DESIGN AND DEVELOPMENT OF IP BASED AUTOMATIC BOTTLE INSPECTION SYSTEM USING CONTROLLINO MAXI AUTOMATION.

ABDULAZIZ AHMED SIYAD

FACULTY OF ENGINEERING

UNIVERSITY OF MALAYA

KUALA LUMPUR

2019

DESIGN AND DEVELOPMENT OF IP BASED AUTOMATIC BOTTLE INSPECTION SYSTEM USING CONTROLLINO MAXI AUTOMATION.

ABDULAZIZ AHMED SIYAD

**SUBMITTED TO THE
FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA, IN PARTIAL FULFILMENT
OF THE REQUIREMENT FOR THE DEGREE OF
MASTER OF INDUSTRIAL ELECTRONICS AND
CONTROL**

2019

UNIVERSITY OF MALAYA
ORIGINAL LITERARY WORK DECLARATION

Name of Candidate: **Abdul Aziz Ahmed Siyad**

Matric No: **KQC170007**

Name of Degree: **Master of Industrial Electronics and Control**

Title of Project Paper/Research Report/Dissertation/Thesis:

Design and Development of IP based Automatic Vision Bottle Inspection System using CONTROLLINO Maxi Automation.

Field of Study: **Industrial Electronics and Automation**

    I do solemnly and sincerely declare that:

(1) I am the sole author/writer of this Work;
(2) This Work is original;
(3) Any use of any work in which copyright exists was done by way of fair dealing and for permitted purposes and any excerpt or extract from, or reference to or reproduction of any copyright work has been disclosed expressly and sufficiently and the title of the Work and its authorship have been acknowledged in this Work;
(4) I do not have any actual knowledge nor do I ought reasonably to know that the making of this work constitutes an infringement of any copyright work;
(5) I hereby assign all and every rights in the copyright to this Work to the University of Malaya ("UM"), who henceforth shall be owner of the copyright in this Work and that any reproduction or use in any form or by any means whatsoever is prohibited without the written consent of UM having been first had and obtained;
(6) I am fully aware that if in the course of making this Work I have infringed any copyright whether intentionally or otherwise, I may be subject to legal action or any other action as may be determined by UM.

    Candidate's Signature   Date:

Subscribed and solemnly declared before,

    Witness's Signature   Date:

Name:

Designation

ABSTRACT

Image processing is becoming vital part in production industries to define the efficiency and accuracy of the bottles become more important. In order to improve the quality of the line this study proposes Automatic vision inspection machine that contains vision inspection part and conveyor line implemented using Controllino PLC and Omron photo-electric sensors and Mobile camera. Stream of real-time videos is acquired from the camera to Matlab using wireless network, there were methods and algorithms used in the vision inspection to analyse and detect the presence and properties of a bottle then extract meaningful information using Graphical User Interface, Noise or unwanted objects were mostly removed using filtering, segmentation and blob analyses.

The experimental results of the system show that its accurate if the camera is positioned in a stable, fixed distance with the bottle, fixed speed of the motor which can impact the results if high speed is adjusted to the motor, the defect detection degree has reached high level with good accuracy in detection.

ABSTRAK

Pemprosesan imej menjadi sebahagian penting dalam industri pengeluaran untuk menentukan kecekapan dan ketepatan botol menjadi lebih penting. Untuk meningkatkan kualiti garis kajian ini mencadangkan mesin pemeriksaan visi Automatik yang mengandungi bahagian pemeriksaan penglihatan dan garis penghantar yang dilaksanakan menggunakan Controllino PLC, sensor foto-elektrik Omron dan kamera Bergerak. Aliran video masa sebenar diperoleh dari kamera ke Matlab menggunakan rangkaian tanpa wayar, terdapat kaedah dan algoritma yang digunakan dalam pemeriksaan visi untuk menganalisis dan mengesan kehadiran dan sifat-sifat botol kemudian mengekstrak maklumat yang bermakna menggunakan Antara Muka Pengguna Grafik, Bunyi atau yang tidak diingini objek kebanyakannya dibuang menggunakan penapisan, analisis segmentasi dan gumpalan.

Hasil eksperimen sistem menunjukkan bahawa tepat jika kamera diposisikan dalam jarak yang stabil, tetap dengan botol, kecepatan tetap motor yang dapat mempengaruhi hasilnya jika kecepatan tinggi diselaraskan ke motor, tingkat kecacatan pengesanan telah mencapai tahap tinggi dengan ketepatan yang baik dalam pengesanan.

ACKNOWLEDGEMENTS

The success and outcome of this project required a lot of guidance and assistance from many people, and I extremely fortunate to have got this all along the completion of this work. Whatever I have done is only due to such guidance and assistance and I would not forget to thank them.

In performing this project, I had to take the help and guideline of some respected people, who deserve my greatest gratitude. I would like to express my special gratitude to my supervisor Associate Prof. Ir. Dr. Mahidzal Bin Dahari who took keen interest in this project and guided me all along, as well as giving me the golden opportunity to do this wonderful project on the topic.

In here I would also like to show my gratitude towards my role model, elder brother Abdullahi Siyad and my dear lovely Mom Hadsan Halane who also had a big role in my journey of education,

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

IP   Internet protocol

PLC   Programmable Logic Controller

CCD   Charge-coupled device

IVIS   Intelligent visual inspection systems

CMOS   Complementary Metal Oxide Semiconductor

APIM   Automatic Particle Inspection Machine

RGB   Red, Green, Blue

HSL   Hue, Saturation and Lightness

SFTP   SSH File Transfer Protocol

AVI   Automated Visual Inspection

FCM   Firebase cloud messaging

ESD   Electronic Software Download

UART   Universal Asynchronous Receiver/Transmitter

CHAPTER 1: INTRODUCTION

1.1 Introduction

Machine based vision inspection systems provide huge understanding of objects that are desirable from single image or many arrays of images. In industrial applications machines inspection systems enhance productivity as well as improving the quality of the manufactured products, in this chapter we are going to demonstrate or study historical backgrounds problems to be solved, scope and constraints of the project.

1.2 Background of the study

Image processing and vision machines is one of the most important sector manufacturing industries and it's among the technologies that are rapidly growing with its major and various applications to enhance and analyse the properties of the product to ensure quality and safety of the product.

In case of the bottle filling, which most of the conventional machines consider only controlling the level of the liquid. Nowadays technologies there are many vision solutions in any other sectors of the manufacturing industry like product selection, raw material washing and final product packaging, and other systems that pose vision machines. Present case solution which are applied after filling of the liquid in the bottle take place before it is sent to the final consumer, it's so important to inspect from defect in several ways including if the bottle is not damaged, label is correctly in position, bottle caps, level of the liquid, and uniqueness or likelihood of the liquid in process. Any of the issues mentioned above pose unique analysis algorithms and image processing which are different from each other. And these algorithms have to be discovered using gray and binary and colour images (Campos, Ferreira, Martins, & Santos, 2010).

Using the automated technology in helping solve image inspection problems including: bottle cracks, lips of the bottle, cracking in the mouth of the bottle, the level of

1

the liquid is not standard etc. these issues in the industry with its research done have discovered many quality inspection machines to guarantee quality, reliability and continuity of the product, like sensors that take place quality inspection or even image processing.

In literature review, with the advancement in technology, variety of inventions are made on quality inspection of the bottles manufactured. Ufuk Sanver, Erdem Yavuz and Can Eyupoglu in 2017 investigated mineral water bottle to detect defects and faulty before packaging using image processing with an algorithm of edge detection called Sobel method and also Haugh transform for counting number of bottles, the system they designed has achieved huge improvements in detecting bottle which are faulty from couple of test samples.

According to (Li, Hang, Yu, Wei, & Xinyu, 2017), study they did propose shows a method of defect detection of a mouth class using or based on OpenCV connectivity domain feature to detect defects of the bottle. (Zhang et al, 2018) Presented Bayesian Bottle Size Detection Classifier especially bottles used in pharmacy by exposing OpenCV function to the processing an also identifying of the type of the bottle by using Naïve Bayesian classifier and also, they figured out the bottle characteristics.

In the study of (Yang et.al, 2015) showed a method of detection of defects method in mouth glass of the bottle by using image processing. First an image smoothing is taking place to eliminate any sort of noise in the image, then segmentation of image by thresholding the level of gray image finally edge detection extraction take place. When compared to other method of solutions in finding edge detection in this study Canny operator was adopted as was a base in this study.

According to (Mathew et.al, 2013), proposed basic principle technique of digital image processing to determine the extent to which glass bottles can be detected in food processing fields

Study presented by Leila Yazdi, Anton Satria Prabuwono and Ehsan Golkar, 2011 Summarized in an automated visual inspection system, the algorithm proposed a new feature extraction technique to investigate these two parameters to detect liquid fill level defects and close bottle caps. In the study by Sile Ma, Bin Huang, Huajie Wang and Junmei Guo, inspection of defect mouth and bottom base empty bottle were presented using straight lines to find points in the bottle mouth position and the position of the bottom of the bottle by random Hough transform is used to inspect the circle defect at the bottom of the bottle.

1.3 Problem Statement

One of the biggest challenges in production line is getting a product which has high quality and zero defects. In some production line due to its complexity defects usually become very tiny, plus defects that are random and irregular shapes. Nowadays human manually inspection systems are replaced by highly sophisticated and complex vision over the last few decades, due to human difficulties of the product and capacity of the product be manufactured. In other terms human inspecting large scale speed line of bottles is susceptible to human error or fault that humans cannot handle Therefore, In this project we are going to demonstrate a product quality vision inspection and monitoring machine to detect the bottle and analyse defects using IP live webcam (android based) camera in bottle inspection and using newly invented industrial automation device Controllino Maxi automation and Omron industrial sensors in a mini conveyor line.

1.4 Aim of the study

To design and Implement IP(Internet Protocol) webcam based Automatic bottle vision inspection machine with the use of Controllino Maxi in a conveyor line that the bottle runs on it while inspection taking place.

1.5 Objective of the study

In this project variety of specific objectives will be met:

1. To design a webcam-based inspection system via Matlab to inspect bottle arrived at the position determined in the conveyor
2. To implement a conveyor line that works with a Stepper motor with Omron sensors to detect visibility and the position of the bottle.
3. To detect and analyse the properties of the bottle's cap, water level, and count the defected and passed bottles.

1.6 Scope of the study

In this study we will design and deal with vision machine. It consist of a motor that runs the belt line and two sensors to sense the detect and take place position of the bottle consist camera to take image of the bottle and, once the bottle is sensed the trigger will be given to camera that will take a picture of the bottle. It will check the value in terms of the pixel of the bottle. If the bottle is half filled or over filled, then it should not reach to the customer. In this case over system reject that particular bottle which is over fill or under fill. Our system avoids human error which occur during our regular working.

1.7 Significance of the study

In the production process industry specially beverage production, bottles mostly experience defects that appear from its mouth, cracks in the bottle upper and bottom parts, mismatched liquid level are most cases production company experience. these

defects have increased in the industry invention and many researches to ensure quality inspection machines to guarantee the product's quality, reliability and continuity.

1.8 Structure of the study

The remaining parts of this research project will be organized and modelled as following:

- Chapter II that deals with the review of literature and relevant research associated with the image inspection systems, discuss and analyse variety of algorithms their results and their evolution of design and work done to reach this highly enhanced vision systems.

- Chapter III that defines the research methodology of image inspection machines using Matlab and also, we are going to discuss the hardware design and procedures used in programming software simulation also its hardware component programming.

- Chapter IV that contains the implementation of the system using procedures we discussed in chapter 3, Analysis of the result on each process of implementing IP-based webcam image processing with using Controllino to inspect and run the conveyor with a stepper motor and Sensors that detect and position the bottle.

- Chapter V finally is the conclusion of the system and the outcome of achievement or objectives we reached during methodology, design and implementing of the project, and recommendations for future research and developing or advancing such a project.

LITERATURE REVIEW

2.1 Introduction

The recent technological development of data and image acquisition systems has directed the development and invention of new machine vision solutions in variety of manufacturing sectors. In this chapter we are going to discuss and analyse historical background of bottle inspection visual machining using algorithms to monitor bottles moving on the conveyor after sensors detected the presence of a bottle.

2.2 Visual measurements

It is the case for bottle filling, where conventional systems only concerned the level control. Vision solutions have nowadays been used in other sub-sectors of the manufacturing systems, such as the final product packaging, washing raw materials, selection of a product, etc. Here is the case of the present solution, which intends to be applied after the filling of beverage bottles that are going to place in the crates. Before these bottles are boxed are sent to the final customer, several items must be inspected, including: If the bottle has the right shape and filled well, if the bottle is damaged, if the bottle has a capsule and if the capsule is correct. Different image processing and analysis algorithms were developed using colour and gray images for each of these inspection problems. The system is currently installed and integrated into the production line and in final adjustment testing(Campos et al., 2010).

One of the computer vision system's primary requirements was that it had to adapt to clear line space. This requirement has affected the layout of the vision system and various algorithms 'specifications and developments. The direct result of this requirement is the small size of the light box and the resulting low light uniformity, which was ideally intended to be uniform and diffuse. The distance from the bottle to the camera, which also had to be reduced, is another consequence. This means that a lens with a small focal length is used to create a strong perspective effect in the image (Campos et al., 2010).

In these years, the APIM has developed to meet pharmaceutical factory requirements. In order to make the most of the machine's use and improve the speed of inspection, the parallel processing architecture is introduced that up to 24 cameras can be equipped with an APIM, as shown in Figure 3. In order to avoid false detection, the idea of double checking is carried out that two different cameras inspect a product twice. However, these changes are still based on the monocular camera algorithm, and because of the inherent shortcomings, there are two important problems listed below that cannot be easily solved at low cost either in computing time or hardware consumption:

1) Narrow Field Depth (NDOF): We usually use small focal lens and large F - number aperture to get enough DOF. However, due to the small size of CCDs or CMOSs, industrial cameras usually use C - Mount lens, which cannot be viewed in wide depth due to changes in focal length and F - number, such as large infusion bottles with a radius greater than 25 mm. In addition, the aperture diameter is relatively smaller than normal. In order to get a greater depth of view, we need a larger F - number, but a larger F - number requires higher light source power, which leads to growth in hardware costs and cooling problems. As a result, the field depth is never sufficiently large and small particles cannot be clearly imaged for the following processing.

2) *Dynamic Background Interference (DBI):* It is mainly due to two types of light interference, the external and the internal interference. The external interference from outside the APIM refers to the light indoors, the sun's rays and so on. Internal interference is caused by multiple reflections within the APIM between the spinning surface of the liquid, machine pillars, scratched sidewalls, even from adjacent bottles, etc. Under the conditions of the laboratory, these interferences can be easily separated by sequential images (Fang et al., 2013).

1 .input conveyer belt
2 .mass transfusion bottle
3 .import wheel
4 .rotating station
5 .abruptly stopping stage
6 .bottom light source
7 .tracking stage
8 .background light source
9 .master wheel
10.slave wheel
11.gripper
12.exit wheel
13.output conveyer belt
14.sorter
15.cameras
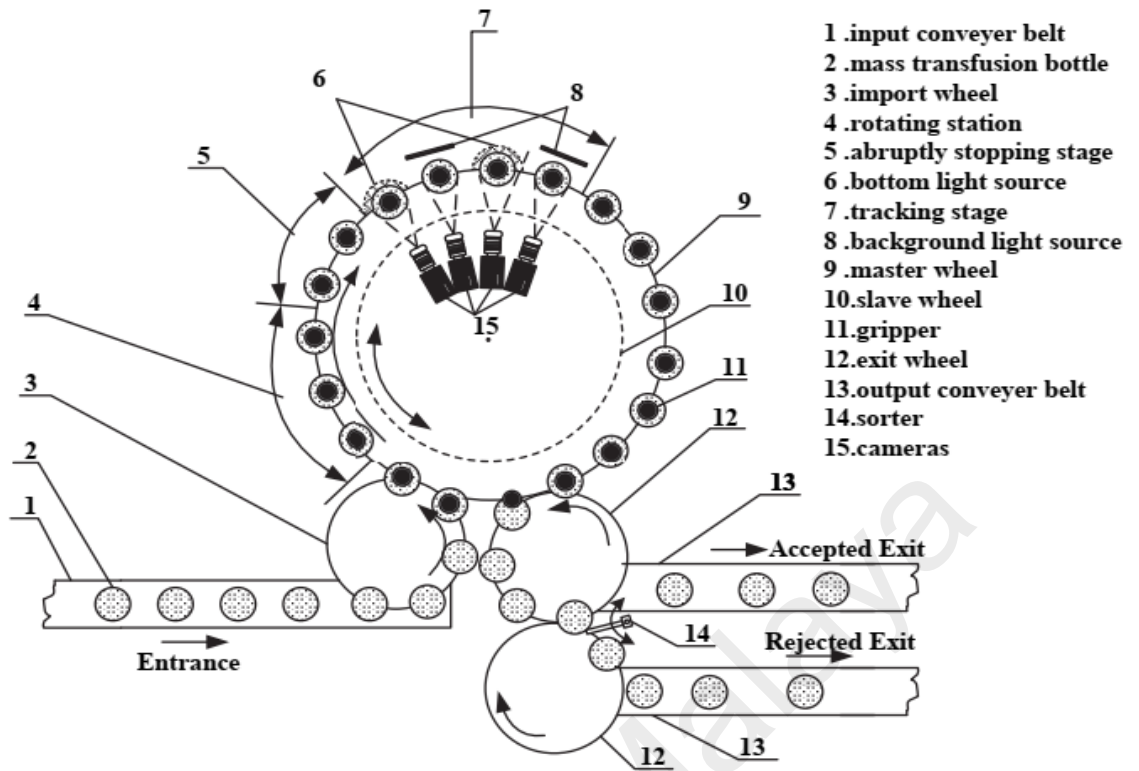
Figure 2.10: APIM structure diagram (Fang et al., 2013).

The lighting conditions play an important part in the quality and enhancement of the acquired images and also in the task of inspection in each image acquisition device. Because natural lighting conditions are dynamic and are constantly changing. Implementing algorithms that are robust to changes in illumination without burning significant computational time is not feasible. The use of artificial lighting is therefore a prerequisite for achieving good and consistent lighting for real-time inspection systems. Several studies exist, e.g. regarding the placement of external light sources around the object being examined. We do not know, however, any work reporting on light sources inside a glass bottle. George et.al suggested designing an electro-mechanical device to acquire images and inspect glass wine bottles using an internal lighting system. This gives us ability to acquire high quality images to avoid unwanted defects causing by the camera or shadow and reflections coming from external light source in the area. To this goal, several mechanisms relevant to bottle inspection have been proposed in the literature ; examples are the neural network system scanning laser beam, the independent component

analysis model, the area or feature-based techniques ; unfortunately, there is no method that is really accurate, low cost and at the same time reasonable. Furthermore, the systems are almost in the market don't agree with the requirements and flexibility of the industrial applications (George, Janardhana, Jaya, & Sabareesaan, 2013).

Specific algorithms have been developed for inspection of each item. The setup of the image acquisition system conditioned them. In particular, they need to be able to support poor illumination uniformity and strong perspective effect. Alternative key requirement is that the system should support different bottle orientations (Saad, Nabilah, Abdul, & Abdullah, 2017).

As mentioned above, the bottle is not evenly illuminated due to the imposed small size of the box lighting. In this sense, the first step in checking bottle defects is to simulate a uniform illumination. This procedure is a color mapping, depending on the pixel position. A white target image was acquired to reflect the illumination's non-uniformity. Differences mapping was created between the target strength and a uniform level (255). By adding this difference (mapping) to the acquired image, an image with more uniform tone is obtained.

In particular, the camera's RGB image is converted to HSL [1,2,6] colour space. The calibration procedure for lighting is applied to component L. Convert the HSL image back to RGB colour space. In the resulting image, the segmentation process with specified RGB thresholds is applied to analyse the type of crate. A number of pixels is made in the binary image. In the case of the resulting number of pixels (area) is less than a predefined threshold, a bottle exchange exists and the process of global analysis is stopped. In vice-versa the convex hull[1,5] of the bottle blob is determined. This process is designed to determine the orientation of the box compared to the image axes and the positioning relative to the centre of the image. This is required for further analysis of the bottle and capsule detection. The distance between the contour generated by the convex hull and the

contour of the blob given by the chain code is quantified after the bottle alignment. Thus, broken box areas can be inferred, as in these situations the distance between the convex hull and the contour exceeds a predefined threshold (Fang et al., 2013).

This procedure is applied to the image aligned with the crate in the RED channel, i.e. crate image oriented with the image axes and the image centre. A previously acquired image of an empty box is also used in this procedure. A morphological filter is applied in both pictures of the crate. The resulting image of the empty box is subtracted after that by the resulting image of the current box.

A set of 15 dilatations is the morphological filter applied to the reference image, with a circular structuring element of 3x3. The filter applied to the current image is using a 3x3 circular structuring element to apply a close-up of 7 iterations. These filters can be applied to minimize background image and foreground bottle details. After subtraction, and for each region of interest defining each capsule's position, a binarization is made and the resulting blob area is quantified. If a predefined threshold parameter exceeds this area then a bottle is present.

2.3 IP Webcam.

IP Webcam turns your phone into a multi-view network camera. View your camera with a VLC player or web browser on any platform. Without internet access, stream video within the WIFI network. For instant global access, optional Ivideon cloud broadcasting is supported.

Two-way audio supported on another Android device in the tinyCam Monitor. Use IP Webcam with MJPG software from third parties, including video surveillance software, security monitors, and most audio players. Some of its characteristics are: Video upload to Dropbox, SFTP, FTP and Email with Filoader plugin, Several web renderers to choose from: Flash, Javascript or built-in, Video recording in WebM, MOV, MKV or MPEG4 (on Android 4.1 +), Audio streaming in wav, opus and AAC (AAC requires

Android 4.1 +), Sound Trigger Detection, Tasker integration, Date, time and battery level video overlay, online web graphing sensor data acquisition, videochat support (only for Windows and Linux video streaming via a universal MJPEG video streaming driver), cloud push notifications on motion and sound, cloud recording for movement-triggered records, Ivideon powered online video broadcasting. Also, they have extensive monitoring features: night vision, motion detection, sound detection.

2.4 Bottle Detection Mechanisms

Conventional method of inspection requires trained workers to manually move bottles up and down to observe particles in a dark room fitted with high brightness and uniform source of planar light. Although the method of manual inspection is very cheap for pharmaceutical plants, the drawbacks are obvious: (a) Low effectiveness, (b) poor robustness, (c) high inaccuracy rate, particularly in the absence of concentration of workers. The Automatic Particle Inspection Machine (APIM) in (Fig.2) it is in great demand after wages for workers have risen after the subprime crisis and the standards of quality of the product raised have greatly increased for the new Chinese pharmaceutical company's health ministry in 2010 and the new GMP compulsory certification has since been implemented. APIM is a machinery, electrical control and optical imaging technology-based system. A type of APIM was previously developed using a monocular camera inspection method and was widely used in the actual product line such as ampoule and small capacity Infusion bottle, which has a relatively small bottle diameter. A bottle loaded with medical liquid spins at high speed in this machine and stops abruptly. This bottle is followed by an image acquisition system in the product line and a series of pictures. The container remains stationary, but due to inertia the liquid inside remains rotating. As a result, image processing and pattern recognition technologies can distinguish the moving particles in the image sequence (Fang et al, 2013).
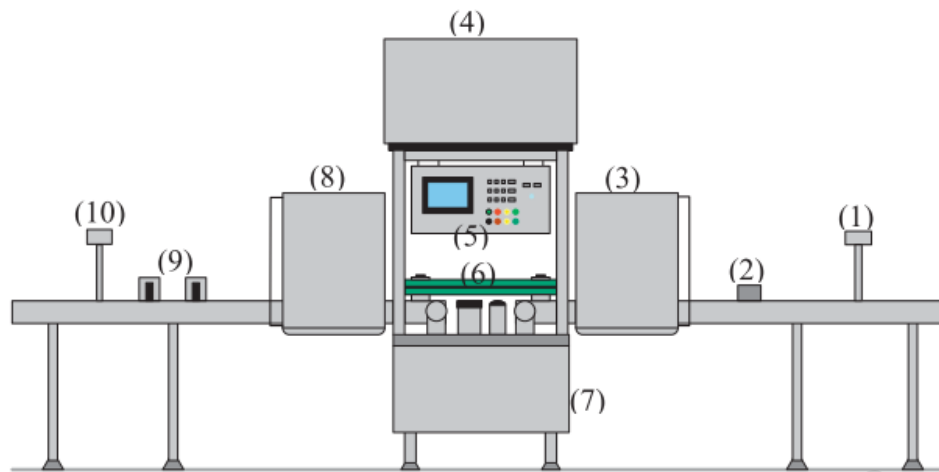
11

Figure 11.2: Structure diagram of the bottle inspection system

For the image above describing bottle inspection system contains (1) Initial inspection (2) Residual liquid inspection (3) Bottle wall inspection (4) Operation and control unit (5) Control panel and bottle mouth image acquisition device (6) Bottle bottom image acquisition device (7) Gearing (8) Bottle wall inspection (9) Reject apparatus (10) Rejection confirm. It is intelligent equipment with machine vision, precision machinery and real-time control, which mainly consists of pre-inspection unit, wall inspection unit, mouth inspection unit, bottom inspection unit, control unit and human–computer interaction unit and man–machine interface unit, as shown in Fig. 1. The main functions include bottle mouth breakage inspection, the dirt and foreign body inspection of the bottle mouth, bottom and the wall and rejecting the bottles unqualified in time(Huang et al., 2018).

Using automated technology to help inspect a bottle issue such as bottle cracking, bottle lips and mouth cracking, packaging volume is not the standard size, etc. These industrial or research problems have invented many quality inspection systems to ensure product quality, reliability and continuity, such as quality inspection of sensors and image processing. In literature, different ways of inspecting the quality of the bottle product are invented. Sanver Ufuk, Yavuz Erdem, and Eyupoglu Can. The detection of defective bottle packaging for a mineral water product is investigated by applying Image Processing

12

and using the Sobel edge detection method and the Hough transform method to check a number of bottle packages.

Fu Li, Zhou Hang, Gong Yu, Guan Wei and Chen Xinyu. Proposed a method defect detection, mouth glass bottle by connectivity domain feature using based on an Open CV for defect detection. Zhang et al. Presented Bayesian Bottle Size Detection Classifier for pharmacy bottles by introducing the Open CV function for bottle type processing and identification with the Naive Bayesian Classifier and bottle characteristics. ZongFang Yang and JianYu Bai. Proposed method of mouth glass bottles detection of defects through image processing. First, by reducing noise, an image is smoothed. Secondly, gray-level threshold control image segmentation and then edge detection extraction. The edge detection method compared with other solution methods. This study uses the Canny operator to find edge detection on the basis. In George Mathew's study, Jaina George, J. Jaya, S. Janardhana, K. J. Sabareesaan introduced the basic principles of digital image processing techniques to defect detection for food processing fields.

(Yang, 2015) presented some basic machine vision algorithms and then uses a vial bottle mouth defect detection scheme from the HALCON platform. Experimental results show that this method of quickly and accurately detecting vials bottle mouth defects is practical and feasible.

In the study of Leila Yazdi, Anton Satria Prabuwono and Ehsan Golkar an automated visual inspection system with a new feature extraction technique was proposed to investigate these two parameters to detect liquid fill level defects and close bottle caps.. In the study by Sile Ma, Bin Huang, Huajie Wang and Junmei Guo, Intelligent for inspection defect mouth and base empty bottle were presented using straight lines to find points in the bottle mouth position and the position of the bottom of the bottle by random

Hough transform is used to inspect the circle defect at the bottle base(Kumchoo & Chiracharit, 2018).

2.5 CONTROLLINO ARDUINO PLC

The "CONTROLLINO Open-Source PLCs", or microcontroller as you might also call them, are modern programmable control systems that are offered in a variety of different versions. They were developed by us with the aim of fulfilling the high expectations of our customers on product quality and functionality. Or in other terms the CONTROLLINO PLC is a small computer (μC = microcontroller) with peripherals based on the "Open-Source Arduino platform". It is installed in a DIN rail housing. Controllino, is a programmable logic controller (PLC) that has the facility for its open language and compatible with other control devices such as Arduino. It is ideal for private and industrial applications in the areas of automation, monitoring and control. Depending on the need of the company, it is presented in 3 Mini, Maxi and Mega motifs. These devices are designed under Atmega328 and Atmega2560 microcontrollers from Atmel.(Cameron Klotz, 2017)

In the industry they are very desirable, for solutions of robustness and where it is necessary to gain space for other structures. Within the needs of companies, Controllino provides simplicity in the testing workshop with obtaining additions that allow faster and more efficient processes; contributing to the technological improvement of any company. Due to the growing need of the market, a flexible solution for the construction and automation of the industry was ideal, it will focus on complete control modules with adaptability, scalability and disposition at any time (Cameron Klotz,2017).

Due to the growing need of the market, a flexible solution for the construction and automation of the industry was ideal, it will focus on complete control modules with adaptability, scalability and disposition at any time (Cameron Klotz,2017).

CONTROLLINO can be described as an industrialized Arduino in one sentence. It combines the Arduino ecosystem's flexibility and open-source nature with industrial grade PLC safety and reliability. With the Arduino ecosystem's simplicity and flexibility, you can drastically reduce your time and cost of project development and focus on what is most important: your project. CONTROLLINO offers up to 61 channels and relays for input/output, ranging from 5V to 230V at 16A. This enables you to use CONTROLLINO for an almost limitless range of applications for automation and control. CONTROLLINO has been developed with the highest industry standards and electronic safety in mind. This makes it ideal not only for prototyping scenarios, but also for end products. Controllino is an application-designed solution where specific environments need to be adapted depends entirely on the project's construction. Within the predictive validity fields,

Controllino has a range of 4 different models that are detailed below:

2.5.1 Controllino Mini

It is the smallest of the range. It has few inputs and outputs it is used in small applications. Their characteristics are: Microcontroller: ATmega328, Atmel Clock speed: 16 MHz, RTC, 1x serial interface, SPI 1x interface, 2C 1x interface, Max input current8A, 6x Output Relays - 230V / 6A, 8x digital / analog inputs, Digital outputs 8x - 2A @ 12V or 24V (CONELCOM,2017)

2.5.2 Controllino Maxi

It is known and used for its flexibility in terms of I/O, their characteristics are: Microcontrollers: Atmega2560, Clock speed: 16 MHz, RTC, Ethernet connector, 2x serial interface, RS485 1x interface• I2C 1x interface, SPI 1x interface, Max input current20 A, 10x output relays - 230V / 6A, 12x Digital / analog inputs, Digital outputs 12x - 2A @ 12V or 24V. This type of maxi has different subcategories with each holds additional features like more I/O that has 0-10V, 5x 16amps relay and also Controllino with stepper motor drivers.   (CONELCOM,2017).

2.5.3 Controllino MEGA

It is the largest PLC in the CONTROLLINO family, used for large and complex applications. Microcontrollers: Atmega2560, Clock speed: 16 MHz, RTC, Ethernet connector, 2x serial interface, RS485 1x interface, I2C 1x interface• SPI 1x interface, Max input current30A, 16x output relays - 230V / 6A, 21x Digital / analog inputs, 12x digital outputs - high side switch - 2A @ 12V or 24V• 12x digital outputs - Half bridge - 2A @ 12V or 24V (CONELCOM,2017).

Figure 2.14: Controllino MEGA   Retrieved from: https://www.controllino.biz/controllino-mega/

2.6   Controllino Maxi Automation Architecture

The MAXI Automation is the version of Controllino MAXI specifically tailored for the needs of automation specialists! It is the perfect compromise between compact size and big input and output number, and the core competence is its flexibility. Controllino is ideal to experience transformation fields not only of companies, industries or business; if not also, of homes. Next, you can find the types of implementation that these great PLCs allow (Cameron Klotz, 2017).

Unlike the Controllino MAXI it has more relay outputs. Among its features are: Atmega2560 Microcontrollers from Atmel, it has Clock speed of 16 MHz, Real Time Control integrated with Ethernet connector, 2x serial interface, I2C 1x interface, SPI 1x interface, Max input current 20 A, 12x Analog / Digital inputs 0-24V, 2x analog inputs

0-10V, 6x digital inputs (2x interruption), 8x digital outputs - 2A (PWM) Analog outputs - 2x 0-10 (0-20 mA), 10x output relays - 230V / 6A (CONELCOM,2017)

2.7 ALGORITHMS

Computer vision systems generally refer to systems that use digital images to extract desired features. The main objective of these systems is to increase scene comprehension from input images. The application of vision systems to automate manufacturing processes in industries is considered as a machine vision. It is also defined as Automated Visual Inspection (AVI) when attempts have been made to monitor, control product lines and identify defects using only images of the product (quality control). In fact, people are slower as inspectors and their effectiveness is affected by their state of exhaustion, disease or other human deficiencies. They need training in some applications in order to acquire proper skills. In addition, sometimes there are special environments that are dangerous and not suitable to human operation (Yazdi, Prabuwono, & Golkar, 2011).

Specific algorithms have been developed for inspection of each item. The setup of the image acquisition system conditioned them. They must be able, in particular, to support the poor uniformity of lighting and the strong effect of perspective. Another key requirement is that the system must support different orientations of the bottle (Campos et al., 2010).

On the other hand, it is necessary to improve quality control and productivity, particularly in the manufacturing environment, in order to sustain an advantage over their competitors. Intelligent visual inspection systems (IVIS) are directly linked to various topics such as pattern recognition, image processing, machine learning, image processing, signal processing and artificial vision systems software and hardware as well as artificial intelligent (AI) techniques. Extensive research on AVIS has therefore been carried out to

propose high levels of visual inspection by merging these areas (Yazdi, Prabuwono, & Golkar, 2011).

To remove noise from a digital image, image filtering is used. In several applications, it is very beneficial such as smoothing, sharpening, noise removal and edge detection. The smoothing or blurring and image process eliminates noise and small fluctuations. This process refers to the removal of high frequencies in the frequency domain. Using fspecial function, a smoothing filter can be constructed in Matlab. It is quite helpful to blur the image to eliminate misclassification and noise removal to detect the defects in fruit quality assessment because the FCM is sensitive to noise. Filtering might be the most basic image processing and computer vision operation. In the broadest sense of the term filtering, in a small neighborhood of the same location, the value of the filtered image at a given location is a function of the values of the input image. In a wide range of applications for image processing, an image must be smoothed while preserving its edges. (George et al., 2013).

2.8 Summary

This chapter presented variety of literature framework related to image vision inspection system and Controllino maxi automation which is Industrialized Arduino PLC module. This review presents an automated vision system for beverage bottle analysis on moving conveyor system using Controllino. Real-time processing is an essential requirement for industrial monitoring use and the algorithms must be cost-effective in computational terms. The system involves the analysis under different conditions of a set of test video sequences.

Chapter 3: Methodology

3.1 Introduction

In this chapter we are going to visualize methods used entirely in various activities that took place during the duration of the project. Quality inspection system is the main important factor in manufacturing systems, and it's what makes the industry to meet its standard and specifications and also customer needs when product is finally in the market. So, we are here to design a conveyor line using variety of materials to meet our requirements and bottle inspection system is the next to inspect the bottle before its packaged to final processes.

3.2 Image Acquisition

Acquiring image from source hardware plays vital role in this project, Machine vision system we are going to demonstrate consists of a Mobile Camera which is 16 Mega-pixel camera is used to acquire stream of images to inspect, Background light source that is used to minimize the level of noise and increase contrast, focus and accuracy of the image, Personal Computer and Software Platform called Matlab which we discuss later. An android Application called Droidcam is used here to transfer live video wirelessly from mobile straight to Matlab.

3.3 Flow diagram of Image inspection

In the stage when the system is fully run up, a series of images is collected in micro-seconds by the Camera and sends it to the Matlab through Droidcam app for image processing , after image is pre-processed in the methods we discussed earlier, we make extraction of the image to obtain the relevant information and properties we needed including the position of the bottle, the length of the bottle, the level and cap information, then defect analysis began to process if there is any problems in the bottle, and each of

that process is done with in short period of time. The flowchart shown below provides

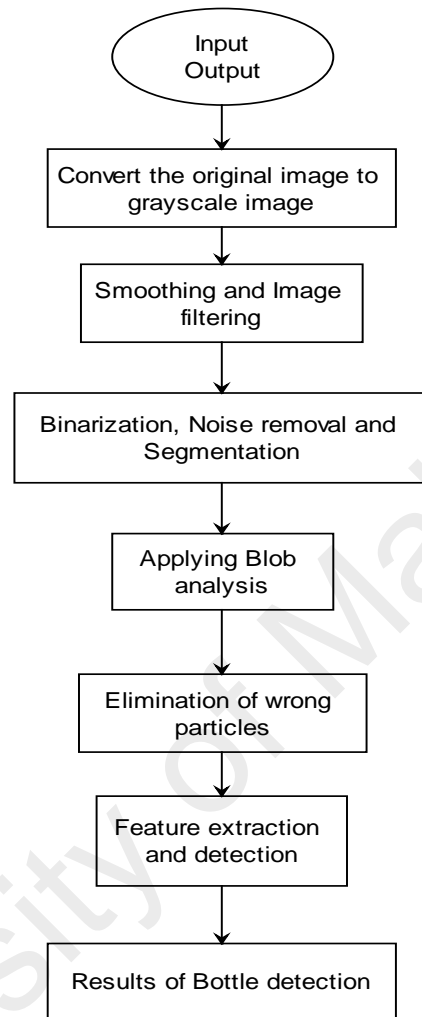steps involving in image processing.

Figure 3.1: Framework of Image processing

3.4 Bottle Inspection and Visual Defect Tracking

The figure below describes mechanisms or methods used to inspect bottle and we

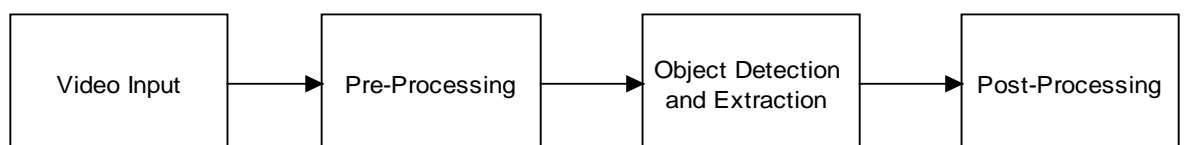discuss each of them in coming sections.

Figure 3.2: Framework of Defect and object detecting

3.4.1 Bottle positioning

In order bottle inspection take place, it's important to know that positioning bottle in a cameras field of vision have an effective result, in here bottle to be inspected is in transmission to destination in a certain speed, and the distance between the camera and bottle must be constant like 20cm, else the characteristics of the image captured at a certain time differs and causes fault in the result. Therefore, to ensure that it is in the region of interest, it is necessary to calculate the position of the bottle bottom in each image accurately.

3.4.2 Video Pre-processing

There are two possible ways of videos used as an input in Matlab, Real time live streaming video from a camera source continuously monitor specific area, and Stored video that is already recorded and easily obtained from storage. Image/Video pre-processing is a vital part in analysis of the image specially when it comes transforming into Gray-scale, binarizing image, enhancing and thresholding image segmentation also edge or corner detection. The image transformation includes converting the captured image into grayscale at a specific requirement of the subsequent processes of the image.

As in the figure 3.3 below converting image into grayscale then into binary makes it easier to follow and analyse specific region of the image that had many layers in RGB mode. Due to the many factors affecting in experimental conditions such as, various hardware and lighting factors, the images of the glass bottle collected in image acquisition device may contain a lot of random noise, and there are more deficiencies in the recognition of bottle. By pre-processing the image improves the region of interest and highlight of the image.

Figure 3.3: Binarized beverage bottle

These binarized effects of black and white, make easily to follow any regional division by taking specified ROI (Region of Interest). Then segmentation of the image takes place to process the target area which pose its own characteristics when compared to other non-targets and we extract the location we want to research if there are a defect to meet the requirements and goals we want to reach. In the image segmentation, there are many noises in the image that needs to be removed, thresholding is used to differentiate the image of the object and its background, setting and having threshold median value can help system to know what and which is the image and background. Proper threshold can remove the white noise in the corner and sides of the target area of the image before extraction.

3.4.3 Bottle Detection and Extraction

The edge and line contain abundant image information during machine vision research and application. The complex edge-line combination is a feature that distinguishes an image from other images. In the irregular structure and unstable image pixel, the contour exists, and there are certainly some in the signal mutation. Effective contour extraction information can be obtained using computer technology in the extraction of the image contour. The computer technology and the Matlab sequence are

used in the design of the subject to store the contour information. An element in the sequence represents each position of the image curve. An object's contour is different from an object's edge. In short, an object's contour is the object's shape that can consist of a series of points. Bottle contour removal is an important part of the process of detection of defects. Below in the fig 3.4 is the contour extraction structure drawing.(Liang et al., 2017)
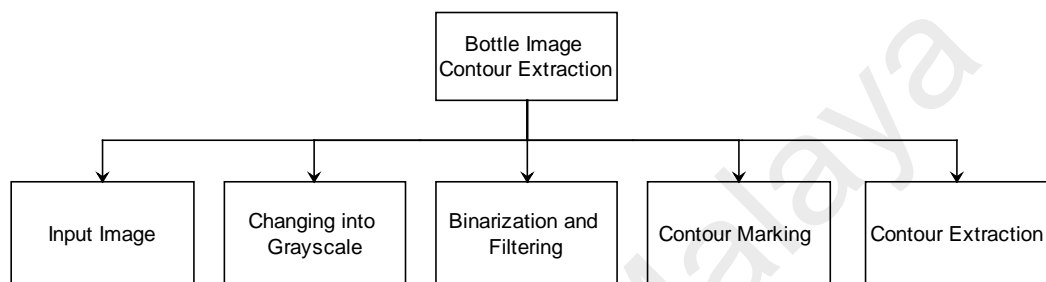

Figure 3.4: Structure of Contour Extraction (Liang et al., 2017)

3.5 Graphical User Interface

GUI is a friendly point and click interface that is used to display and monitor the results in the inspection process. In the figure 3.5 below is the main prototype of the inspection.
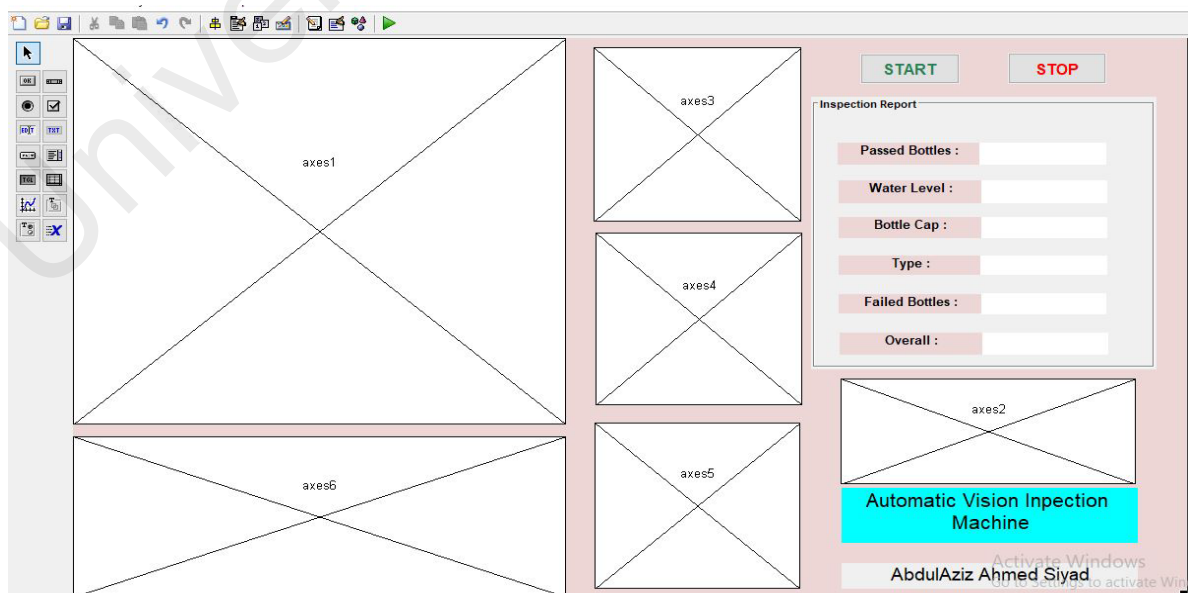

Figure 3.5: Graphical User Interface of the layout

24

Different axes are used in the figure above which show livestream of the visual field and the presence of the bottle in the area. An axis1 is used to monitor the main field, an axis6 is used to show the histogram of the image detected, other axes are 3,4,5 which show the Segmentation process such as filtering, Binarizing image and image after noise is removed. One of the important parts is where the report results are showed, to monitor and count any presence of a bottle and measuring the liquid level, defect detecting if there are no caps on it, and the type of drink in that visual area.

Figure 3.6: Inspection report layout

3.6 Block diagram of the project

In this section Structure and flow of the project is introduced. As in the figure 3.5 below, mentioned components are used for overall of the project, each of the components will be discussed in the coming section. First 24V DC motor starts and allows conveyor belt to move in different position, then Omron sensor detects whether there is a bottle is present on the conveyor, if there is a bottle present sensor responds the motor to stop at a specific time which image acquisition and defect detection is taking place, In real applications high quality industrial cameras which high accuracy in image acquisition is used in fast moving bottles, when a motor stops at a period of time, image processing takes place in series of steps, then motor starts to move again which makes the bottle to transfer in the next process of industrial line.
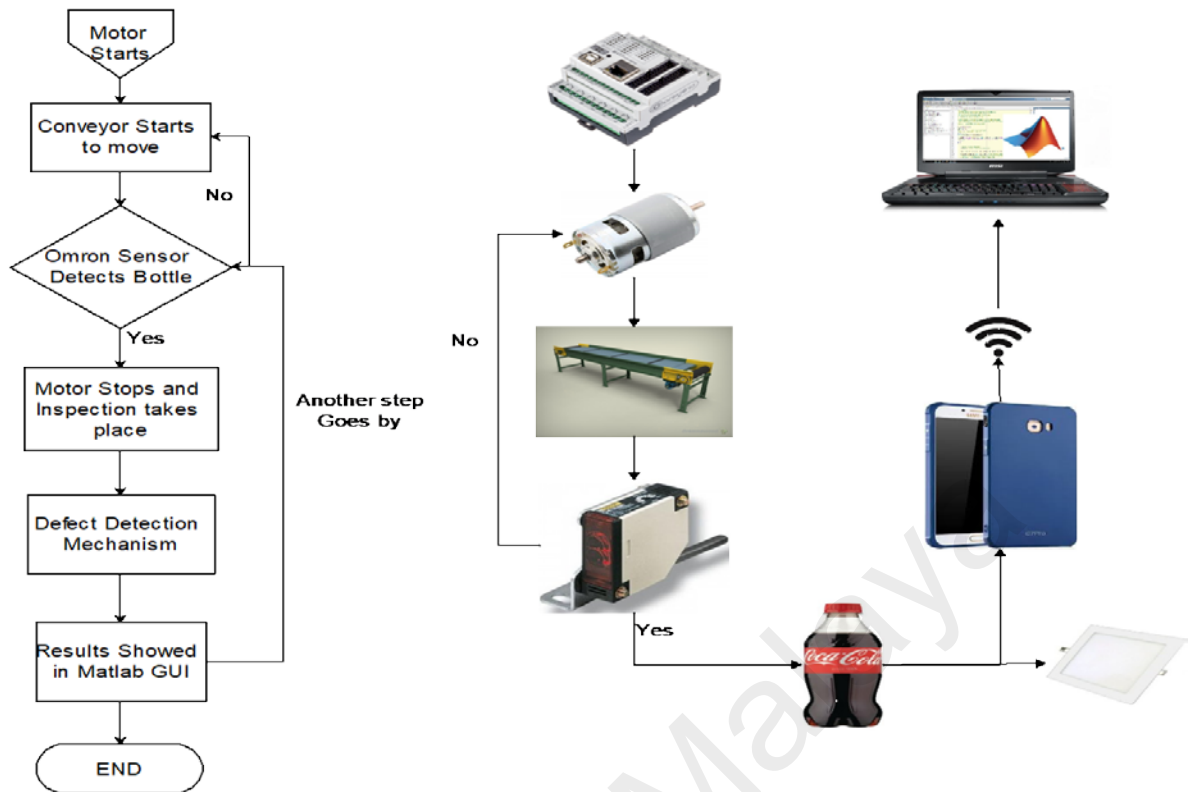
Figure 3.7: Block Diagram of the proposed project

3.7 Hardware Components of Inspection machine

A simple bottle filling and inspection process control system is a good way to understand the fundamentals of Programmable Logic Controllers, In this project the assembly line consists of a conveyor belt that is connected to a motor drive, Omron sensors, A main frame that is attached to the conveyor, Controllino, and Camera which is android cam and light source, the conveyor moves to one direction at a time with a bottle filled with contents and the presence of the bottle is captured by a sensor, which stops the motor to let inspection takes place, then process it in to the next cycle, and the process continues again and again until the system experiences further interruption.

1. Controllino

This technology is mainly discussed in chapter 2. It is a new device that functions as a PLC, based on Arduino Open Source Software Technology. They have all the functionality of a common Arduino, it usually has more inputs and outputs than a normal

PLC, as well as some features of Arduino, like the use of all its bookstores. (CONELCOM, 2017).

Supply voltage

The voltage terminal of the CONTROLLER manages different voltages, depending on the type of PLC. This device can operate with a rated voltage in the range of 12V or 24V and GND. Also, it is possible to supply the device with fixed voltages that do not affect due to misuse; among these, 10.8V to 13.2V and 21.6V to 26.4V.(Conelcom Gmbh,2016)

USB Connection

The USB connector has the ability to provide bidirectional communication between the Controllino PLC and the microprocessor. It is the important basis for programming the PLC from an Arduino or other programming interface. Its utility provides a USB to UART conversion that delivers a virtual COM port on the PC.(Conelcom Gmbh,2016).

RST button and LED

The Controllino, is equipped with important functions like the RST button. This has the task of providing a memory reset leading to start the program sequence from the beginning. It relies on the display of an LED that is lit when the button is operated and goes off when the RST has been performed.(Conelcom Gmbh, 2016)

ETH connector

ETH, it is a connector of the Maxi and Mega PLCs that allows the connection through Ethernet cable with reference Rj-45 to a network where it is paired with a computer, using a 1: 1 network cable. Through the WIZnet W5100 Ethernet Chip application, you can connect to LAN or the Internet without any inconvenience.(Conelcom Gmbh, 2016)

This Ethernet chip is paired to the SPI bus needed in a task with Arduino Ethernet Shield. In order not to present operational problems, you must have a Controllino library in the

Arduino IDE, in this way the Ethernet automatically starts up. In case you want to know or know the status of the port's functionality, we can validate by observing the green LED as active connection and yellow LED as indicator in the real data transfer.(Conelcom Gmbh, 2016)

Analog inputs (A0 ... Ax)

Controllino PLCs, are devices that bring multiple analog inputs, even, in a certain part digital is used to advance in the necessary solution. Next, the operation and characteristics of each option of the ports will be explained: (Conelcom Gmbh,2016)

Digital inputs (I ..)

This type of tickets are only for digital use. If a logical 1 is detected, the actuator or Ax LED will indicate that the service is active through that port. Otherwise, the LED will turn off. This type of information is interactive for the operator, since it allows you to quickly identify the current status of the entry.((Cameron Klotz,2017))

The following logic levels have been considered, depending on the logic supply voltage.

- 0 - 12V 0 .. 3.6V

- 1 - 12V 9 ..13,2V

- 0 – 24V 0 .. 7,2V

- 1 – 24V ..26,4V

Interrupt inputs (IN0 and IN1)

Controllino PLCs incorporate 2 important interrupt inputs for programming development. With these inputs, the programmer can measure the operations that come from the commutation and in this way, it would be understood as an electrical behaviour the

delivered value; but not only the value of the input is enough, you can also execute subroutines at the level of change of entries.(Conelcom Gmbh, 2016)

Digital output (D0 ..Dx)

For the digital reference outputs (High-Side-Switch) and Half-Bridge (only MEGA) has some markings with the symbology "D0 ..Dx "on the top of the Controllino housing. These terminals perform the switching of the voltage in the outputs and can be charged with 2A - 12V or 24V.(Conelcom Gmbh, 2016)

One of the great advantages of this type of PLCs regarding their outputs is that allows short-circuit protection and route the current in an autonomous. As with any circuit, it is important to consider dissipation or resistance to the passage of large currents. Controllino PLCs handle internal resistors of 70 mΩ when its operation is (High-Side-Switch) and 240 mΩ when determining Half-Bridge outputs (Conelcom Gmbh,2016)

Relay outputs

The relay outputs handle an ideal pairing to connect external circuits on ports R0 to RX.It is important to mention it switching current in a range of 6 to 250V AC or direct current from 6A to 30V.(Conelcom Gmbh,2016).

Pinheader connector (X1 .. X4)

The Pin-header connector will make it easier for the programmer to enter directly with the microcontroller. These entries vary according to their status, taking into account the relays. Important the level of power that will operate that should not exceed 5V. For added security, these pins will be protected against ESD (Cameron Klotz,2017).

RS485 interface

The RS485 interface, it is very important to the level of communication between P reference SN65HVD08 is able to communicate with other same RS485 feature receivers.

This type of protocol executes the communicates up to 32 receivers at a distance of up to 1200m. Additionally, RS to the UART (TXD3 / RXD3) of the Arduino ATmega2560 (Conelcom Gmb, 2016).

RTC (real time clock)

Each of the Controllino PLCs handles an internal clock in real time reference (hour, minute, second, day, month and year).This type of watch is 2123-C2-TA-QC-020.One of the great advantages, is that this RTC pu approximately for a period of 2 weeks in a row, without being connected to the power supply.(Conelcom Gmbh,2016)

2. **Photo-Electric Sensor**

This type of sensor used in this project is Compact Omron E3JK-R4M1 Retro-reflective photo Electric sensor which have adjustable sensing distance and can reach until 4 meters, 250VAC/24VDC 2.5A max relay contact output, in picture 3.8 below shows mechanisms of Retro-reflective and wiring cables, when beam is broken; White and Black wires are contacted together completing a circuit and White and Grey are opened, but usually gray is not normally used, and beam has 24VDC supplied to the Brown and Blue cables.

For applications such as industrial safety and automation, sensors such as optical sensors were used to automatically monitor the presence of objects in certain defined regions. In an example application type, optical devices pose transmitters that trigger light pulses to a specified region and a sensor that has the ability to detect if there are objects, using the reflected or scattered light beams from the obstacle.
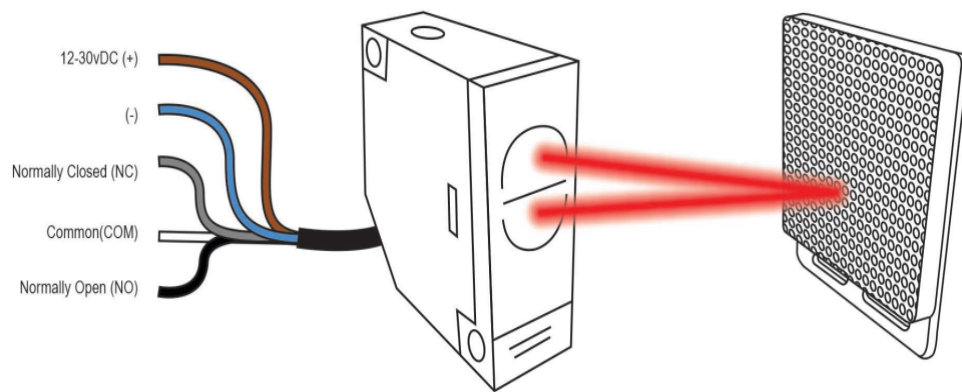
Figure 3.8: Working Mechanism and wiring (Fright-Props, 2015)

Light signals above a threshold level can be detected when an object is located in the monitored region as a result of reflecting or scattering transmitted light into the sensor, If light signals above a threshold are detected, however, the detected signals may be from sources of noise, such as neighbouring transmitters or lighting sources, rather than an object located in the monitoring region. Different methods and devices have been used to reduce the likelihood of false evaluation, e.g. determining that an object is in a monitored region if it is not due to noise (Stecker et.al, 2016).

Figure 3.9: Omron Photo-Electric Sensor and Reflector

In this sensor, we have a sensing mechanism as shown in the figure, turning the sensitivity adjuster clockwise (increase the sensitivity) until the indicator is turned ON, and define this adjuster position as (A). Remove the sensing object, turn the sensitivity adjuster clockwise until the indicator is turned ON by a background object, and define this position as (B). Turn the sensitivity adjuster counter clockwise (decrease the sensitivity) from (B) until the indicator is turned OFF and define this position as (C). The position in the middle of (A) and (C) is the optimum position. If the indicator is not turned ON by the background object at the maximum sensitivity, set the adjuster in the middle of (A) and maximum sensitivity. The sensitivity adjuster may be damaged if an excessive force is applied.
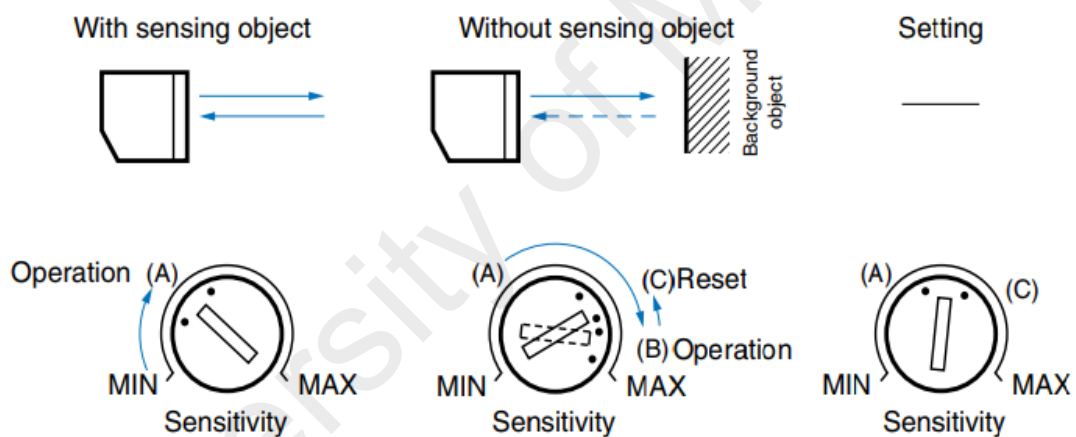
Figure 3.10: Sensitivity of the sensor

3. **Stepper motor**

Three components are required to operate the NEMA 17 stepper motor with a torque of 0.42 Nm: a DC power supply, an Arduino Uno microcontroller and a stepper motor driver module. In our case of selection was the accuracy and fast performance in each step that the motor should take after bottle is detected in the region and having a variety of frequencies needed to develop the experiment. Nema 17 shown in the figure 3.8 is 4 wired bipolar motor which has 1.8 degrees per step in accuracy and smoothing

while in motion and torque holding, this kind of motor has a maximum 1.7amps per-phase of current which means it can be controlled easily using stepper motor driver, Controllino maxi automation and external power supply
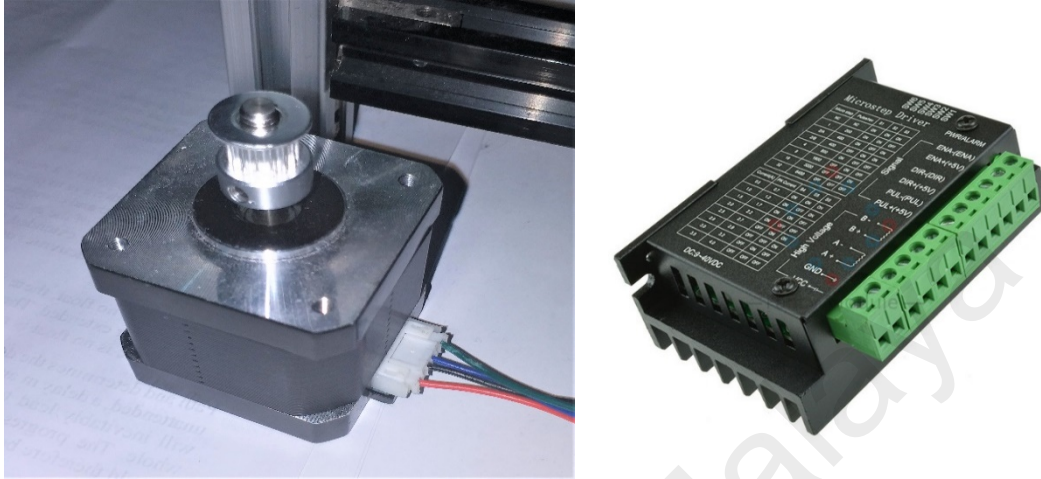
Figure 3.11: Nema 17 Stepper motor with teeth pulley and driver module (AliExpress, n.d)

4. Mobile Camera

One of the main part in this project is Camera device to transmit objects on the conveyor to the Matlab for inspection purposes, in here we have used this type of mobile camera which has 16 mega pixel camera, an app called Droidcam takes stream of images which then transmits it to the Matlab , the resolution of the Picture to be taken will be set at the coding section in the Matlab.

Figure 3.12: Samsung Galaxy C7 pro (FlipKart, n.d)

5. Main frame of the conveyor

In constructing the frame of the conveyor as shows in the figure 3.12, there are a lot of mechanical elements with different in lengths like Bearings, Belts, Aluminium profile extrusion frames, motor brackets, different types of screws and nuts, teeth pulleys, Light sources, timing belts, linear bearing shafts which are summarized in in the table below

Table 3.1: Materials needed in the conveyor frame

No	Brand Name	Quantity	Model	Size
1	Aluminium Profile extrusion frames	2	2020 extrusion T-slot	1000mm
2	Aluminium Profile extrusion frames	4	2020 extrusion T-slot	200/150 mm
3	Aluminium Profile extrusion frames	4	2020 extrusion T-slot	200mm
4	Aluminium Profile extrusion frames	2	2020 extrusion T-slot	100mm
5	T-Slot Nut		M5 Tnut/20AL	
6	T slot 90 degree inside (2020)	20	L-Shape type	
7	Motor Bracket	1	Nema 17	
8	8mm ball bearing with housing	8	KP08	
9	GT2 timing belt	2		280mm
10	Linear shaft	2		8mm x 300mm
11	Hex Allen screw	set	M5	
12	Hex Allen cap screws	20	M5	8mm
13	GT2 16 teeth pulley	1		5 mm
14	GT2 20 teeth pulley	2		8 mm
15	Conveyor belt	1		2 m
16	LED Panel Light	1	6" 18W	
17	Hex Allen wrenches	1		

Here are the assembly of the proposed mechanical parts of the conveyor mentioned in tables above with an area of 1000x200mm.

Figure 3.13: Assembled conveyor prototype

3.8 Software Specification

3.8.1 Arduino IDE

Arduino Integrated Development Environment IDE is a platform application that is used to write and upload codes to devices that has Arduino board compatibility, mainly designing this app its used and written in java language in the programming. With the help of third-party cores, it can also be used in other development boards like Controllino and many others by choosing the board you need from a selection you can easily write, compile and upload any codes. This software supports C/C++ using special rules when constructing a code.

Writing a code in Arduino IDE mainly lies in many series stages, first the platform requires library declaration compatible which the type of the project, second stage is providing common inputs and output procedures of the programming module, main

program loop or cyclic executive stage with the GNU toolchain and including the IDE distribution the code with an extension of *avrdude* is converted to executable code and compiled then a board needed to upload the code by not forgetting to choose the port of the board (Castro, 2015).

3.8.2 Matlab

Matrix Laboratory MATLAB is a Multi-programming language, Multi-operating system compatible platform started in the late 1970s, Matlab is a numerical computing platform that allows high order matrix operation, functional plotting of data and implementing algorithms and creating graphical user interfaces. Inside the platform we are going to (Ferreira, 2009).

3.9 Summary

Combined mechanical elements and Matlab image processing technique is discussed in this chapter, Conveyor system is designed to run a bottle on it using stepper motors and PLC Controllino, with photo electric sensors assisting to ensure the presence of the bottle in the field, if available mobile camera records real time videos then sends to Matlab series of frames for image processing, algorithms used in this inspection system is discussed in this chapter, the process continues after one inspection to another and counting is done if any of the bottle failed.

4.1 Introduction

To verify the validity and claims discussed and presented in previous chapter, in here we are considering the implementation, testing, the whole system components and connecting the all phases and implement them with each other using separate physical or hardware components and designing it with its vision system as we mentioned earlier and we will be discussing the results obtained from the system.

The figure below illustrates physical structure of Controllino based vision inspection system project in the state of image processing to analyse the properties of the bottle. In the coming sections we will discuss how this bottle passes in these simultaneous steps during line inspection and what mechanisms taken to ensure the quality of the bottle and its contents.

Figure 4.15: Bottle in the inspection process

4.2 System structure

Building a miniature industrial process replica is the main idea in implementing this project, in this particular case; constructing a line inspection system is the main area of this research environment for industrial automation using Controllino maxi automation which is industrialized Arduino-PLC grade that poses flexibility and open-source nature of the Arduino ecosystem. In designing geometric dimensions of the main frame more than 12 T slot nuts were used in construction process.

4.2.1 Transmission of motion

The main consideration in designing phase of this project was to have the least possible amount of mechanical elements, therefore in this system 1.8 meters length conveyor is running by a 0.42Nm 24V stepper motor, there are two 8mm, 5mm; 16 teeth pulleys and 6mm synchronous timing belt taking part sending mechanical rotations from the motor to run the conveyor. In order the conveyor get the rotations smoothly additional 8mm diameter bearings and 300mm length linear axis bearing shafts were attached to the main frame of the system as shown in the fig 4.2.
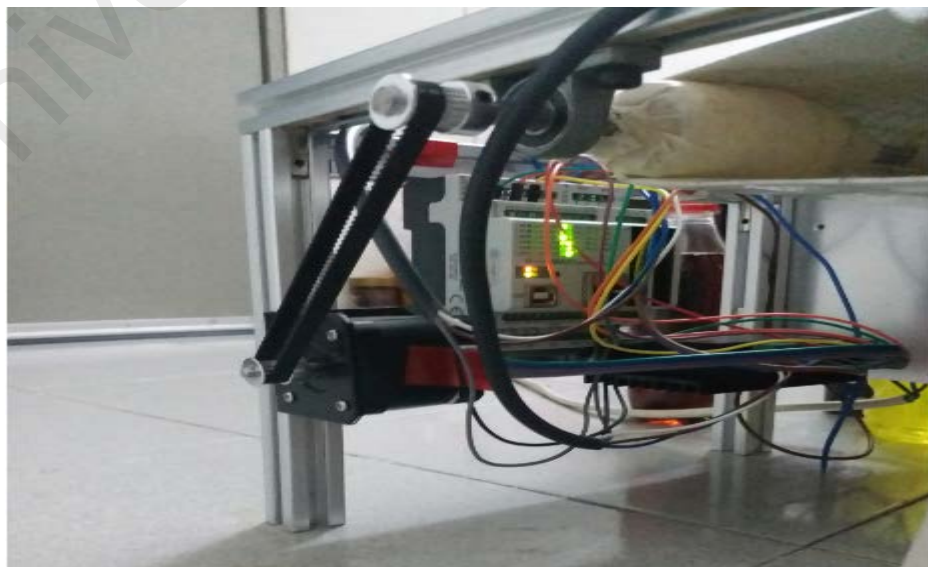

Figure 4.16: Shows transmission of motion from motor to conveyor

4.2.1.1 Modifying conveyor belt

To achieve best results in image processing and avoiding the use of additional tensioners, less weight, nearly elastic and lightly weighted while material is needed as a conveyor, plastic whiteboard is used here for a research purpose, this enhances and give us flat, stable and smooth surface in which the camera assumes as a background since it's a white colour and has a more robust in this project. The length and width of the belt was estimated to be less than the frame and not reach the bearings, so it will auto-tension, so 1.8meters in length and 0.25meters wide was implemented to satisfy this need.

4.2.2 Speed control and Controllino

Controlling the speed of the motor is the most important part of the transmission and rotation of the conveyor, we have used TB6600 driver module and Controllino to control each step and positioning of the motor, the stepper motor has 1.7amps which makes each phase to have 0.7amps the figure 4.3 shows the torque curve of the motor which can reach up to 2500 RPM, with the speed controller can handle and power up the motor up to 4amps.
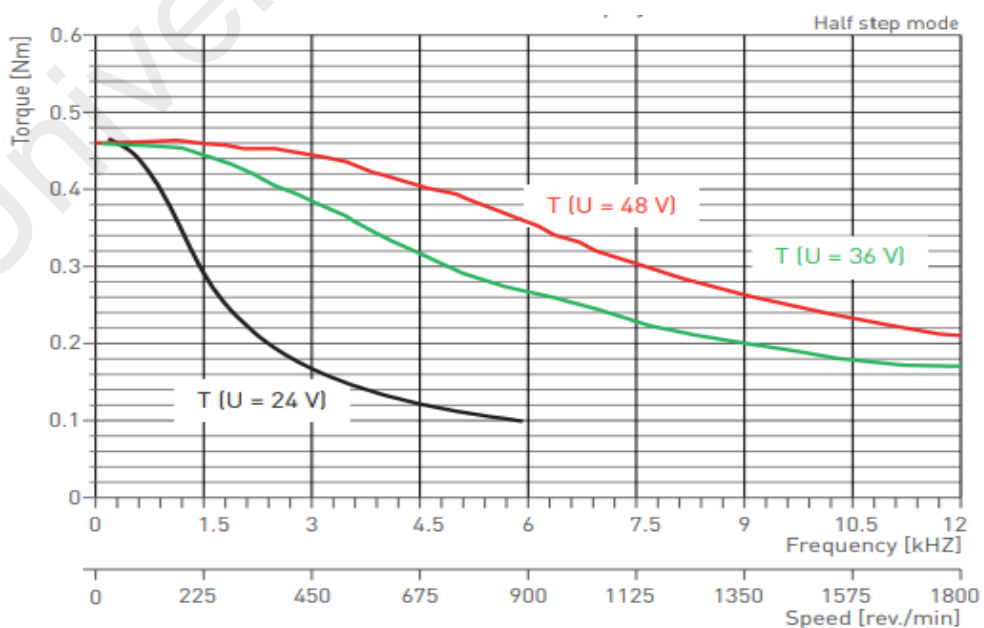

Figure 4.17: Frequency characteristics of NEMA 17 stepper motor (Phytron, 2017)

Controllino maxi automation was used for automating these tasks, the speed of the motor was set normally to be 0 to 300 RPM approximately, direction of the stepper motor is been set and controlled by the Controllino, to power up these devices (Controllino and TB6600 module) a 24 volts must be applied. Fig 4.4 below shows these devices in operational phase.

Figure 18.4: Controllino and TB6600 module in operation

4.2.3 Controlling the Photo-electric sensor

Detecting and controlling the position of the bottle is considered important part of the project. This type of sensor can have ability to detect within 200ms after turning it ON. Wiring Considerations Connection / Wiring The sum of load currents of L-ON output (NO) and D-ON output (NC) should be within 100 mA when using the DC transistor output type. The load short-circuit protection can be activated if the sum of load currents exceeds 100 mA. (The short-circuit load protection is reset by turning the photoelectric sensor's power off.)
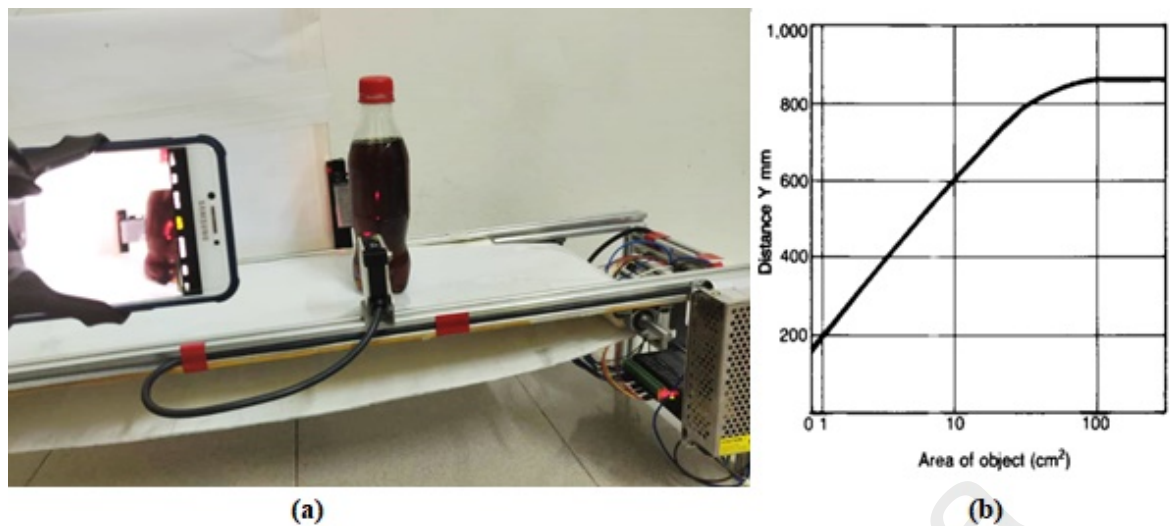
Figure 4.5: Photo Electric sensor (a) in operation, (b)Sensitivity of the sensor

To control the sensor, the direct input of the Controllino module allows it to be connected to any electronic device in which the logical level information that is delivered to this module. This type of Controllino has only 4 digital inputs, from DI0 to DI4, which means each 2 of these 4 inputs is connected to 1 sensor.

4.2.4 Programming the sensor and motor

At the beginning of the sketch we include the Controllino library and initialize the Controllino device library, then we jump into the setup to declare the outputs and inputs of the devices that is going to be connected to the Controllino, such as digital input pins if there is an incoming signal from the sensors and Digital output pins DIR which is connected to D0, Enable pin also connected to D2 and D4 is connected to Pulse or Step pin of the stepper motor driver that runs the motor,

In the loop section we enable the motor to move in a forward direction by sending 200 pulses for making one full cycle rotation, it is proposed to turn on and off an output of the module in this case with an ignition delay of 1000 milliseconds and a shutdown delay of 500 milliseconds. end a pulse train in the D0 output. we used if else statements

to control the motor if sensor senses bottle, which makes the motor to delay 2 seconds for inspection purpose, then motor runs again until another sensor detects the bottle which reverts the direction of the motor; but in industrial another step goes by which we didn't cover in this project.

4.3 Visual measurements

In this section, different algorithms for defect detection are used on a streaming video, with a resolution of 640x480 and series of frames or pictures taken with in microseconds, we are able to construct series of algorithms to detect and track presence of a bottle in the region, extraction and analysis are made to decide the properties of the bottle in the Region of interest, the figure below shows the prototype of the developed system's graphical user interface which is figured out results of the photos taken by the camera during inspection.
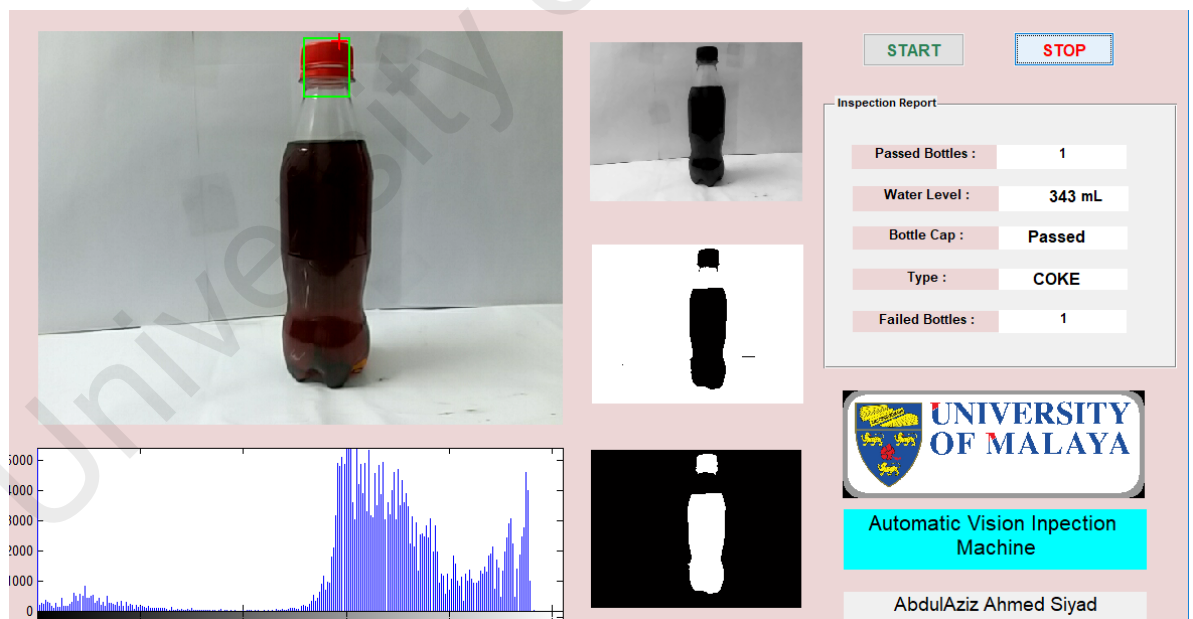

Figure 4.6: Passed bottle report of the inspection system

For performance evaluation, a combination of foreground detection and blob analysis will be analysed. These methods are designed to overcome specific problems

related to the different methodologies. The systems are tested to detect and count properties of the bottles passing by.

Then, experiments are performed on these three data sets for evaluating the parameter sensitivity and performances of the ROI localization and defect detection. Experiments are conducted on a computer equipped with an Intel(R) Core(TM) i3-2848M (2.3GHz) and 4 GB of memory, it's highly recommended using other updated alternatives to achieve flexibility and get accurate results. The program is implemented in Matlab.

4.3.1 Image filtering and segmentation

After image is captured in milli seconds or lesser, image frame is clustered into three layer RGBs, then filtering takes place using *imopen* function in order to perform binary image with structuring element *strel* or SE, this element must be a single structuring element for example in this occasion we used '*diamond*' which creates flat, diamond structured element to oppose as an array of objects. The morphological open operation is an erosion followed by a dilation, using the same structuring element for both operations. The fig 4.7 below shows after this simultaneous operation to convert the snapped image to binary. Which shows a lot of noises in the neck of the bottle being formed in the snapping process which later to be removed.

Figure 4.7: Inspection before noise removal

4.3.2 Noise removal

Usually, any picture taken can experience noise or unwanted defects that is not the exact properties of the object, after we have filtered and segmentation takes place, the bottle in fig 4.7 shows the results which has tiny pixel of noises, in order to remove that we use *beawareopen* statement to small objects from binary image in fig 4.7 above. This function removes from a binary image all connected components (objects) that have fewer than any desired area pixels, producing another binary image which noise is less than the original. This operation is known as an area opening. The default connectivity is 8 for two dimensions, 26 for three dimensions, and conndef(ndims(BW), 'maximal') for higher dimensions.
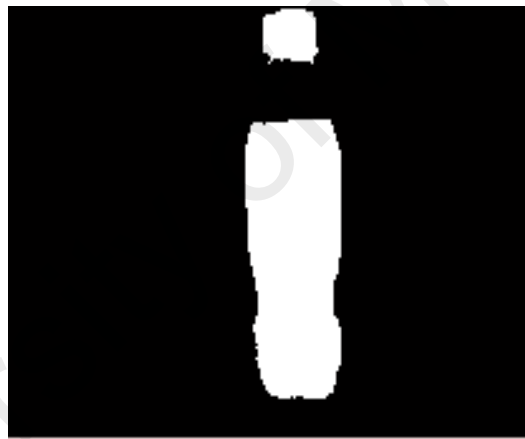

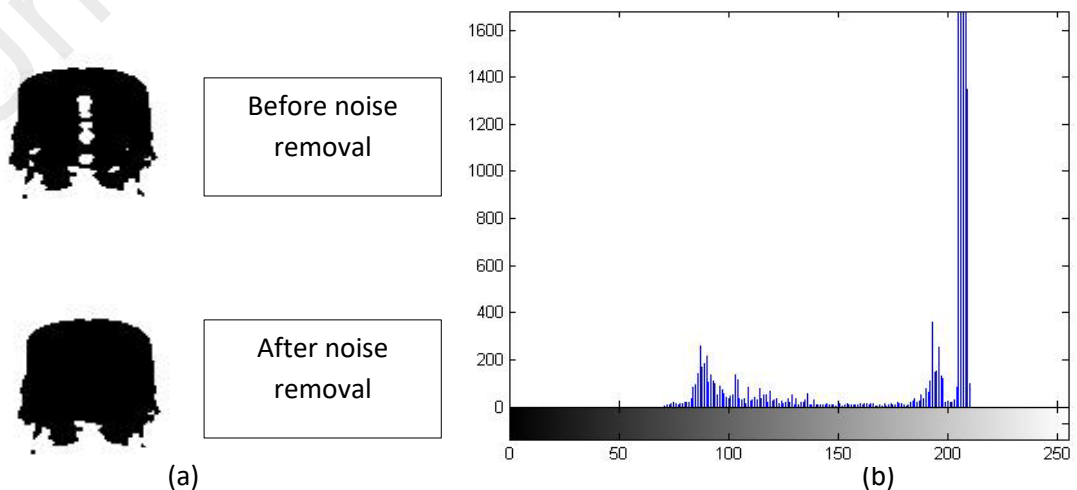**Figure 4.8: Binarized image after noise removal**

(a)   (b)

Figure 4.9: Bottle cap (a)Before and After noise removal (b) histogram of the cap

4.3.3 Blob analysis

Blob analysis is a procedure for extracting pixels of connectivity or pixels in a binary image region. The pixels are divided into black and white by calculating the object's position and size. Extraction also processes the position of the object moving. The Blob Analysis object computes statistics for connected regions in a binary image.

Using the binarized image in the above step we have used blob analysis to compute and return statistics of the binary image above to extract the properties by choosing some property parameters specified in the code.

The fig 4.10 below shows is the histogram that is a graphical representation of the figure after blob extraction has been made the horizontal axis is the tonal variation of the image, whereas the vertical represents the numbers of pixels in each particular tone. The black and dark areas are represented by the left side of the horizontal axis, the middle is medium gray and the right side represents light and pure white areas. The vertical axis is the size of the area captured in each of these areas. This type of histogram composes few dark areas which are the contents of the bottle and bottle cap which makes shadows of the 1700pixel left site the contents of the bottle and cap of the bottle will have most of its data points on the right side and centre of the graph.
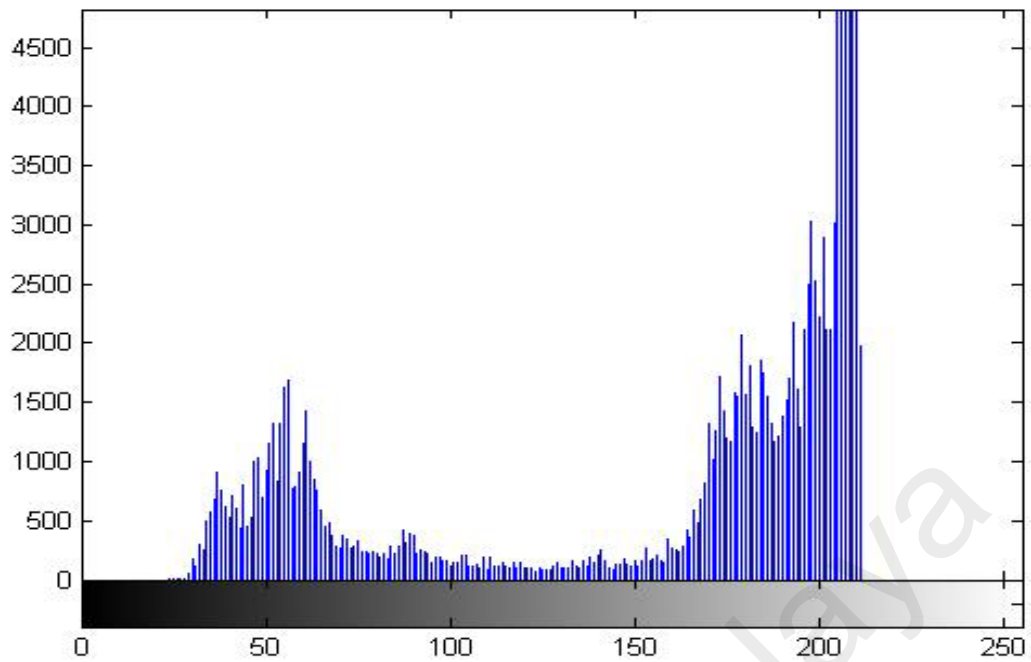
Figure 4.10: histogram of the image after blob analysis

4.3.4 Feature Extraction

In this section we are going to extract the results of the bottle inspected which is the crucial part of the project, we will discover how are going to distinguish correct bottle from the deformed bottles and how can we discover if there are no bottle present at that moment, and what would happen if the streaming is experienced additional non-invited pixels coming such as other huge objects in the area which sometimes if avoided can cause inaccuracy in the inspection results.

After noise removal and blob analysis, image is clustered to find the properties of specified region, in this occasion cap and below neck of the bottle is figured out. By putting bottle related parameters to the Matlab code, including the type of the bottle, cap, level of the contents, for example finding water level we used if area of the bottle is greater than 32000 'Bottle is passed' else fail, likewise in the cap if the area of the cap is between 2000 and 4000 the bottle would be recognized to have a cap available else no cap is detected. These results are showed in the inspection part of the GUI as in fig 4.13 below.

Figure 4.11: inspection report section

In figure 4.6 shows the results of a bottle which after series of algorithms met shows that the bottle is passed, also the fig 4.12 below shows that the bottle encountered some dark shadow caused by the bottle which blob analysis has detected and removed the noise which finally doesn't impact or change the results and the properties of the bottle are detected. The fig 4.12 also shows that the bottle doesn't have any cap at all, which then displays in the report area that cap is "Missing".
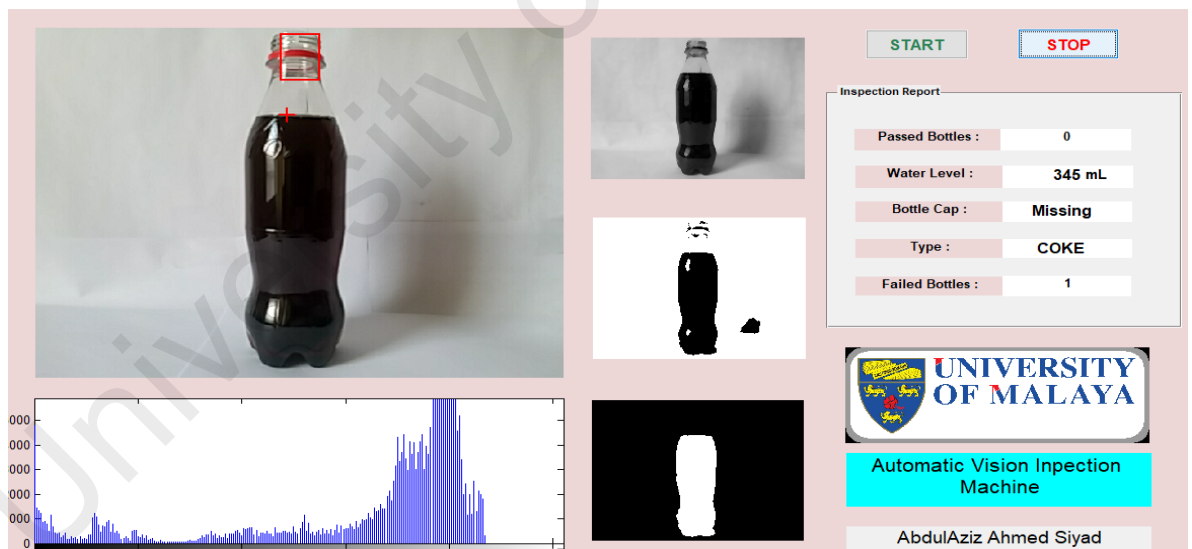

Figure 4.12: Failed bottle cap of the inspection system

Similarly, the fig 4.13 shows that the water level is less than the parameters we set on previously in the code, also cap were not present either. This system can detect one bottle

at a time which makes counting of bottles to count after inspection of each report whether they failed or passed, so in the figure failed bottles shows three.
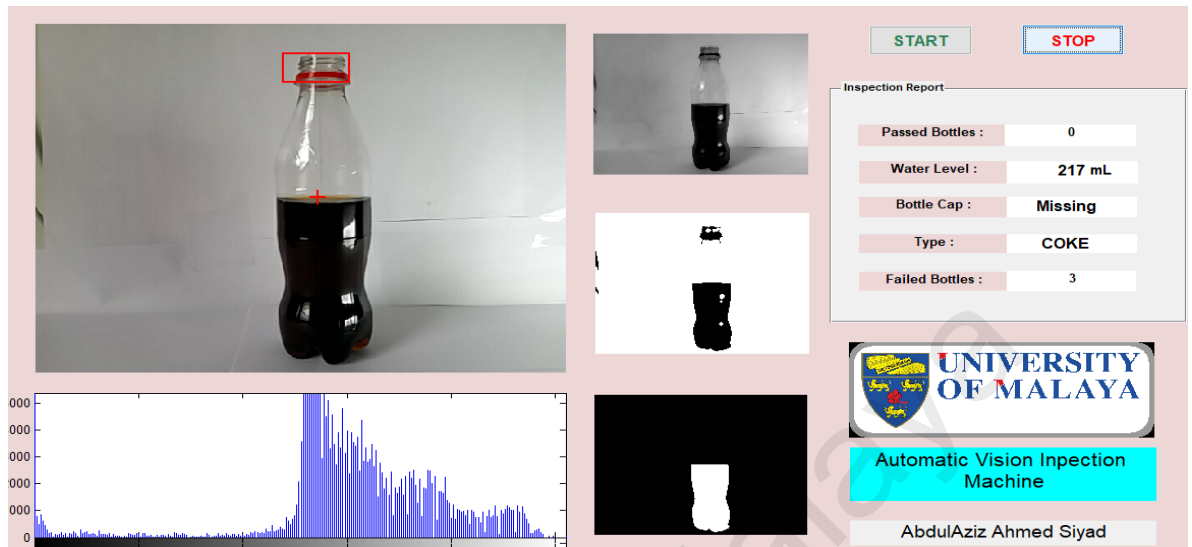
Figure 4.13: Failed bottle cap and water level

Here we have another bottle in fig 4.14 which after inspection shows the presence of a cap in the region which previously had a lot of noise coming from the left side of the image then removed after noise removal and blob analysis is done. In the results it lacks the level of the water which finally becomes not acceptable and failed bottle is counted in the inspection report panel.

Figure 4.14: Passed cap and failed water level

Table 4.1: The defect detection results

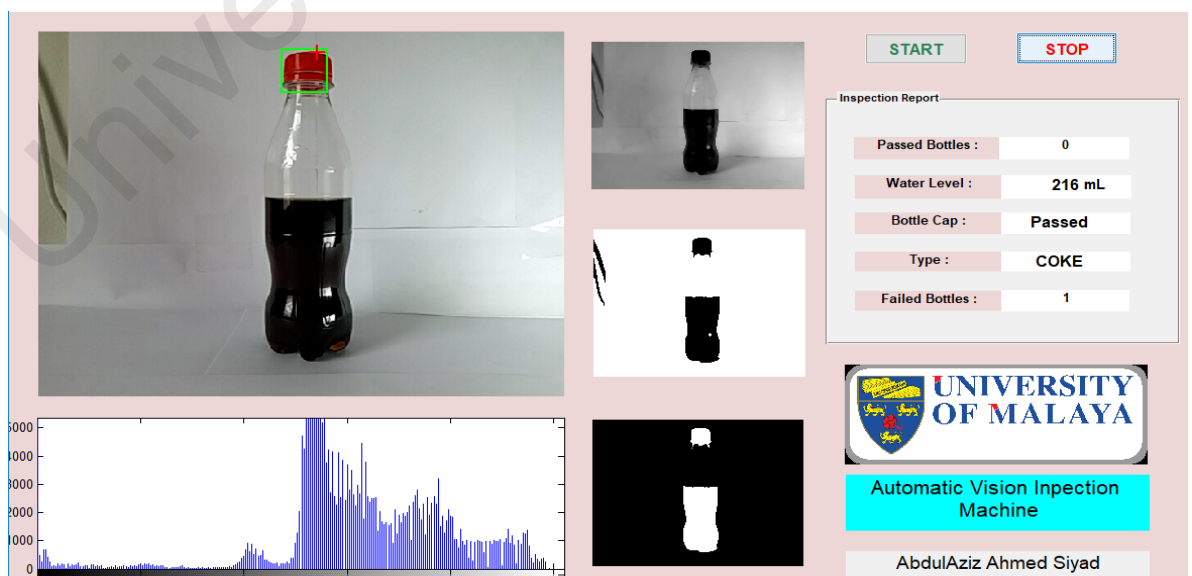| Detection of bottles	Actual level of bottle	Result in Matlab	Success rate %	False detection rate %	Cap
No bottle	0	No bottle detected	0	0	0
Bottle	330	343	96.21	3.79	Passed
	330	345	95.65	4.34	Missing
	211	217	97.22	2.76	Missing
	211	216	97.68	2.31	Passed
Hand or object detection	0	Please remove the Obstacle	0	0	0

4.4 Summary

Greater requirements for smooth running and precision are often necessary, especially in line production. Accurate and consistent movements with fast settling times of the driven system are significantly improved

With the implementation of the Controllino PLC module with Image vision system, it was proved that the systems when subjected to laboratory practice, they are extraordinary in the construction of knowledge dedicated to science. This allows implementations with a more optimal degree of efficiency and with the necessary requirements of automation and control; so, the gaps to the development of mechanisms without restrictions, allow the development of good ideas, mostly, universities.

Image vision system is implemented using variety of algorithms to analyse and detect the properties of a bottle which finally shows series of advantages which can enhance the performance of this system can have in the industry. Video streaming were used in this inspection system which makes a lot of critical and vulnerable to noise and other objects in the area which can impact the performance of the system which is

49

challenging to find properties of fast moving object and find its defects which in short period of time, we have used mobile camera for this inspection as a camera source; connected wirelessly to its Matlab using single wireless network.

As a result, one of the system algorithms is the subtraction method of the background. The background subtraction was applied to their research, which set background for excellent results, according to the researchers. The algorithm of the system also applies optical flow for a robust background that supports tracking correction. The results also suggest that the human video tracking system is accurate when the camera is set to the right location, certain background, proper distance between camera and human, separate human, and proper light.

The constant development of automated systems and the new era of less robust devices in scheduled tasks. They help us to generate solutions with the highest protection and quality against industrial needs; where the strengths dedicated to research by means of modern PLCs like Controllers. They become a necessity in institutions where the professionals in course, need to foment a creativity in front of the challenges of the daily life; or before the resolution of problems encountered in the development of their learning.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The overriding purpose of this research was to design and implement Automatic vision inspection system using PLC based Controllino to find and inspect the quality and properties of a beverage bottle using many algorithms for defect detection and noise cancellation in the video streaming and the results were shown using Matlab GUI.

Related to that study it became vital to understand the nature of the vision system in technological literacy and prospective, to ensure that we can build such a project, implementation could be perceived and measured as a viable component. Once these fundamental steps had been accomplished, it was possible for this research to continue until its success.

A research with PLC Controllino maxi automation, teaches us the importance of control over the physical and virtual platforms that have adverse uses. Having great compilation of sentences focused on researching new compatible languages such as: flow diagrams, source codes in C++, or structured texts that are not easy to understand or associate; besides being able to discard the ambiguous use of PLCs that has no other alternative in the programming with block diagrams or they are only elaborated for comply with a standard defined by the manufacturer.

To provide for the possibility that we can construct such a project could be perceived and measured implementing as a viable component. Once these fundamental steps were achieved, this research was able to go forward until its success.

5.2 Major Findings

In starting every study or a project, it should have objectives that is to be reached and goals being met after all it has done. This project used some objectives for the

establishment until implementation to reach those objectives. This project had a various objective they are:

1. Design a webcam-based inspection system via Matlab to inspect bottle arrived at the position determined in the conveyor

The goal of this objective was to design wireless camera attached to the Matlab, that can detect live and stream of frames from a vision field and its almost reached, we have used Droidcam app to send stream of images to code and then image enhancement process starts to eliminate the unwanted objects in the image using variety of algorithms from filtering, noise removal, using blob analysis. In order to get the best results; one important thing to remember is the distance between the camera and the bottle which must be constant for this study we took 20cm. we have avoided too much noise in the field by taking white background that makes us easy to separate the bottle from the background or other noise in the area.

2. Implement a conveyor line that works with a Stepper motor with Omron sensors to detect visibility and the position of the bottle.

In this part we have implemented a whole system of a conveyor that contains Controllino PLC Module, mainframe, conveyor belts, sensors stepper motor, power supply, cameras and other mechanical elements, which the results we have get was accurate, we have set the speed of the motor by using Industrialized Controllino and Stepper motor drivers to control the currents and the steps in the motor, in sensor part we have used Photo-Electric sensor to detect the presence of the bottle in the field, if it detects, the sensor sends signal to the motor to stop for image processing purposes, after two seconds the bottle moves again until another sensor detects to stop the stepper motor.

3. To detect and analyse the properties of the bottle's cap, water level, and count the defected and passed bottles.

After removing the unwanted noises caused by reflection of light and shadow in image acquisition, the third final objective was bottle extraction to extract the properties of the bottle and then finding the whether the bottle have defects and less than parameters we have set it on, like the cap, measuring water level, type of the bottle and counting passed and failed bottles, the results we have got is almost accurate and the quality of your results depends on the wireless network and constant distance and stability between the camera and the bottle, however our results had ±3 tolerance, which came from the background and light sources.

4.3 Recommendations and future work.

Although the goal of the project was mostly covered, further researches can be aimed by developing and enhancing some of the shortcomings of the current simulations and extending the ideas explored here to address several other relevant projects in emerging modern vision inspection system and replacing conventional PLCs with Controllino since they are more features and flexibilities.

Finally, its recommended using variety of different algorithms for feature extraction to get better results, also object prediction multiple gaussian mixture models in order to remove additional unwanted moving objects in the video that are not part of the foreground bottles which is moving in a constant velocity.

References

Ali, M. S. R., & Pal, A. R. (2017, December). Multi machine operation with product sorting and elimination of defective product along with packaging by their colour and dimension with speed control of motors. In *2017 International Conference on Electrical, Electronics, Communication, Computer, and Optimization Techniques (ICEECCOT)* (pp. 1-6). IEEE.

Ardi, S., & Abdurrahman, H. (2017, October). Design of pokayoke systems to increase the efficiency of function check oxygen sensor machine using programmable logic controller in manufacturing industry. In *2017 4th International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE)* (pp. 192-196). IEEE.

Babiker, M., Khalifa, O. O., Htike, K. K., Hassan, A., & Zaharadeen, M. (2017, November). Harris corner detector and blob analysis featuers in human activty recognetion. In *2017 IEEE 4th International Conference on Smart Instrumentation, Measurement and Application (ICSIMA)* (pp. 1-5). IEEE.

Bahaghighat, M., Mirfattahi, M., Akbari, L., & Babaie, M. (2018, March). Designing quality control system based on vision inspection in pharmaceutical product lines. In *2018 International Conference on Computing, Mathematics and Engineering Technologies (iCoMET)* (pp. 1-4). IEEE.

Bargal, N., Deshpande, A., Kulkarni, R., & Moghe, R. (2016). PLC based object sorting automation. *Int Res J Eng Technol (IRJET)*, *3*(07).

Bedruz, R. A., Sybingco, E., Bandala, A., Quiros, A. R., Uy, A. C., & Dadios, E. (2017, December). Real-time vehicle detection and tracking using a mean-shift based blob analysis and tracking approach. In *2017IEEE 9th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM)* (pp. 1-5). IEEE.

Campos, M., Ferreira, M., Martins, T., & Santos, C. (2010). Inspection of bottles crates in the beer industry through computer vision. IECON Proceedings (Industrial Electronics Conference), 1138–1143. https://doi.org/10.1109/IECON.2010.5675529

Cha, Y. Y. (2016). A position decision of photo sensor using a PZT nano positioning stage. *Journal of Institute of Control, Robotics and Systems*, 22(4), 271-275.

Cruz, M., & Anticlia, D. (2017). *Diseño de modulo con contraladores logicos programables para la enseñanza-aprendizaje de electronica para los estudiantes de la Carrera de Ingenieria en Sistemas Computacionales* (Bachelor's thesis, JIPIJAPA-UNESUM).

54

De Castro Rivera, A. S., Canchila Aguirre, F. A., & Anaya Pineda, A. A. (2017). Diseño e implementación de un módulo de entrenamiento de automatización y control utilizando PLC Controllino, programado en Lenguaje C, para actividades prácticas en los laboratorios de electrónica de la Universidad Cooperativa de Colombia sede Santa Marta.

Fang, J., Wang, Y., & Wu, C. (2013). Binocular automatic particle inspection machine for bottled medical liquid examination. *Proceedings - 2013 Chinese Automation Congress, CAC 2013*, 397–402. https://doi.org/10.1109/CAC.2013.6775767

George Mathew ; Jaina George ; J. Jaya ; S. Janardhana ; K. J. Sabareesaan. (2013). Computer Aided Visual inspection : A Review, 105–109. https://doi.org/10.1109/ICCTET.2013.6675921

Huang, B., Ma, S., Wang, P., Wang, H., Yang, J., Guo, X., … Wang, H. (2018). Research and implementation of machine vision technologies for empty bottle inspection systems. *Engineering Science and Technology, an International Journal*, *21*(1), 159–169. https://doi.org/10.1016/j.jestch.2018.01.004

Han, K. T. M., & Uyyanonvara, B. (2016, March). A survey of blob detection algorithms for biomedical images. In *2016 7th International Conference of Information and Communication Technology for Embedded Systems (IC-ICTES)* (pp. 57-60). IEEE.

Indrabayu, B., Achmad, A., Nurtanio, I., & Mayasari, F. (2015). Blob modification in counting vehicles using gaussian mixture models under heavy traffic. *ARPN Journal of Engineering and Applied Sciences*, 7157-7163.

Kumchoo, W., & Chiracharit, W. (2018, February). Detection of loose cap and safety ring for pharmaceutical glass bottles. In *Electrical, Electronics, Computer and Telecommunications Engineering (ECTI-NCON), 2018 International ECTI Northern Section Conference on* (pp. 125-130). IEEE.

Li, F., Hang, Z., Yu, G., Wei, G., & Xinyu, C. (2017). The Method for Glass Bottle Defects Detecting Based on machine vision, 2–5. https://doi.org/10.1109/CCDC.2017.7978567

Morón, C., Diaz, J., Ferrández, D., & Saiz, P. (2018). Design, Development and Implementation of a Weather Station Prototype for Renewable Energy Systems. *Energies*, *11*(9), 2234.

Muthugnanambika, M., Bagyammal, T., Parameswaran, L., & Vaiapury, K. (2018). An Automated Vision Based Change Detection Method for Planogram Compliance in Retail Stores. In *Computational Vision and Bio Inspired Computing* (pp. 399-411). Springer, Cham.

Nunes, P. C. (2017). *Desenvolvimento de unidade digital de controlo auxiliar para baterias de condensadores* (Doctoral dissertation, Instituto Superior de Engenharia de Lisboa).

Ohmae, S., Gondo, K., & Iida, Y. (2015). *U.S. Patent No. 8,947,652*. Washington, DC: U.S. Patent and Trademark Office.

Ovhal, K. B., Patange, S. S., Shinde, R. S., Tarange, V. K., & Kotkar, V. A. (2017, December). Analysis of anomaly detection techniques in video surveillance. In *2017 International Conference on Intelligent Sustainable Systems (ICISS)* (pp. 596-601). IEEE.

Peltonen, M. (2017). PLC Virtualization and Software Defined Architectures in Industrial Control Systems.

Perticone, D., & Foland, A. D. (2018). *U.S. Patent Application No. 15/986,422*.

Prabuwono, A. S., Usino, W., Yazdi, L., Basori, A. H., Bramantoro, A., Syamsuddin, I., ... & Allehaibi, K. H. S. (2019). Automated Visual Inspection for Bottle Caps Using Fuzzy Logic.

Rahman, N. A., Saad, N. M., Abdullah, A. R., & Wahab, F. A. (2018). The internet of things beverages bottle shape defect detection using Naïve Bayes classifier. *International Journal of Human and Technology Interaction (IJHaTI)*, *2*(1), 71-76.

Ramalingam, S., & Varsani, V. (2016). Vehicle Detection for Traffic Flow Analysis. *2016 IEEE International Carnahan Conference on Security Technology (ICCST)*, 1–8. https://doi.org/10.1109/CCST.2016.7815693

Saad, N. M., Nabilah, N., Abdul, S., & Abdullah, A. R. (2017). Shape Defect Detection for Product Quality Inspection and Monitoring System, (September), 19–21.

Sanver, U., Yavuz, E., & Eyupoglu, C. (2017, February). An image processing application to detect faulty bottle packaging. In 2017 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus) (pp. 986-989). IEEE.

Sharma, S., Krupa, K. V., Gandhi, R., Jain, A., & Shah, N. (2015). Empty and Filled Bottle Inspection System. *Image Video Process*, 1122-1126.

Singh, A., Kumar, R., Tripathi, R. P., & Arya, U. (2016, February). Vehicle Target Area and Tyre Detection Image Processing Technique. In *2016 IEEE 6th International Conference on Advanced Computing (IACC)* (pp. 368-371). IEEE.

Singh, A. K., & Ali, M. S. R. (2017, April). Automatic sorting of object by their colour and dimension with speed or process control of induction motor. In *2017*

International Conference on Circuit, Power and Computing Technologies (ICCPCT) (pp. 1-6). IEEE.

Stecker, J. A., Carlsten, K. D., & Anderson, D. S. (2016). *U.S. Patent No. 9,507,049*. Washington, DC: U.S. Patent and Trademark Office.

Xie, H., Lu, F., Ouyang, G., Shang, X., & Zhao, Z. (2017, December). A rapid inspection method for encapsulating quality of PET bottles based on machine vision. In *2017 3rd IEEE International Conference on Computer and Communications (ICCC)* (pp. 2025-2028). IEEE.

Xu, M., Ma, Y., & Chen, S. (2017, July). Research on real-time quality inspection of PET bottle caps. In *2017 IEEE International Conference on Information and Automation (ICIA)* (pp. 1023-1026). IEEE.

Yang, Z. (2015). Vial Bottle Mouth Defect Detection Based on Machine Vision. 2015 IEEE International Conference on Information and Automation, (August), 2638–2642. https://doi.org/10.1109/ICInfA.2015.7279730

Yazdi, L., Prabuwono, A. S., & Golkar, E. (2011, June). Feature extraction algorithm for fill level and cap inspection in bottling machine. In Pattern Analysis and Intelligent Robotics (ICPAIR), 2011 International Conference on (Vol. 1, pp. 47-52). IEEE.

Zhang, G., Liu, J., Tian, L., & Chen, Y. Q. (2016, March). Reliably detecting humans with rgb-d camera with physical blob detector followed by learning-based filtering. In *2016 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)* (pp. 2004-2008). IEEE.

Zhou, X., Wang, Y., Xiao, C., Zhu, Q., Lu, X., Zhang, H., ... & Zhao, H. (2019). Automated Visual Inspection of Glass Bottle Bottom With Saliency Detection and Template Matching. *IEEE Transactions on Instrumentation and Measurement*.