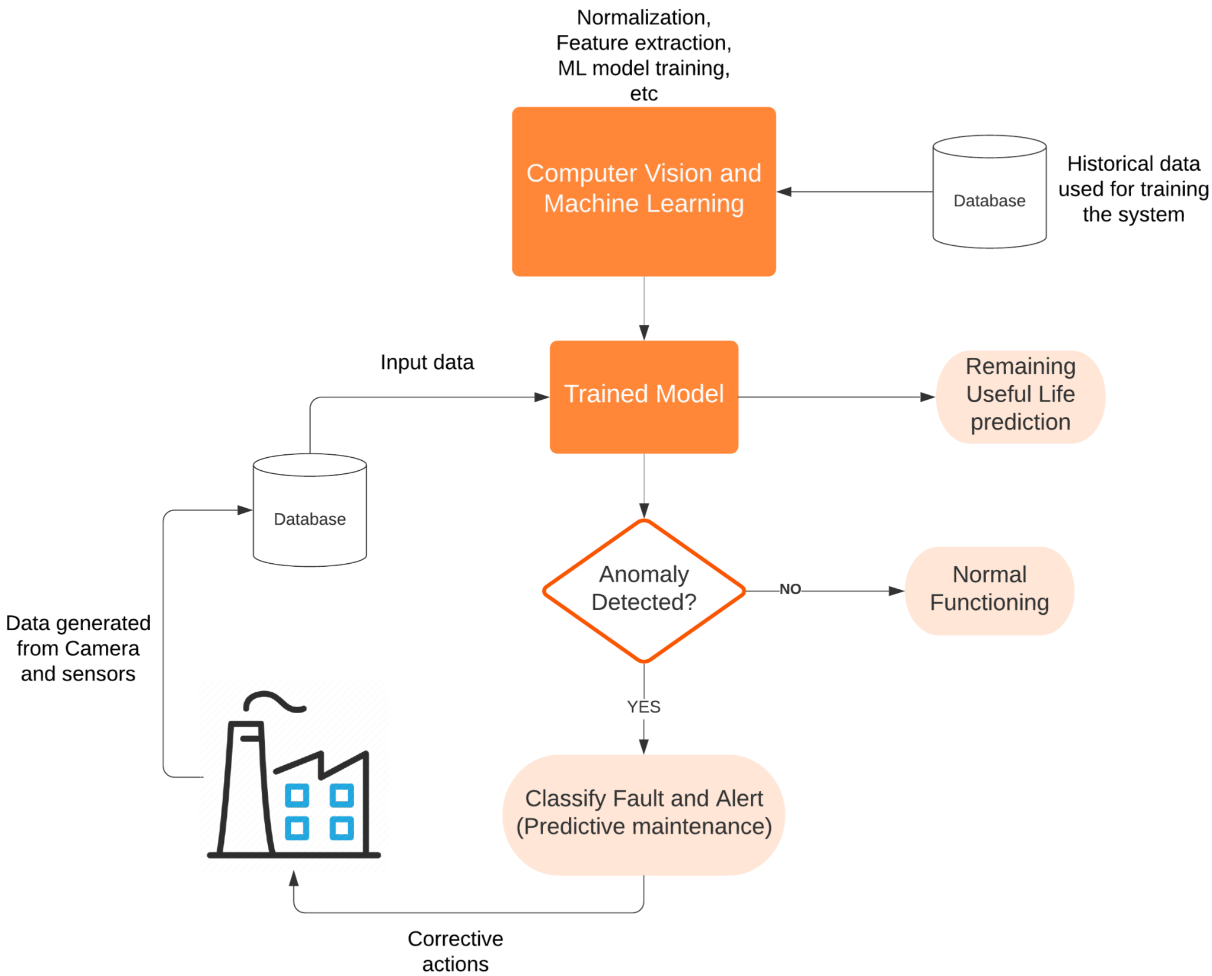


3.4 System Analysis and Design

3.4.1 Requirement Specification

- Cognex 2d Camera
- WebServer
- React (Javascript Framework)
- MySQL Database

3.4.2 Flowcharts / DFDs / UML



3.4.3

3.4.4 Design and Test Steps

- The system is designed using a Cognex vision camera.
- A ML model is trained on images taken of mould products and from a normally functioning mould manufacturing machine.
- The trained model is tested on a manually generated dataset to determine its accuracy and performance.
- The model is then deployed onto the vision cameras.
- These cameras are then installed at the industrial site near the machines to be monitored and thus an automatic fault monitoring system is setup.

3.4.5 Algorithms and Pseudo Code

Cognex PatMax pattern recognition algorithm

Cognex PatMax is asic accelerated computer vision algorithm to pattern matching. It is a proprietary algorithm provided with cognex software.

4 Performance Study

4.1 Implementation/Simulation Environment

In-Sight Explorer Software

Ease-of-use is built into the heart of In-Sight vision systems starting with easy to use but powerful vision tools and In-Sight Explorer software interface. A spreadsheet view makes the user experience very simple for maximum control over your optical inspection applications. The In-Sight Explorer software also includes an EasyBuilder configuration environment for deploying reliable applications quickly

Tasks performed-

1. Find missing bottle caps in a grid of bottle caps.

   Implementation -

   After successfully configuring the insight explorer software following steps were followed to perform the required task:-

   1. Selecting the model of camera.
   2. Importing the images from the camera/network/pc.
   3. Locating the part to be inspected.
   4. We had a 3 X 3 matrix of bottle caps, we divided it into 3 different rows and counted the number of caps present in each row.
   5. To count the number of bottle caps in each row we used the pattern tool which was present in the counting tools.
   6. Sum of the number of caps in each row was the required answer.

2. Count the number of randomly spread out pen caps.

Implementation -

After successfully configuring the insight explorer software following steps were followed to perform the required task:-

1.Selecting the model of the camera.

2.Importing the images from the camera/network/pc.

3.Locating the part to be inspected.

4.Under counting tool the patmax pattern tool was used to count the number of pen caps.

5. The result obtained was not accurate.

6. Tweaking performed -

Changed angle tolerance to 180 degree.

Ignored polarisation

Image filtering

7. Current accuracy achieved is around 80%.

4.2 Results and Analysis

Find missing bottle caps in a grid of bottle caps

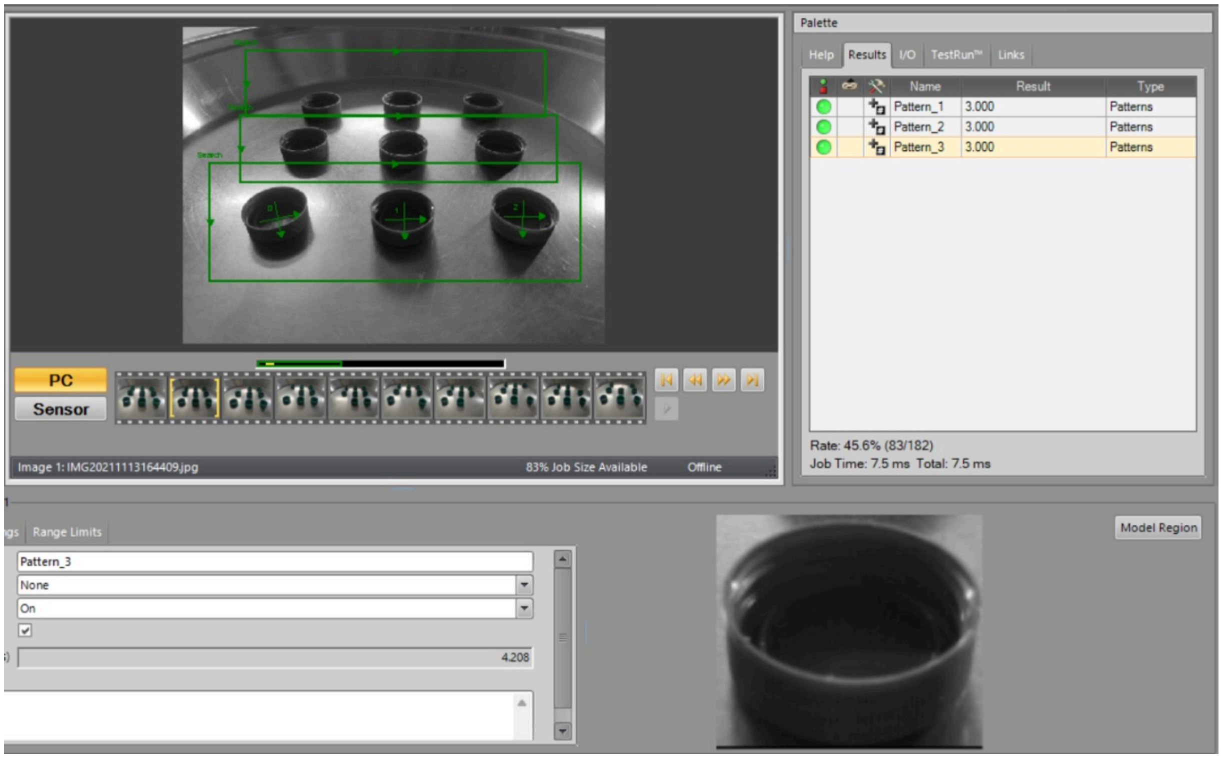


Fig 1 All the caps are present in the grid and are detected .

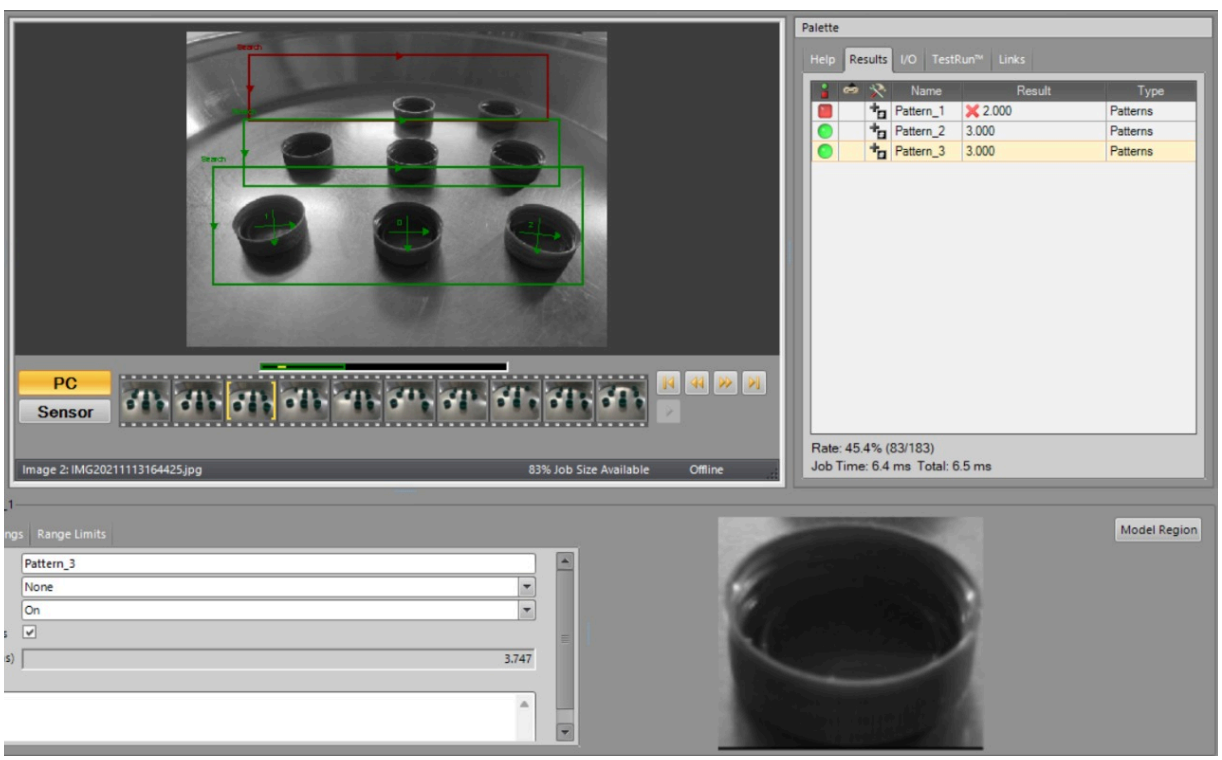


Fig 2 A cap is missing in the first row.

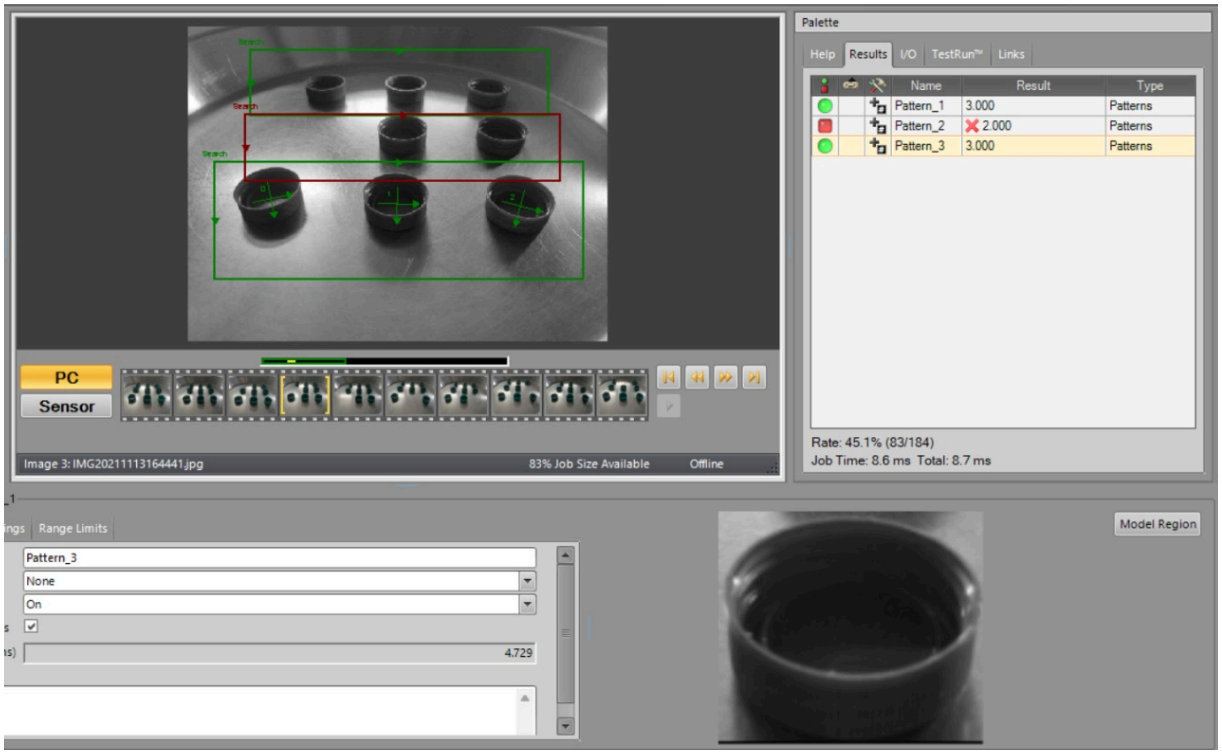


Fig 3. A cap is missing in the second row.

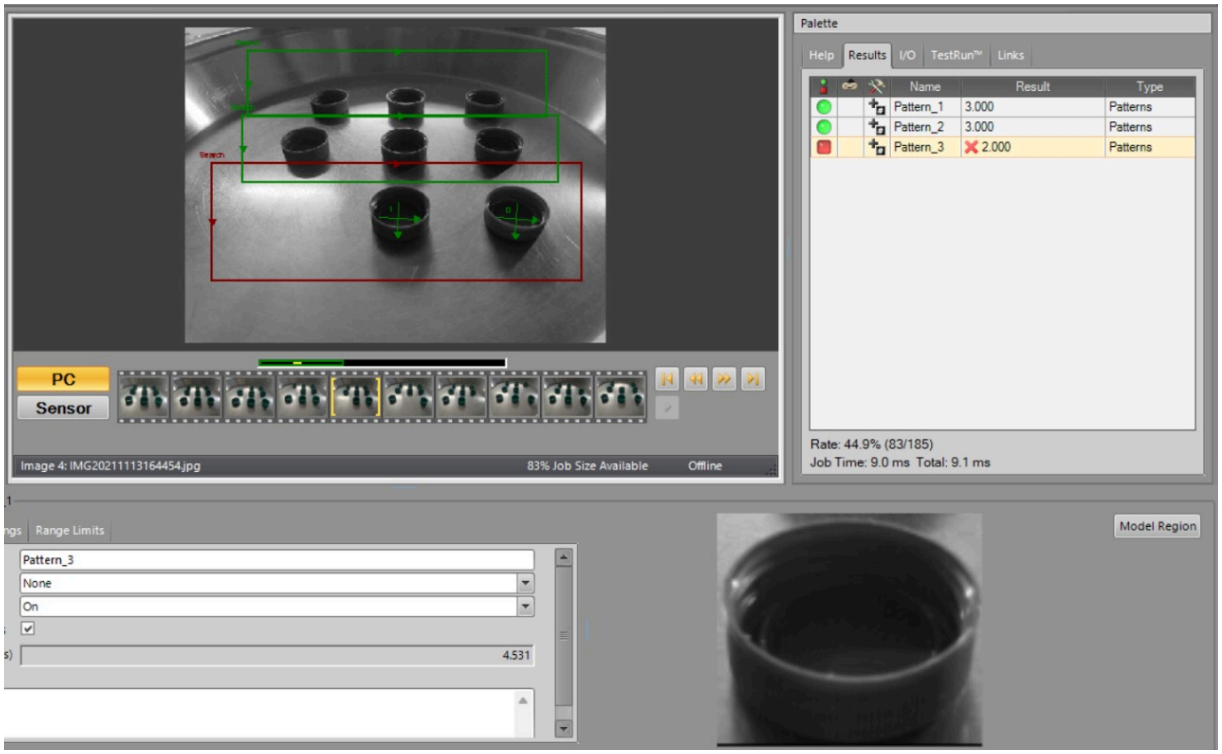


Fig 4 A cap is missing in the 3rd row.

Count the number of randomly spread out pen caps.

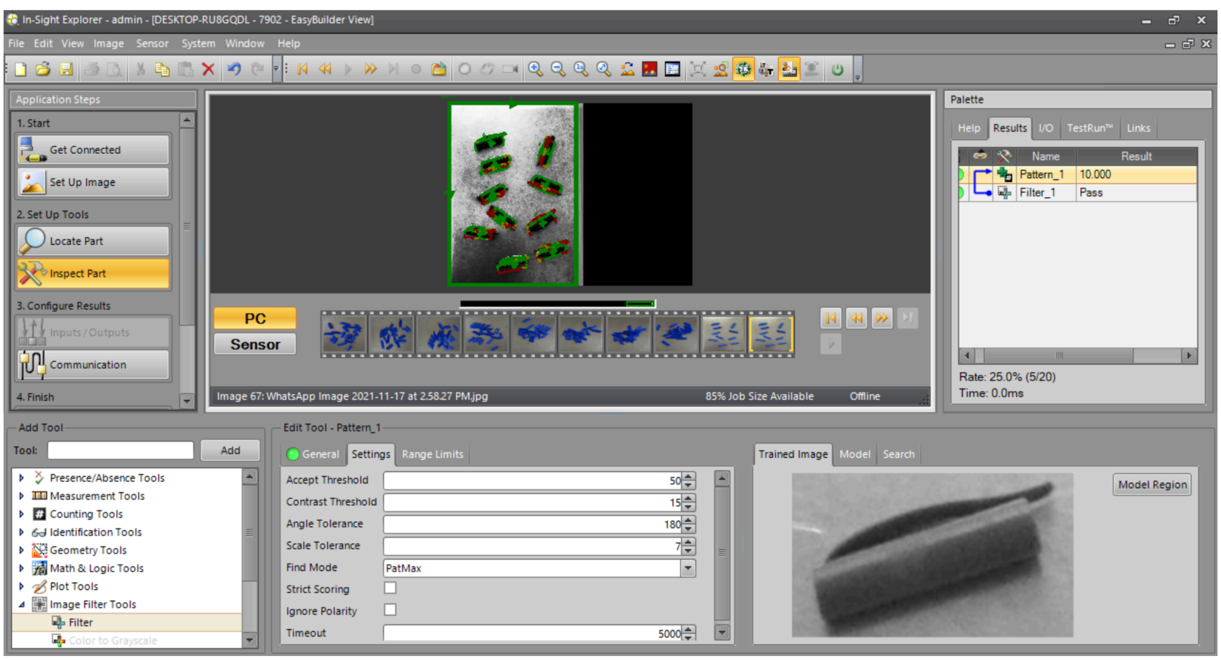


Fig 5 Counting the 10 randomly placed bottle caps using the equalize filter.

4.3 Summary of performance study

We were able to achieve 99% accuracy in counting the number of bottle caps and an accuracy of 40-50% in counting the number of pen caps.

5 Conclusions and Future Work

We studied the moulds and cavities present in the moulds. We studied about the manufacturing process of different moulds .We studied about the cameras ,different types of camera present on the cognex platform .While studying the placement of camera in the industry we found out the problem that the angle will be different we reconsider the studying images of the bottle caps at 15 degrees for the bottlecaps .we faced problem while collecting the data because as the 99%data did not showed any fault in the mould only 1% data had the faults . After that we trained the images on the cognex using the student credentials and trained the images of the products of the mould .Which give the condition of the mould by considering the number of items manufactured to the number of items it is supposed to manufacture .

Future Works

1)Increasing the Efficiency of the model the cognex platform efficiency can be increased by training more variety of mould by the different industry to make it available for the different industries as well

2)Surface quality assessment of the mould

the cognex platform can be trained to analyse the surface quality of the mould by training the mould images on regular basis

3)remaining life of the mould prediction of the mould

6 References

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