PLC and image processing based segregation of objects using pneumatic control system

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A project report submitted in partial fulfillment of the requirements for the Degree of
Bachelor of Technology
(Electronics Engineering)

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CERTIFICATE

This is to certify that the work contained in this report titled "PLC and image processing based segregation of objects using pneumatic control system" has been carried out by Himanshu Sharma and Adhish Dubey under my supervision and has not been submitted elsewhere for a degree.

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ABSTRACT

The project work considers the application of PLC and image processing in automation industries as a machine vision system to control the segregation, and other pressing related operations as per the input given to the image processing device (USB Camera in our case). The project involves the acquisition of the image, comparison of the acquired image with the already stored image and then to process a signal of either a high voltage or null. Using this signal, the actuation of the PLC operations such as segregation operations can be achieved. The significant use of the work done is in the automation industries which is thus helpful in freeing people for other pursuits by automating all such processes and accuracy of the machine vision systems is definitely much better than manual operations. The project work is not only limited to the segregation operation but also to condition the signal is of prime importance as the signals generated out from the image processing device should be sent to the PLC machine and PLC only take electrical signals of 24V whereas the sound signal generated from the system is in milli volts, thus the interfacing needs a signal conditioning circuit. As the power, frequency ratings of generated signal and the desired signal differs in voltage ratings, thus it is needed to condition the signal before sent to the machine vision system for the operation.

Object sorting using machine vision is accomplished using pattern matching algorithm of machine vision. A pattern image template was created and stored into the memory of computer. When the object sorting application runs, the camera acquires the image of the object into MATLAB. The vision application analyses the image, and sends an electrical signal to the sorter if the acquired image matches the template image. In addition, the communication between the PLC and MATLAB is enabled using the sound signal.

CHAPTER 1
INTRODUCTION

1.1 Introduction

- **Machine vision (MV)** is the technology which is utilized to provide imaging-based automatic analysis and its inspection for applications like automatic inspection, its processing, and guidance of machines in industry. The scope of Machine Vision is very vast..

- **Automation** is the utilization of various control systems for operating equipment's machinery, processes in factories, boilers and heat treating ovens, switching in telephone networks, steering and stabilization of ships, aircraft and other applications with reduced human intervention. Some processes have been completely or partially automated.

The major advantage of automation is that it saves human force; however, it is also used to save power and materials and to improve quality, accuracy and precision.

Benefits of automation increases when Machine Vision Systems operate the automation industry as the systems having vision on the system can operate the machines with greater accuracy, no biasing and problems of defects in output products and results can be reduced. Not only this but machine vision system is right now following the concept of artificial intelligence by freeing people for other pursuits and making the automation more reliable and error free.

1.2 Aim

The aim of our project is to segregate the objects using machine vision system where the segregation is done as per the image captured in the camera (whether the image is desired or rejected). The project involves two process, first process is the image processing and the second process is the segregation process which is done using PLC. And then the interfacing is done between both the processes. The image processing steps include acquisition of the image, compare it with the already stored image and then to process it to generate an audio tone or signal, which will be further used to generate an input to the PLC input port and the segregation process is achieved. The sound signal is needed to be converted to an electrical signal using a signal conditioning circuit.

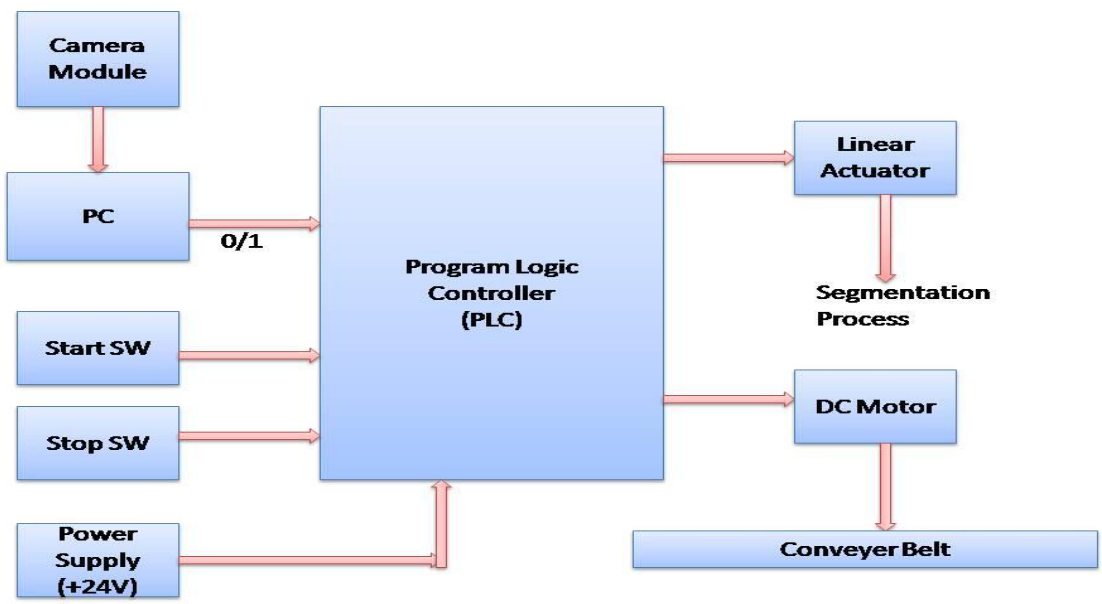


Fig1 : Block Diagram representation

1.3 Why Machine Vision Systems Important to study

Today, Automation Industry has acquired almost all the industries with a single aim to operate and achieve target with greater accuracy and zero biasing. In present time when it's pretty much important for all the industries to become the top brand it's important to give their products proper finishing and no or very small difference between the products of the same brand. So it is an advantage to work in industries more smoothly if a fresher or a trainee is well aware of the automation systems steps and it's configurations. Machine Vision system is a system which simply adds a feature to the automation which does not require manual supervisors to keep an eye on the operations of the machines and thus such systems are now eliminating the manual segregators from the segregation industries and supervisors from all automated and automobile industries.

1.4 Evolution of MV Systems

Machine Vision is a branch of computer science that has really grown over the last 20 years to become an important feature of manufacturing. Today machine vision systems provide greater flexibility and further automation options to manufacturer's, helping to find defects, sort products and complete a number of tasks faster and more efficiently than humans alone ever could. But how did this important and growing technology start? Here is a quick timeline of the key events leading to machine vision as we know it today:

1. **1950's** – Two dimensional imaging for statistical pattern recognition developed: Gibson introduces optical flow and based on his theory mathematical models for optical flow computation on a pixel-by-pixel basis is developed.

2. **1960's** – Roberts begins studying 3D machine vision: Larry Roberts wrote his PhD thesis at MIT on the possibility of extracting 3D geometric information from 2D views in 1960. This lead to much research in MIT's artificial intelligence lab and other research institutions looking at computer vision in the context of blocks and simple objects.

3. **1970's** – MIT's Artificial Intelligence Lab opens a "Machine Vision" course – Researchers begin tackling "real world" objects and "low-level" vision tasks (i.e. edge detection and segmentation: In 1978 a breakthrough was made by David Marr (at the MIT AI lab) who created a bottom up approach to scene understanding through computer vision. This approach starts with a 2D sketch which is built upon by the computer to get a final 3D image.

4. **1980’s** – Machine vision starts to take off in the world of research, with new theories and concepts emerging: Optical character recognition (OCR) systems were initially used in various industrial applications to read and verify letters, symbols, and numbers. Smart cameras were developed in the late 80’s, leading to more wide spread use and more applications.

5. **1990’s** – Machine vision starts becoming more common in manufacturing environments leading to creation of machine vision industry: over 100 companies begin selling machine vision systems. LED lights for the machine vision industry are developed, and advances are made in sensor function and control architecture, furthering advancing the abilities of machine vision systems. Costs of machine vision systems begin dropping.

1.5 MACHINE VISION TODAY

Today machine vision systems continue to move forward. 3D systems that scan products running at high speeds are becoming affordable, and systems that do everything from thermal imaging to slope measurement can be readily found. Machine vision continues to be a growing market, with many new advances driven by the wide array of possible applications and the other market drivers. Now, Gesture based interfaces allow operators to control computers and machinery with thoughts and gestures rather than with keyboards and other input devices.

1.6 ADOPTED METHODOLOGY

Machine vision system adopts a continuous and interconnected steps flow methodology. The first step is Image Acquisition to acquire or capture the image of the object. Image Comparison is the next step, giving an output either in high or low voltage to the signal that is supposed to generate out and sent to the PLC to carry out the desired operation as per the object image captured and its processing. PLC should be able to actuate the automation process as per the signal generated out of the vision system. Signal conditioning circuit is needed to carry out the signal from the vision system to the controller (PLC).

1.7 PROBLEM INVESTIGATED

Certain problems are investigated during the operation of machine vision systems in automation industries. The major problem among them is to operate the machine vision device in synchronization to the microcontrollers and other controllers which are intended to be operated as per the output generated from a image acquisition and image processing systems. As the requirement of the whole process needs to send the generated signal out of the vision system to the controller input, say PLC in our case. The operating voltage and frequency ratings should be specifically matched with each other so that the generated signal should provide at least the threshold input at the input port of the controller. For Instance, take the example of MATLAB or SKYLAB where image processing can easily be done after the image is acquired but to send the signal, only two ports are available. Out of these two, one is the USB port which needs at least 5 minutes to operate and the other one is the headphone port from where a sound signal can be generated out as an output for high logical output. But the voltage ratings of sound signal would obviously not going to match the input signal at the microcontroller input port, thus it is needed to use the signal conditioning circuit before sending the signal to the input port , thus the complexity of signal handling is increased and thus chances of investigating the problem in such system increases. Solution to such problems in machine vision system is to first carefully study the signal conditioning circuits and the elements used to make a signal conditioning circuit.

CHAPTER 2
LITERATURE REVIEW

LITERATURE REVIEW

Image processing has been useful in objectively inspecting various characteristics of the images being viewed. Machine vision systems come into origination to meet the needs of automation with higher accuracy and zero biasing. Initially, such systems were started when the need of supervision overcomes the automation industries .Number of researchers had done research in field of machine vision systems experimented on different objects and by the time , as the research were done, many new facts has been evolved out since the time the automation industries started focusing on the machine vision systems . Initially research were done on the quality of rice and segregation of rice as per the rice quality Image analysis has also been used to determine milling quality of rice. In 1994, a machine vision system was developed to inspect and quantify internal damage in rough rice kernels using a back light illumination technique. The machine vision system was reported to be 91.5% successful overall in categorizing rough rice into undamaged, spot damaged, and damaged. The system was comprised of a RGB, CCD camera, coupled with RGB/PCI frame grabber, personal computer and fiber optics ring light.   Yadav and Jindal in 2001 has showed two dimensional imaging of milled rice kernels could be used for making accurate assessment of rice yield and degree of milling for monitoring and controlling rice milling operations.

❖ Machine vision can be defined as the acquisition of image data, followed by the processing and interpretation of these data by computer for some useful application. This is rapidly growing technology, with its principal applications in industrial inspection (Grover, 2000).

❖ Machine vision system can be characterized as newly approach field and diverse. The machine system is now being used in many fields such as medical, industrial quality control, military, astronomy field and other fields.

- The machine vision implementation in industrial quality control alone is growing. The facts supplied Automated Imaging Association (AIA) showed that global market for machine vision products primarily concentrates on the high developed industry regions in North America, Europe and Japan as well as the upcoming countries China, South Korea and Taiwan. According to the AIA, the worldwide machine vision market is expected to grow at an average of 1 1 percent as a minimum per year during the next five years. For 2004 the AIA estimated worldwide sales with machine vision products of about 7.2 Billion US$. By 2008 the worldwide turnover with machine vision products is expected to grow by 37 percent to reach 10.0 Billion US$ (Basler, 2006).

- Even though earlier work exists in machine vision research, it was not until the late 1970's that a more focused study of the field started when computers could manage the processing of large data sets such as images. Many of the methods and applications regarding machine vision are still in the state of basic research, but more and more methods have found way into commercial products, where often constitute a part of a larger system which can solve complex tasks.

- Although some machine vision algorithms have been developed to mimic human visual perception, a number of unique processing methods have been developed to process images and identify relevant image features in an effective and consistent manner.

- Machine vision and computer vision systems are capable of processing images consistently, but computer-based image processing systems are typically designed to perform single, repetitive tasks, and despite significant improvements in the field, no machine vision or computer vision system can yet match some capabilities of human vision in terms of image comprehension, tolerance to lighting variations and image degradation, parts' variability. Machines vision is commonly use as automated inspection in electronics industry as small electronic components are not suitable to human vision inspection. The capability of machine vision camera to zoom in is the right choice for this kind of specific task.

- To insure interchangeability and precision these products are to be 100% quality checked. As a consequence, the inspection process is often expensive and expensive. In a typical manufacturing plant, approximately 30% of all manufacturing tasks are related to inspection, of which 60% of inspection tasks are visual. The breakdown of typical defects found during visual inspection is approximately 30% part defects, 50% assembly defects (20% of which are incorrect parts or missing parts) and 20% soldering defects.

- It should be noted that, in order to maintain a certain level of quality in electronics manufacturing process, an increase in the number of solder joints by a factor of 10 requires that the number of defects be reduced by a factor of 10. Therefore, the effectiveness of an inspection system used to control a process will have a direct impact on the quality of products shipped to customers. This places an extraordinary pressure on human inspectors who are trained to identify defective parts by visual examination (Edinbarough ET a1.2005). Machine Vision possessed a power lid tool to provide effectiveness of an inspection system that required quality control inspection and this will be further discussed.

- Human Machine Interface has grabbed lots of eyes by the time the evolution is done on different processes of automation. Currently, the only technology that satisfies the advanced requirements of hand-based input for HMI is glove-based sensing, where the use of hand as an input has been considered as one of the attractive method for providing such interfaces in real time applications. The three dimensional study and movement of the hand directions are also noted in mind while designing the interfaces for such machines to interact directly to computers.

- A machine vision system had also been developed with an irregular imaging functions so that a thorough growth of the process can easily be figured out. Because whensoever image is being detected, the image also shows the number of defects shows below the image which creates great redundancy in the image data. The system can irregularly sample images with a high resolution in the defect area and a low resolution in the background area, which reduces the total data in image processing and increases the speed and accuracy of real-time inspection significantly

- Another paper reviews the research literature for both outdoor and indoor applications of machine vision of plants, which reveals that different environments necessitate varying levels of complexity in both apparatus and nature of plant measurement which can be achieved. From the literature reviewed, it is argued that augmenting a monocular RGB vision system with additional sensing techniques potentially reduces image analysis complexity while enhancing system robustness to environmental variables. Therefore, machine vision systems with a foundation in optical and lighting design may potentially expedite the transition from laboratory and research prototype to robust field tool.

- The possibilities of an energy efficient use of compressed air in pneumatic drives such as cylinders in combination with switching valves. It presents a numerical optimization realization with which an energy optimal open loop control of standard pneumatic systems with switching valves is derived. The main part of air savings results from a better usage of the energy stored in the compressed air namely the expansion energy. It is shown that savings could be done up to 85% depending on the application. The optimization results are validated with measurements and are compared to standard pneumatic control of cylinders.

- Some algorithms applied for the calibration of the 3D scanning system and image analysis in the experimental system for positioning the work pieces on the CNC machines were discussed. The idea of the scanning is based on the application of photogrammetric algorithms using the fringe patterns approach. An experimental system consisting of three cameras and three structural light projectors has been built in order to acquire the images representing the scanned object with projected light patterns. These images are then analyzed in order to obtain the depth information for each point representing the work piece or the background.

- Pneumatic actuators have been started widely used in industry and many other applications, whereas low energy efficiency has been recognized as a critical drawback compared with corresponding hydraulic and electrical actuators. Researchers are continued to incorporate high performance driven machine vision systems with the pneumatic actuators. Our research in our project also faces a problem of signal handling but at large scale industries has to manage such signal handling operation with great care because of the high difference between the signal generated out of the system and the desired signal.

- Now days, wood manufacturing industries, shaping industries get an advantage of such systems by providing high production volume and less production cost and time involved. Machine vision has become the new trend to improve the accuracy of the work in automation industries. Still the research is being done to improve the quality of vision so that a single camera can detect and take the multiple inputs at one time to reduce the timing of the work and thus the high performance is achieved by operating the machine vision systems in a multitasking way.

- An energy efficient pneumatic-electrical system and control strategy development system has right now emerged which presents a new hybrid pneumatic-electrical system aiming at energy efficiency improvement by recovering exhaust air energy from pneumatic actuator outlets to generate electricity. A closed-loop control strategy is proved to be essential to ensure the exhaust energy recovery work properly and to maintain existed actuator operations simultaneously. The whole system mathematical model and the simulation results are presented in the paper. The laboratory test results are also given. The simulation and experimental study demonstrate that the designed system with the proposed control strategy can operate at the relative higher energy efficiency state for the specified working conditions.

CHAPTER 3
THEORETICAL DEVELOPMENT

3.1 MACHINE VISION PROCESS

Generally, the processes involved in machine vision applications can be categorized into three areas as:

- Image Acquisition
- Image Processing
- Output

- Image acquisition is the process of acquiring an image with an image acquiring device, a camera. While the image acquiring device captures an image, the image would lose much information. This loss might be due to bad light exposure, bad angle adjustment, noise in the surroundings, and so on. So, in order to extract and regain the lost information, the images needs to be further processed using image processing and machine vision tools for a better output.

- Image processing: The acquired image needs to be further processed by using image processing tools such that the information lost during acquisition could be regained. Some of the generally used image-processing tools for machine vision applications are as follows:

  - Pixel counting: Pixel counting is one of the most common image processing methods. It involves counting of the light or dark pixels that an image is formed of. It can be analyzed by histogram that shows the gray scale distribution in an image.

  - Thresholding: It is the simplest process of dividing the image into segments. It is used for creating a binary image from a gray scale image so that the region of interest is separated from the background. It requires that the region of interest and the background have enough contrast.

- Image filtering: Different image filters can be applied for the image processing. Ready-made filters are available and also user-customized filters can be created. Linear filters, spatial filters, FFT (Fast-Fourier Transform filters), etc. are some of the filters used in image processing. The algorithms of the image processing filters are not included in this thesis. But, usually the software that is being used for machine vision has most of the common filters inbuilt.

- Output: Output is of immense importance in any process. Something is done to get something in return. Machine vision applications also have a final output. Generally the outputs of machine
  Vision applications are categorized as Pass/Fail. But additional attributes for Pass/Fail outputs can also be de-fined, for instance number of passed/failed items, setting an alarm if the items are failed, and so on. It depends on the objective of the application. But it is always significant to define the attributes for further RND tasks.

3.2 MACHINE VISION AND OBJECT SORTING

Object sorting is one of the most important processes in industrial production lines. During the production process, many damaged or undesirable products are also produced. These kinds of products are unfit for use and deploying into the market and thereby need to be sorted out.

To sort those unfit products manually is time consuming, expensive, inaccurate and tiresome. The application of machine vision enables this task to be implemented with higher degree of accuracy in comparatively less time, negligible labor, and low cost. However, technical problems might arise sometimes.

Today, several machine vision software and cameras are available in the market. The software available is so effective that ready-made applications for automated inspection already exist. The user needs to give only the inputs to the software. But the users can develop their own application. One significance of developing own application is the reduction in the expenditure because, the ready-made application demands extra budget. A machine vision application is similar in both ways-theoretically as well as practically. Furthermore, the more a user is experienced, the more significant application can be developed. As per demands, different methods may be applied to develop machine vision applications. But, only few methods for object sorting have been dealt in this document.

3.2.1 Machine vision methods for object sorting

Object sorting has become a common procedure in industries. The application of machine vision in object sorting can be significant as it increases accuracy and reduces redundancies in the products. Different vision inspection methods can be applied for object sorting depending upon the products and standards to be met. Different algorithms made ready for executing inspection through machine vision by different hard-working programmers and software companies are available. The customers are free to choose from the ready-made algorithms or create their own customized algorithms using the tools provided by the software. Some of the methods that can be applied for object sorting are described in the following subsections.

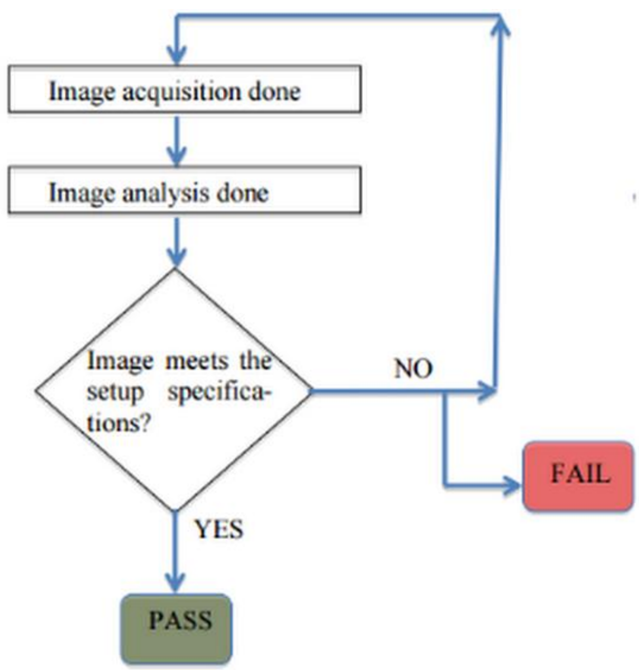


Fig1: Figure shows the algorithm

3.2.1.1 Pattern matching: Patten matching is the process where a template image is defined and stored in the memory. This template image is also referred to as reference image. When the real-world images; for example, image of products in a factory production line are acquired using camera, the software searches for instances of the template images stored in the memory and confirms if the product matches the pattern defined in the template image or not. A rectangular box around the image often indicates pattern matching. Pattern matching is a significant machine vision tool as it is independent of lighting variation, blur, and noise.

Pattern matching technique can be used for gauging (measuring lengths, diameters, angles, etc.), product inspection (detecting flaws such as missing parts or components from a product), and product alignment (determining the position and (or) orientation of a known object by locating fiducially. Hence, pattern matching can be applied for quality control of the products.

3.2.1.2 Edge detection: Edges are of importance while determining the structure of the object. Typically edges occur between the boundary separating two regions in an object. So edges are the significant changes to analyze the image. These local changes are seen in intensity of different regions in an image. The change or discontinuity in the intensity might give rise to the formation of step edges, line edges, ramp edges or roof edges. Figure shows the original image and the edge-detected image Figure shows the step edge formation behavior of the intensity in an image. Line edges occur when the intensity abruptly changes its value but regains its original value within a short distance. The line edge formation behavior is shown in Figure below. However, step and line edges are rare in the real world images. The behaviors of step edges changing to ramp edges, and line edges changing to roof edges are respectively shown in Figures below. The edge detection algorithms are typically used in three different areas of machine vision applications namely gauging, alignment, and geometric transformations of objects.

3.2.1.3 Geometric matching: Geometric matching locates regions in a grayscale image that match a model, or template, of a reference pattern. Geometric matching and pattern matching tools resemble closely. It is also independent of lighting variations, blur, noise, and geometric transformations. And, the steps involved are also quite similar. Like pattern matching, a template image is created that works as a reference image for which the geometric matching tool searched from the acquired images

3.3Machine Vision Components

When it comes to discuss about the components of Machine Vision, Depth of field , f-number of the camera used, lens equation and the type of lens used in the system, the resolution of the image and the field of view are the various components come into existence. Machine Vision components give the exact information about the location, position of the camera and the other devices used for machine vision. Some of the Machine Vision components are described as under:

3.3.1 Field of view: Field of view (FOV) may be defined as the extent to which a camera can view the real world image in an instant of time. It depends on the focal length of the lens. With smaller focal length, the angle of view is larger. This allows the lens to cover wider area of the image. Figure 11 shows the schematic diagram of FOV. The region surrounded by the height and width of the scene falls inside the FOV.

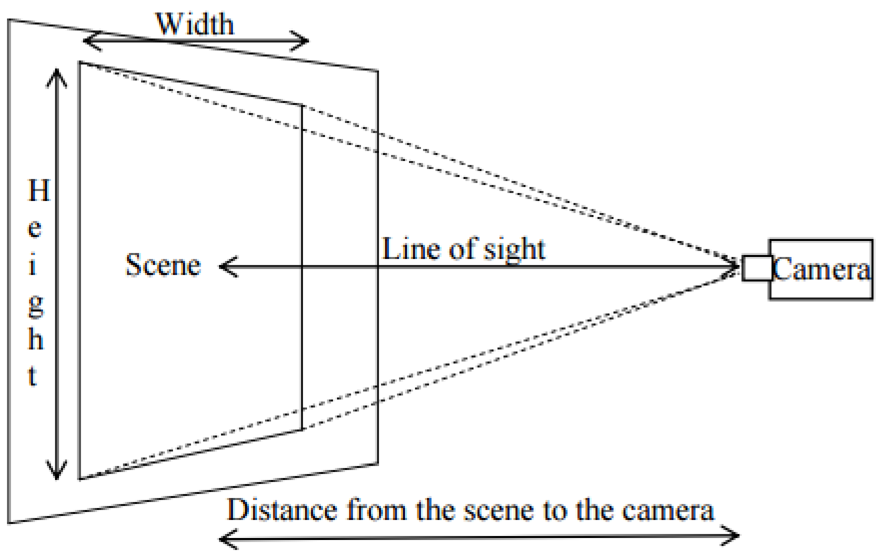


Fig2.: Field of view

3.3.2 Depth of field: Depth of Field (DOF) is the measure of the distance between the nearest and the farthest objects in a scene that can be captured by the camera and be acceptably sharp in the image (Wikipedia, 2013. Depth of Field). Figure 12 illustrates the DOF of a lens. Figure 12 Depth of field of a camera (Wikipedia. Depth of Field) In Figure 12 above, the area within the DOF appears sharp whereas the areas in front and back of it appear blurry. It depends on the focal length and the aperture size of the imaging device. The larger the focal length, smaller is the DOF; and also the larger the aperture size, smaller is the DOF. Although the lens can focus at one point at a time, the gradual decrease in sharpness occurs on both sides of the focus point. So, within DOF the unharness is unpredictable under normal conditions.

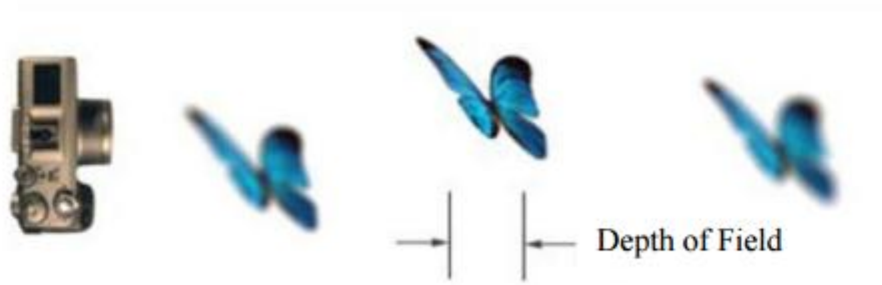


Fig3: Depth of field

3.3.3 Image resolution: Image resolution indicates how clearly an image is visible. In other words, it is the minimum distance between two lines in an image such that the image is visibly resolved. Image resolution can be defined in different ways such as pixel resolution and spatial resolution. Pixel resolution is indicated in the form M x N (M by N). M represents the number of pixel-columns (width) whereas N represents the number of pixel rows (height). It is also sometimes indicated by the total number of pixels in the image or the region of interest in the image. The more the pixel resolution, the better is the image visibility or quality. Below figure shows the visibility with different image resolutions for the same image. Spatial resolution is the measure of how closely lines can be resolved in an image. It is determined by the pixel spacing, lens aberrations, diffraction and the depth of field. But in most machine vision applications, pixel spacing and depth of field are the deterministic features of spatial resolution. It suggests that images with high pixels are not necessarily sharp.

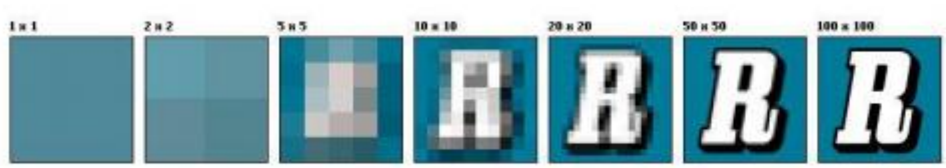


Fig 4.: Image Resolution

3.4 Machine vision tools

Machine vision tools refer to the software algorithms used for image processing and analysis. These are the building blocks for developing machine vision applications. These tools are supplied by different manufacturers but all have the same working principles. All the machine vision tools are developed in a way that they analyze a particular set or number of pixels within a defined region of interest of the object, show the graphics of the object being analyzed, and provide data information about the image to make a decision for the controller and the output devices. The vision tools can be categorized into different types as described in the following sub-sections.

3.4.1 Image processing and filtering tools: Before an object is analyzed, the image filters (or image pre-processing filters) can be applied to the image of the object to sharpen the image pixels, increase the edge contrasts and remove noise from the image or even the reverse of these. Lighting variations and insufficiencies brings quality degradation in the image. Thus the filters enhance the image.

3.4.2 Positioning (or locating), counting and measurement tools: Machine vision tools are widely applied in industries for object positioning, object counting and measuring dimensions of the objects. Basically, all these processes are interconnected. So, all these can be achieved with the same adjustment or utilization of the vision tools. For example, object positioning requires finding distances between two objects or matching the pattern where the object needs to be located.

3.4.3 Application specific tools: Different application specific machine vision tasks such as bar code reading, defect detection, color recognition, etc. can be accessed using machine vision tools.

3.5 Vision section of the station

Figure below shows the diagrammatic section of the station that is responsible for providing information to the sorter if the image of the object meets the required specifications or not.

If the machine vision application matches the object the sorter moves from position A to B (marked in Figure 26 above). By default, the sorter is always at position A; thus the sorter moves only if the object matches. The sorter also has to return back to position A, when it has moved to position B; this was done in the automation codes. The codes for resetting the sorter can be found in Appendix 6. In

Figure above, it has been indicated that the pattern matches. Therefore, in this condition, the sorter should move from position A to B as indicated by the arrow (move A to B).

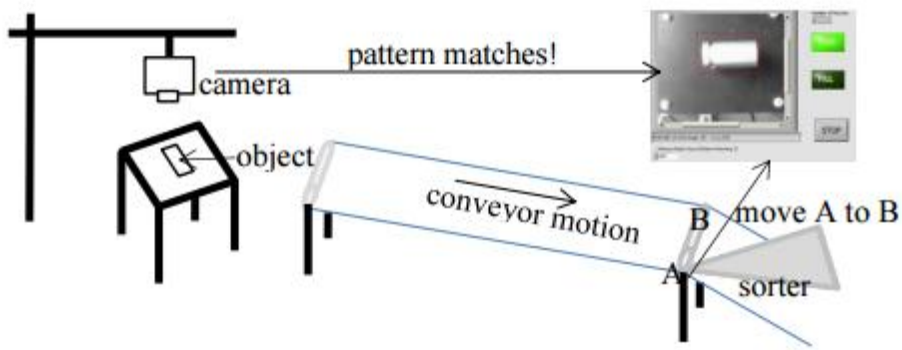


Fig 5: Vision Section Of the Station

- **System communication**: The PLC is interfaced to the computer using an adapter. The bus coupler, LC3100 was networked with the PLC using PROFIBUS cable. Also the communication is done using the generated sound signal. A diagrammatic representation of communication among the system components is shown in Figure.

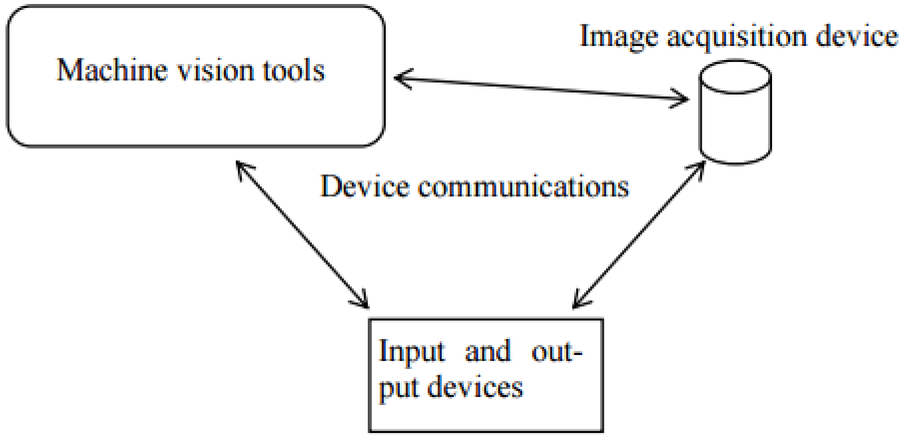


Fig 6: Representation of the system communication

- **<u>Setting up the imaging system</u>**: Setting up the imaging system is the most important part for developing a vision application. Before an image is acquired, the imaging environment should be favorable for the image analysis method going to be used. The imaging environment should produce image with quality high enough to extract the information needed. The important aspects to be fulfilled are the type of camera being used, the lens of the camera, its resolution, and the surrounding lightings. Lighting is a vital aspect for image acquisition as poor or vivid light accounts for poor image and thus a lot of information from the image is lost.. The camera should always be positioned in a way that it is perpendicular (90° angle) to the object(s) being analyzed as shown in Figure . It is alright if some errors in perpendicularity occur as the software is capable to compensating such errors but it is recommended that the camera be placed perpendicular to the object as precisely as possible. A clamp and stand could be used to install the camera perpendicular to the object.

- **<u>Calibrating the imaging system</u>**: After the imaging system is set up properly, the next step would be calibrating the imaging system. Calibration of the imaging system is critical because, all the machine vision tasks will be based on the calibration made. The better the calibration, the better would be the image analysis and machine vision tasks. Calibration involves assigning the real-world coordinate system to the pixel-based coordinate system. It also assists in compensating perspective and non-linear errors that might be present in the imaging system. Perspective errors arise due to the camera not being perpendicular to the object under inspection while non-linear errors arise due to lens aberration of the camera. Simply to understand, lens aberration can be defined as the fault in the lens that prevents the lens from converging different rays of lights to a single focus point.

3.6 Pneumatic Components

The pneumatic actual configuration of components and their arrangement in industries is as below:

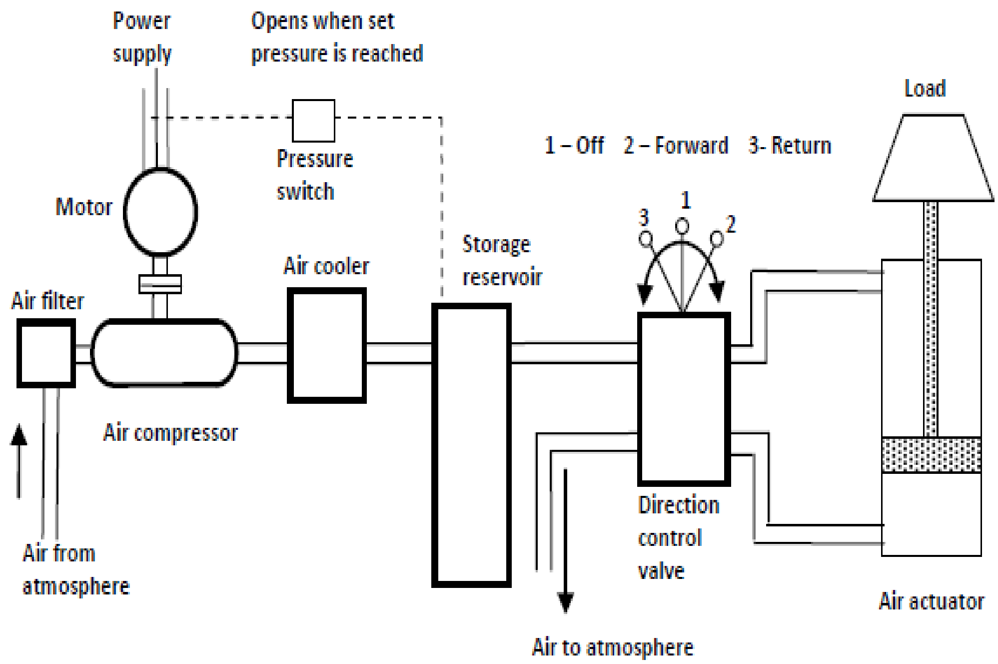


Fig 7: Pneumatic circuit diagram/ description and arrangement.

❖ Solenoid Valve

Electrically actuated directional control valves form the interface between the two parts of an electro-pneumatic control. The most important tasks of electrically actuated DCVs include.

i) Switching supply air on or off

ii) Extension and retraction of cylinder drives

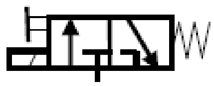
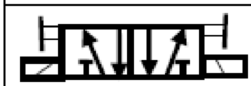
Electrically actuated directional control valves are switched with the aid of solenoids.They can be divided into two groups:

i) Spring return valves only remain in the actuated position as long as current flows through the solenoid

ii) Double solenoid valves retain the last switched position even when no current flows through the solenoid.

In the initial position, all solenoids of an electrically actuated DCVs are de-energized and the solenoids are inactive. A double valve has no clear initial position, as it does not have a return spring.

The possible voltage levels for solenoids are 12 V DC, 12V AC, 12 V 50/60 Hz, 24V 50/60 Hz, 110/120V 50/60 Hz, 220/230V 50/60 Hz.

Symbol	Details
	**3/2 way Single solenoid valve (spring return)**
	**3/2 way pilot operated single solenoid valve(spring return)**
	**5/2 way single solenoid Valve (spring return)**
	**5/2 way double solenoid valve.**
	**5/2 way piloted operated double solenoid valve.**

<u>Table 1: Types of solenoid valves</u>

❖ **<u>Single Acting Cylinder</u>**

Single acting cylinders have comparably the simple construction and have small dimensions with large focus to approx. 25000 N. It has limited stroke of ca. 60nm and has the simple installation and is thus inexpensive. It is used more in areas of Clamping, Bending, Punching, Ejecting operations, etc.

<u>Properties of single acting cylinders:</u>

- ✓ End strokes limited by external limit stoops.
- ✓ No air or spring return.
- ✓ Force varies with the stroke.
- ✓ Limited stroke.
- ✓ Inclination of the end plates by up to 15degree possible.

<u>Application Areas:</u>

- ✓ Lifting platforms.

- ✓ Lifting tables.
- ✓ Clamping and transporting devices.

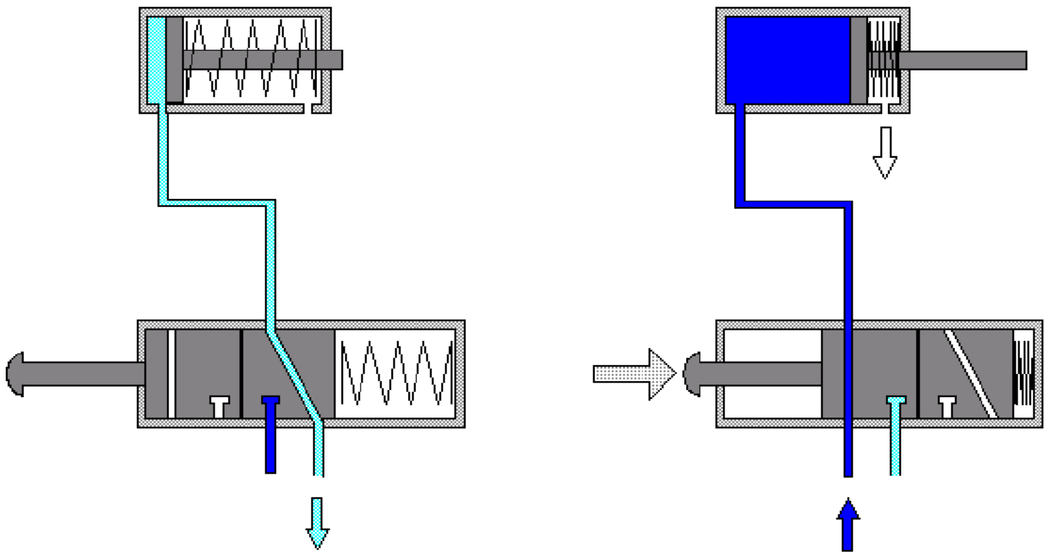


Fig 8: Control of Single Acting Cylinder

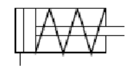
❖ **Double Acting Cylinders**

There is a possibility of working from both sides and has constant bearing separation. It has low lateral loading and has equal piston area on both sides giving the same force in both directions.

Application Areas:

- ✓ Movement of flaps
- ✓ Sorting.
- ✓ Movement of stoops.
- ✓ With n cylinders with different strokes, 2^n positions can be attained.

Speed of movement is dependent on pressure difference between front and rear compartments. Movement is only possible if there is a pressure difference between the two sides. A cushioned cylinder slows down piston speed at the end of travel to avoid damage due to impact.



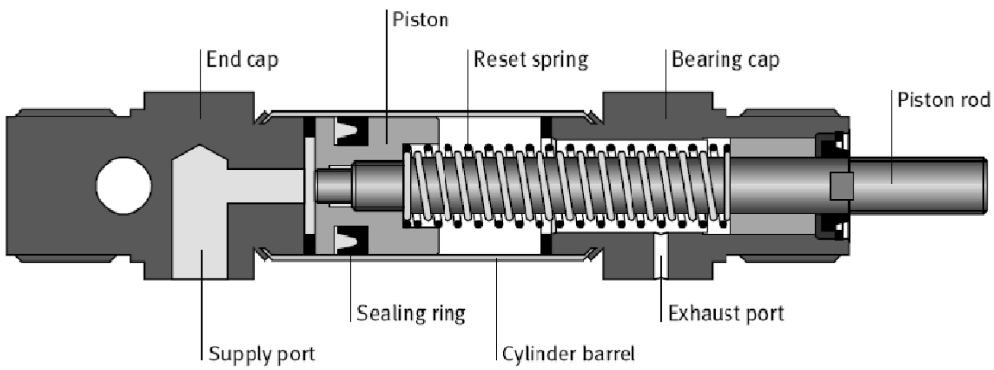


Fig9: Double-Acting Cylinder

❖ **Directional control valve**

Valves control the movement of a drive unit by controlling the airflow in and out of it. Directions of arrows in the symbol indicate direction of air flow. Number of boxes indicates number of valve positions. The second position from the left shows default position. Each box indicates what the valve will do when it is in that position. In the symbol, all outputs are shown on the top. Inputs and exhausts on the bottom. However the physical location of various ports on the valve body may be different.

❖ **Air Filter**

Better suited for small volume applications. And has moderately efficient water removal. It has Inexpensive method with low maintenance requirements. Water has to be manually drained out.

Optional automatic water drainage is also available. Filter must be rated at 40 microns or better. Finer filters (0.01 - 5 microns) are required for more sensitive equipment.

- **<u>Air Regulator</u>**

A pressure regulator is used to keep the pressure in the equipment constant. A regulator can reduce, but not increase the pressure.

- **<u>Air Lubricators</u>**

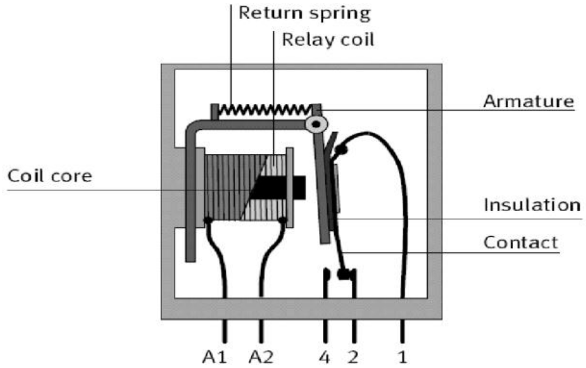
Following are the types of lubrication oils available in Indian market, which are equivalent to those recommended by Bosch Rexroth (India) Ltd.

• Servo Spin 12 from Indian oil Corporation Ltd.

• Hyping VG 10 from Indrol Lubricants & Specialties Ltd.

- **<u>Relays</u>**

Relays are the electromechanical switches used to segregate two circuits and control the high operated voltage circuit with the circuit running at low voltage and operating at low current ratings. Relays are basically used when the requirement of the signal a the input port needs much higher voltage and current ratings than the voltage generated out of the system being used in the previous sections of the system. Thus to control the load with high power ratings , a relay or opto coupler is required to control the say 24v operated load with at least 5v supply on the other side of the relay. PLC uses the high current rating relays whereas the signal conditioning circuit we have used here in our project requires only 5V operating dc relay because the signal generated out of the system is at near about 3.89V and thus at least 5V relay will be required to control the load side i.e. the actuator used in the PLC.



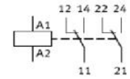


Fig 10: Structure of a RELAY

❖ **Boyle - Mariotte's Law:**

The product of Pressure and Volume of a given amount of gas is a constant, provided the temperature remains constant
(P1 x V1 = P2 x V2).

❖ **Gay - Lussac's Law:**

The volume of a gas is proportional to its absolute temperature, provided the pressure remains constant. -273 °C is the lowest possible temperature in the universe and is known as absolute zero [0 °Kelvin]. Absolute temperature is measured in º Kelvin. A change of 1 °C results in a change of 1 °K. 0 °C = 273 °K and 1 °C = 274 °K.

3.7 Signal Conditioning Circuit Construction

As already discussed, it is evident that the signal conditioning circuit is being used in the project to acquire the signal produced by the system and to pass it on to the PLC. A sound signal is produced at the output of the MATLAB coding and thus as we know a sound signal can only produce 0.2mV at the output circuit, thus it becomes much difficult to use that sound signal to operate the PLC machine. Thus the sound signal will be converted to the electrical signal by using a condenser microphone which will thereafter be amplified and the output we got at the output pin is near about 3.89V and hence this voltage will be used to drive a relay which will help to run the Actuator which needs a supply of around at least 24V.The below is the signal conditioning circuit used in the project.

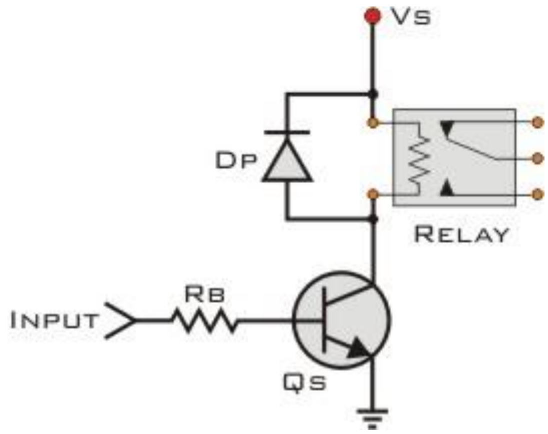


Fig11: The relay driver circuit .

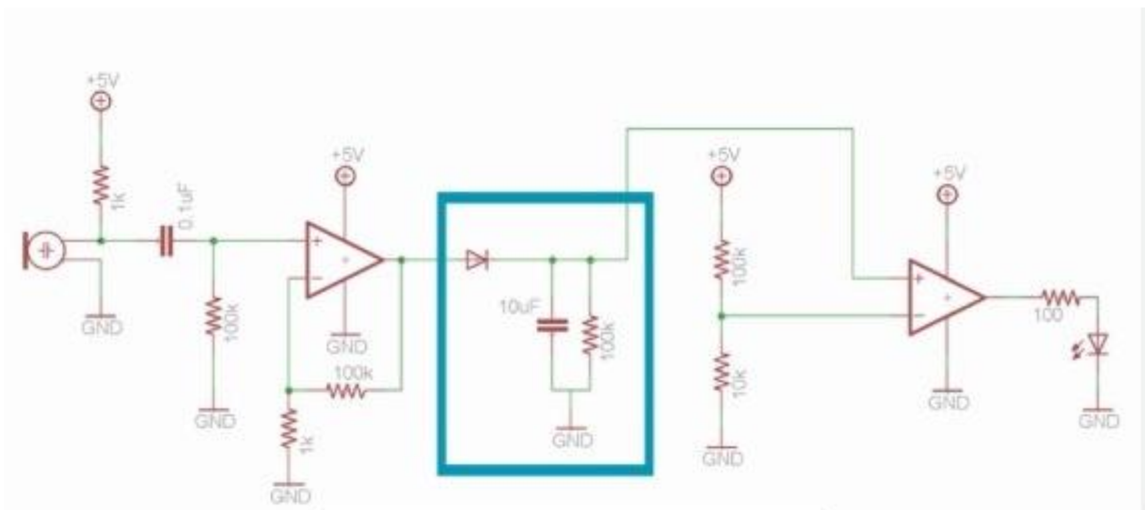


Fig 12: Signal conditioning circuit

LM324: is a 14pin IC consists of 4 independent operational amplifiers (op-amps) being provided in a single package. Op-amps are the high gain electronic voltage amplifiers with a differential input and, usually, a single-ended output. The output voltage is many times greater than the voltage difference between input terminals of an op-amp.

These op-amps are operated by a single power supply **LM324** and need for a dual supply is eliminated. These can be used as amplifiers, comparators, oscillators, rectifiers etc. The conventional op-amp applications can be more easily implemented with LM324.Below is the table representing the functions and description of pins of the IC used i.e. LM324.

Pin No	**Function**	**Name**
1	Output of 1st comparator	Output 1
2	Inverting input of 1st comparator	Input 1-
3	Non-inverting input of 1st comparator	Input 1+
4	Supply voltage; 5V (up to 32V)	Vcc
5	Non-inverting input of 2nd comparator	Input 2+
6	Inverting input of 2nd comparator	Input 2-
7	Output of 2nd comparator	Output 2
8	Output of 3rd comparator	Output 3
9	Inverting input of 3rd comparator	Input 3-
10	Non-inverting input of 3rd comparator	Input 3+
11	Ground (0V)	Ground
12	Non-inverting input of 4th comparator	Input 4+
13	Inverting input of 4th comparator	Input 4-
14	Output of 4th comparator	Output 4

Table 2: Pin description and function of pins of LM324

Below is the Pin Out description of the IC LM324:

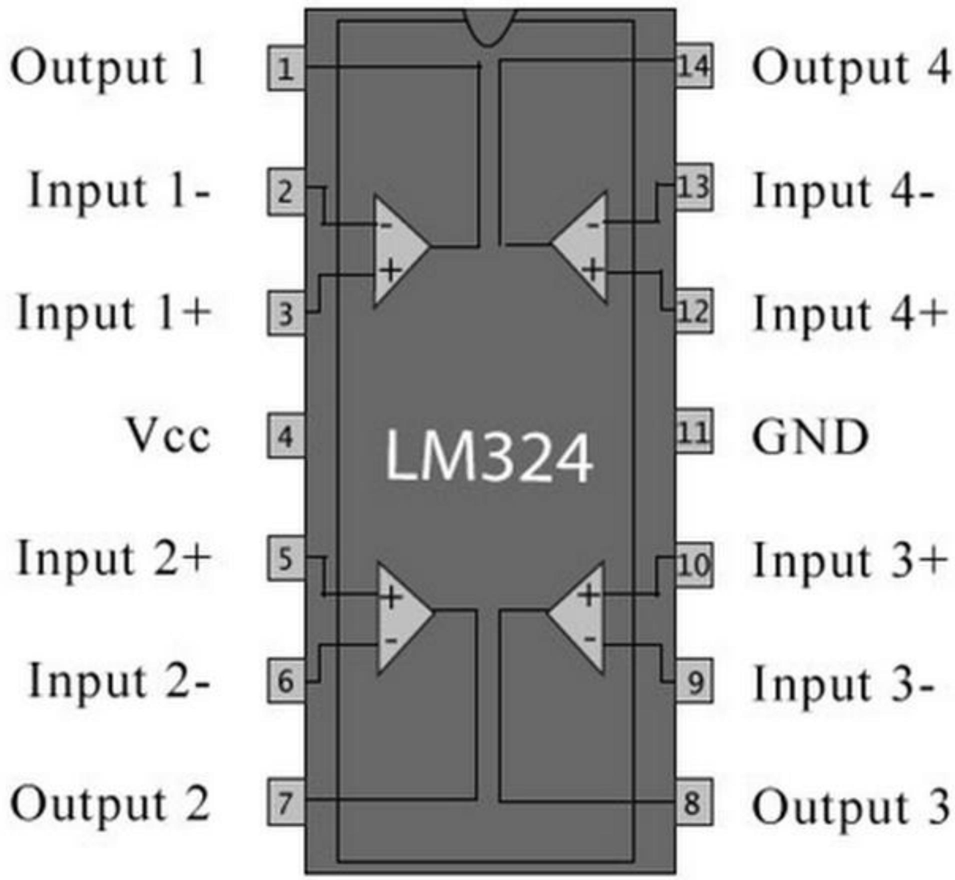


Fig 13. Pin out of LM324

RELAY

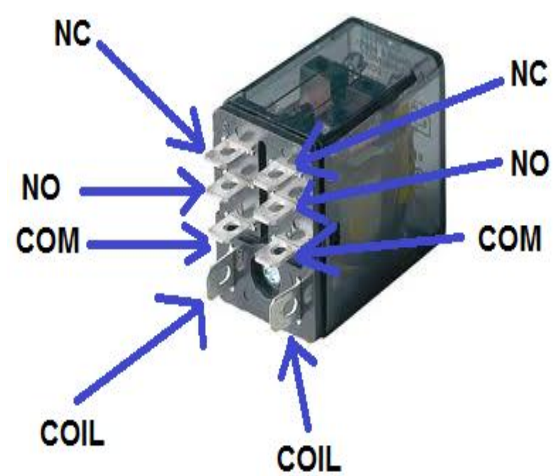
The relay used in the project is a 8 pin relay with the configuration of 8 pins as given below in the following diagram. The supply will be given to the coil pins, where one pin gets a voltage of +5V and other gets the connection of ground to excite the magnetic field in the coil in excitation state.

Pin No	**Function**	**Name**
1	Gets the +5V Supply	COIL

2	Common pin for 1st pole	COM
3	Normally Open for Pole 1	NO
4	Normally Closed for pole 1	NC
5	Normally Close for pole 2	NC (2)
6	Normally Open for Pole 2	NO (2)
7	Common pin for2nd pole	COM (2)
8	Gets ground connection	COIL

<u>Table3: Pin description and function of pins of 8 pin RELAY.</u>

And the description of pins is done below using an IC pictorial figure.



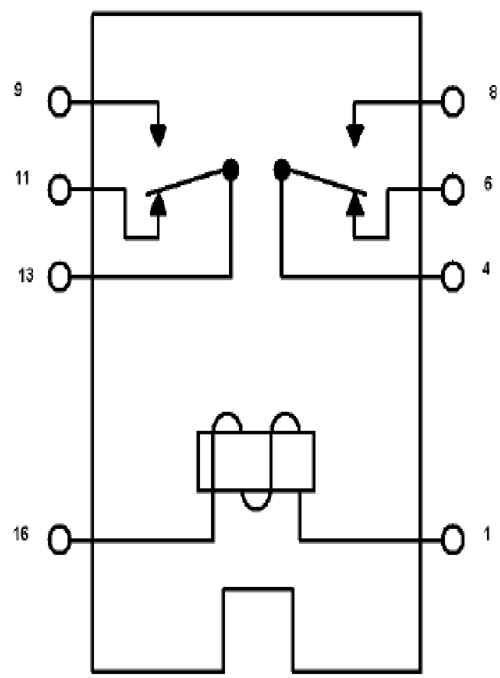


Fig 14. DPDT Relay . Fig 15. Pinout of DPDT Relay

BC547:

BC 547 is a transistor (NPN) used to drive the relay at 5V which is the least voltage at which relay is configured and operated and thus when 0.7V i.e. the sufficient current and voltage passes through the emitter terminal of the transistor, it will complete the circuit of relay by providing ground to the 8pin Relay. Once the relay used is operated at 5V, it will be helpful to drive the actuator at 24V.The following picture shows the pin out of BC547, showing the terminals of the transistor and the arrangement of the terminals to drive the relay. Thus it is useful to make a driver circuit which helps from back current and provides protection from back EMF, along with the diode used in flywheel position i.e. 1N4007. Basically BC547 is an NPN bi-polar junction transistor. A transistor, stands for transfer of resistance, is commonly used to amplify current. A small current at its base controls a larger current at collector & emitter terminals.

BC547 is mainly used for amplification and switching purposes. It has a maximum current gain of 800. Its equivalent transistors are BC548 and BC549.

The transistor terminals require a fixed DC voltage to operate in the desired region of its characteristic curves. This is known as the biasing. For amplification applications, the transistor is biased such that it is partly on for all input conditions.

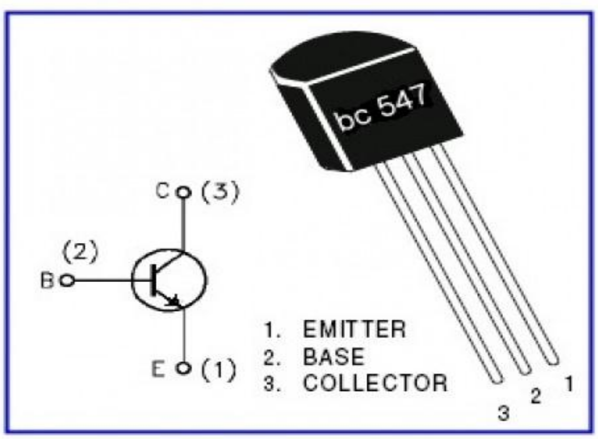


Fig 16. Pinout of BC547

For more information on the characteristics of BC547, see Appendix B.

- **Latching:**

Latching is the process in which relay is placed in parallel to a switch and is used for the process of continuation of the supply to the load and switches .This latching can be done in two different ways. One is Dormant and the other one is Non-Dormant Latching.

.

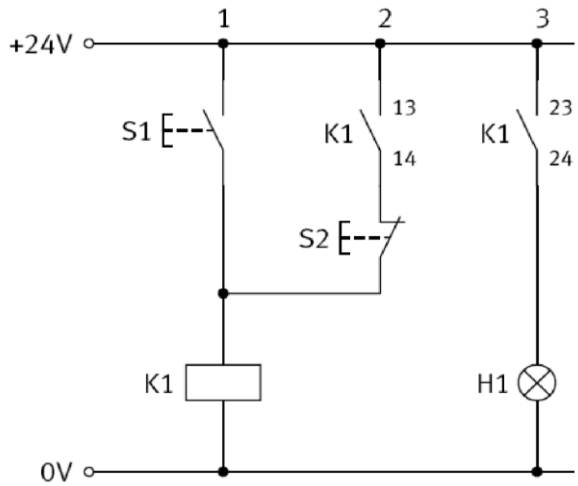


Fig 17. Dormant Latching

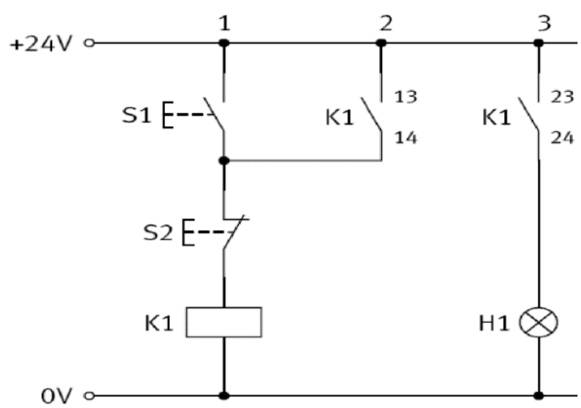


Fig 18: Non-Dormant Latching

- **Air Consumption by a Cylinder :**

We know that P1*V1 = P2*V2 ----- 1

V1= the air consumption in cubic cm, P1= 1 Bar*
the air consumption is always calculated at atmospheric pressure, i.e. 1 Bar as per standard practice.
V2= Volume of cylinder in cubic cm,
P2= working pressure in Bar.

Substituting the above in formula 1 we get
Air Consumption by cylinder (cubic cm / min) = Volume of cylinder * Working Pressure * Cycles / Min

CHAPTER 4
Experimental Methodology And Computation

4.1 METHODOLOGY

So far, we have studied the theoretical explanation of each component intended to use in the project work to make a machine vision system where an image acquisition device is incorporated with PLC and thus image processing is done simultaneously along with the operation of the segregation or the sorting operation using the control of PLC. Now we are going to see the step by step working of all the components and the devices used in this chapter. And thus starting from acquisition of image, generating the signal out through a port of the system, handling the signal to the input port of PLC, and thus carrying the segregation operation as per the control input given to the actuator. The block diagram of the whole process is shown:

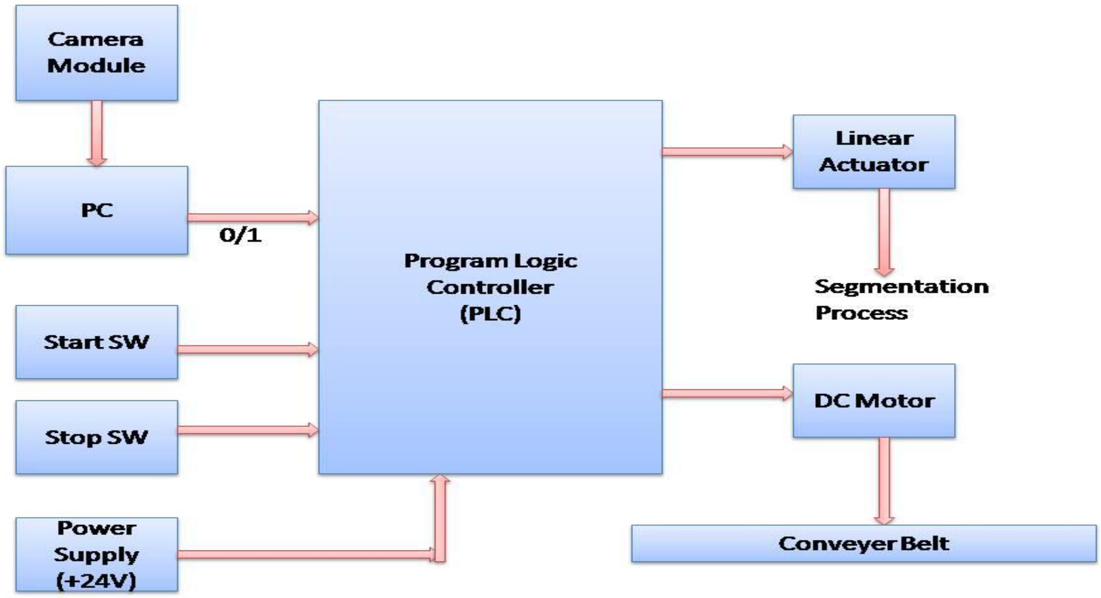


Fig 19: Block diagram representation of the segregation process

4.1.1 Step1: Image Acquisition

The initial step after preparing the set-up once is to acquire the image of the object . The object needs to be placed on the conveyer belt and as it is discussed in the previous chapters there should be the exact location and adjustable position of the camera adjusted over the conveyer belt perpendicularly to give the better view of the image being captured. The image acquired is going to be handled by MATLAB. Thus it is needed to know that the image is captured using frames and the frames number will be given in the Image Acquisition Tool in MATLAB which will be discussed in the later sections.

4.1.2 Step2: Feeding/Storing the template of the desired Object

Before analyzing the acquired image and process it in the software in the system, it is recommended to first store the image of the object which is desired and going to be accepted in the operation of sorting or segregation. Once the template of the object is saved, all the operations in image processing will be done by taking the stored image as the reference one and the stored image is useful for the comparison of the acquired image with the already stored image or some of its features to check whether the image should be accepted or rejected while performing the segregation operation.

4.1.3 Step3: Image processing Steps

Before processing the image in the system, it is first needed to set all the targets for the acquired image in the Image Acquisition Toolbox of MATLAB. We have an option there in the toolbox to select the source of the image acquisition whether it is Webcam integrated in the system or the webcam we take as from the outside source as in the project, for better quality of the image to be captured, we have used the source 2 by using the INTEX- 360 PC based Webcam easily available in the market. And thus the frames per trigger should be set as per the speed of the capturing operation we need to perform. Generally, Frames per Trigger is set at the default rate of 10 frames per trigger. In image processing steps, we need to follow certain required steps as discussed under:

- ❖ Conversion of RGB Image into gray scale and to convert the Gray scale image to the binary image to calibrate the count from 0 to 255 as 0 to 1 , 0 being at lower logical level and 255 being the higher logical level.

- ❖ Mathematical Morphology is the next step to follow. Mathematical morphology is a kind of technique used to analyze and to process the different structures of geometry, based on the sets and relations theory, topological features, and other random functions. This is very commonly applied to non analog images, but it can be employed as well on the graphs, and many other spatial structures. The basic operators used to run the basic morphological operation are:

1. **Erosion**

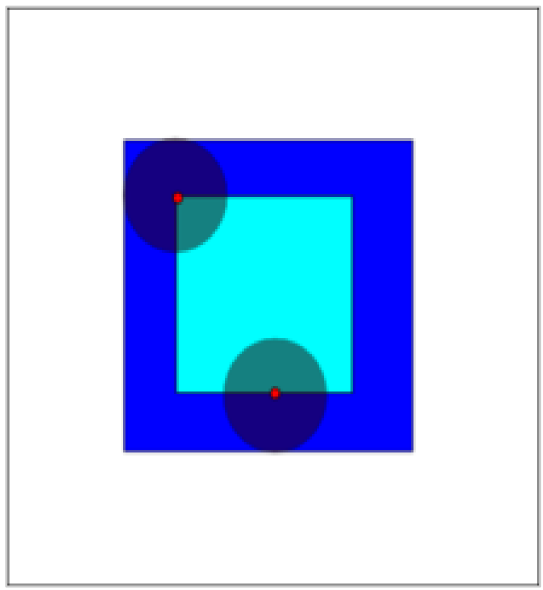


Fig 20. Figure showing Erosion operation.

The erosion of the dark-blue square by a disk, resulting in the light-blue square. The erosion of the binary image A by the structuring element B is defined by: $A\ \theta\ B = \{z \in E | B\ \in A\}$,

Where Bz is the translation of B by the vector z. When the structuring element B has a center (e.g., B is a disk or a square), and this center is located on the origin of E, then the erosion of A by B can be understood as the locus of points reached by the center of B when B moves inside A. For example, the erosion of a square of side 10, centered at the origin, by a disc of radius 2, also centered at the origin, is a square of side 6 centered at the origin.

The erosion of A by B is also given by the expression: .$A\ \theta\ B = \cap\ A$

Example application: Assume we have received a fax of a dark photocopy. Everything looks like it was written with a pen that is bleeding. Erosion process will allow thicker lines to get skinny and detect the hole inside the letter "o".

2. Dilation

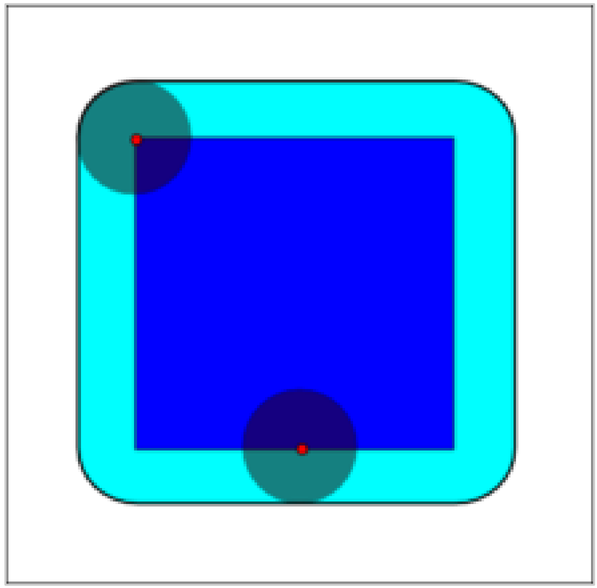


Fig.21 : Figure showing Dilation of an image.

The dilation of the dark-blue square by a disk, resulting in the light-blue square with rounded corners.

The dilation of A by the structuring element B is defined by:

$$A \oplus B = \bigcup_{b \in B} A_b.$$

If B has a center on the origin, as before, then the dilation of A by B can be understood as the locus of the points covered by B when the center of B moves inside A. In the above example, the dilation of the square of side 10 by the disk of radius 2 is a square of side 14, with rounded corners, centered at the origin. The radius of the rounded corners is 2.

Example application: Dilation is the dual operation of the erosion. Figures that are very lightly drawn get thick when "dilated". Easiest way to describe it is to imagine the same fax/text is written with a thicker pen.

- After morphological filtering, the next step to compare the captured image with the image already stored in the working directory. Now comparison can be done in many ways.

  1. Histogram development of both the images would give us the comparison between the histogram of the 2 images being carried out under the operation of comparison.

  2.Then the other method is of correlation, where the correlation of two images is discovered and as per the correlation output, the extent to which both the images resembles to each other is known.

  3. Segmentation: Partitioning a digital image into multiple segments to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze.

  4. The simplest method of image segmentation is called the Thresholding method. This method is based on a threshold value to change a gray-scale image into a binary image. The key of this method is to at first select the threshold value .Several popular methods are used in industry including the maximum entropy method, maximum variance and k-means clustering.

  5. Edge detection is the next alternative which again is used to identify different points in an image (digital) at which the brightness of the image changes sharply or, formally, has discontinuities. The points at which image brightness changes sharply are typically organized into a set of curved line segments.

- Once the comparison is done using any of the above technique, we start focusing on the output. To display the output more effectively, we start with displaying the output in figures to show the plots and subplots of the captured image , it's histograms and the image already stored so that even a layman could compare both the images with their histogram and get to know whether the result generated as a signal is accurate or not. The whole process in MATLAB is carried out as shown:

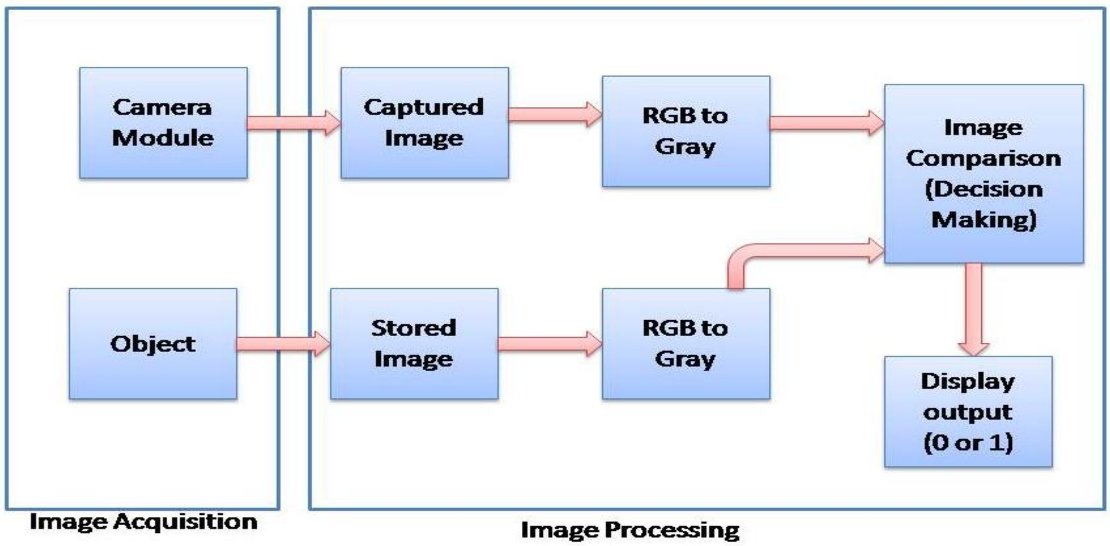


Fig 22: Block Diagram of Image acquisition and processing

For Coding to process the image in MATLAB, see Appendix A.

- ❖ Now the time comes to convert the signal whether it is a high level logic or a low level logic, it needs to be sent out of the system (PC in our case) through any port of the system. Generation of signal to the output ports in case of MATLAB only gives us two options; one is the headphone/earphone port through which a sound signal can be generated to show the presence of the high level signal i.e. 1 at the generated signal out of the system. A sound file has already been recorded or downloaded from internet and saved in the current working directory, so that after the comparison, in the program it can be called under the statement saying that if 1 is generated out of the comparison, sound should be produced at the port of the system, otherwise at 0 signal been generated out, no sound signal will be produced and thus the whole process stops there only.

4.1.4 Step4: Signal Handling Process

Signal handling is the most crucial and the important step to follow to perform the machine vision operations. Generally this process of signal handling is not considered when we talk about the machine vision systems incorporated with the automated controllers like PLC, because this comes into picture when we talk about the practical approach to solve the problem of signal handling in such operations. As it is discussed in the previous section that the signal generated out from the PC will be a sound signal of particular frequency say near about 40Hz which is hardly audible to the human ear, but at the same time the voltage signal generated out of the sound signal is completely negligible, not even going to be measured under the milli volts reading. In such case signal conditioning circuit is generally required to convert the sound signal to an electrical signal so that it can easily trigger the input port of the PLC. And the discussion over the signal conditioning circuit used in the project is discussed as under:

- ❖ The sound signal can be heard using head phones or using speakers connected to the earphone port of the computer but is not used as an electrical signal needed to trigger the input port of the PLC.

- ❖ Thus the sound signal has to be converted to an electrical signal, For that purpose sound generated out of earphones or speakers should be sent to the microphone first so that a sound signal will be converted into an electrical signal however the electrical voltage produced at the terminals of the microphone is very less, yet this small amount of electrical voltage near around 0.2V is sufficient to make a signal conditioning circuit.

- ❖ As the microphone internal working has already discussed in the previous section, As the voltage has been generated at the terminals of the microphone due to the vibration of the diaphragm inside the microphone and the change of capacitance, this small voltage will be amplified using LM324 quad op-amp IC through a peak detector circuit so that even a small and momentary voltage can be acquired and the highest among all the momentary values would be noted and is thus sent to the output terminals until we get the next highest value of voltage at the terminal.

Below circuit generates the voltage of 3.89V at the output of the IC used i.e. LM324. This voltage is the amplified voltage we get after conditioning the signal. This is obviously not going to be used to drive a relay or a actuator in PLC systems. Because in PLC based actuators, we need at least 24V supply and also the relays could not be operated under5V supply. The description is shown diagrammatically below how a sound signal will be able to drive a 24V operated actuator in PLC and pneumatic circuit.

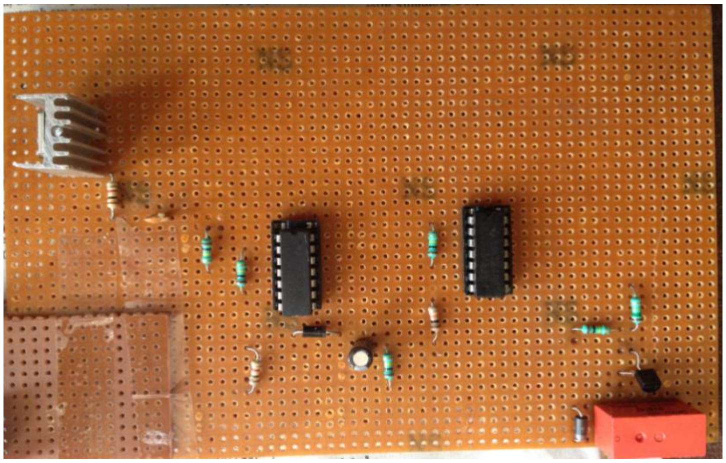


Fig 23: Amplification of 0.2V signal and signal conditioning

- ❖ A driver circuit consisting of transistors and resistors will be used to safeguard the relay to prevent it from the high back current coming from the load side. However a flywheel diode is used in parallel to the relay to prevent it from back EMF, still there are chances of sinking the current back to the IC from the load side to the supply, thus a driver circuit is used. Operating the relay needs the flywheel diode to operate in the reversed biased mode. And the circuit is explained already in the theoretical section of the signal conditioning circuits

.

4.1.5 Step5: Segregation of the desired and undesired objects

Now as the signal is passed to the input port of the PLC, the actuator is connected at the output with input being connected at the signal generated port. Ladder Logic in INDRAWORKS Engg. Will be used to program the PLC to control the process of actuation as per the image of the desired and the required image is captured in the camera and a high voltage signal is produced at the output. And thus the sorting of the objects on the PLC will be operated without using any sensor. The hardware model prepared is shown:

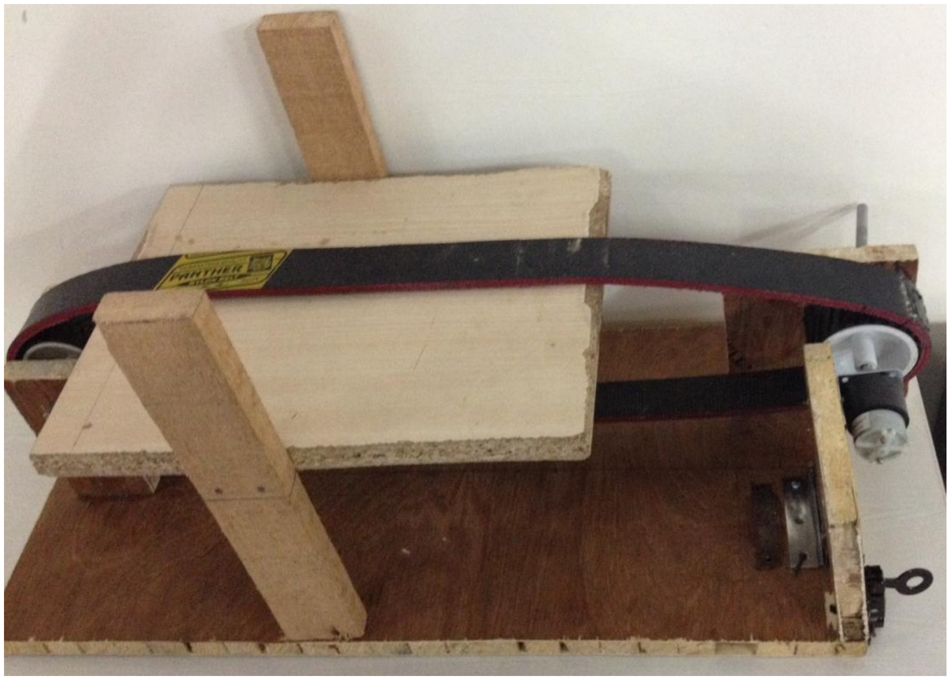


Fig 24: Figure shows the hardware model prepared for the segregation process**.**

Above are the steps needed to be followed to do the segregation operation in the automation industries without using any industrial sensor and without any aid of manual supervision.

CHAPTER 5
RESULT AND DISCUSSION

5.1 Result

The result of the work done is finalized in steps from the capturing of an image to the generation of the signal and then generation of a signal to the signal handling steps and the actuation process in PLC and pneumatic operations i.e. here to segregate objects as per the image of the object captured. The result of each operation has been discussed uniquely and separately to discuss further the consequences of result of one step on the next one and the process is continuing further like this.

5.1.1 Step 1

The image has been captured using USB webcam (IT-360WC INTEX Webcam) readily available in market. The captured image has been compared against the already stored image in the working director of the software currently working software in the system, here in our project we have used MATLAB to first capture the image using USB Webcam and then to compare it against the already stored desired image. As the comparison is done, using the result of comparison, a signal is generated i.e. a sound signal as per the result of the comparison. This means if the image captured using Webcam matches with the already stored image, there will be a sound signal generated out of the PC's headphone port and it will play the music file which will already be stored and feeded into the working directory and using code can be easily called as per the matching of two images to generate a sound signal which will be useful in detecting the object and tracking its features and to further process the segregation process.

5.1.2 Step 2

As the signal has been generated out from a PC's port, the signal will then be used to generate the sound but this sound will not be sufficient enough to drive a actuator. Thus signal handling is achieved here by using signal conditioning circuit to convert the sound signal to the electrical signal having microphone as a mediator to convert the vibrations produced by sound signal to the electrical signal.

For this process, a quad op-amp IC LM324 is used and thus the output of LM324 is giving the voltage of near around 3.89V whenever the sound signal is generated out of the port of system. Thus amplification of signal is achieved and signal conditioning of the sound signal is also done by converting it into the electrical signal. Once this voltage of 3.89V is achieved, this is helpful to drive a transistor that will drive the relay afterwards at 5V supply to run the actuator as per the generation of sound signal out of the PC port.

5.1.3 Step 3

In next step the generated signal drives the 24V operated actuator as per the 0.2V generated electrical signal using signal conditioning circuit, thus as per the image acquired matches with the image already stored or some of their feature matches the actuator will be given 24V supply and this controlling will be done using MATLAB software and thus the PLC operated system which is developed to segregate the objects will sort the objects and the whole functioning will be done automatically without any need of manual supervision.

5.2 Discussion

The recent research on machine vision system are done to make such system works incorporating with the PLC machine in industries to give more accurate results and thus the high production volume can be achieved. Right now in our project, major challenges has been faced in making of the signal conditioning circuit to handle the signal once it has been generated out of the system. That means that to make the signal work as the input to the PLC machine and control the actuation as per the output of the MATLAB software used to acquire and compare the image.

CHAPTER 6
CONCLUSION AND RECOMMENDATION

6.1 Conclusion:

During the last 15 years, the machine vision technology has matured substantially, and has emerged by becoming a very important and in some cases, an indispensable tool for manufacturing automation. Today, applications of machine vision crop up in many industries, including semiconductor industries, electronics and pharmaceutical industries, packaging and medical devices, automotive and consumer goods.

While vision technology might not have reached this point yet, recent advances in the vision industry have helped to facilitate and to accelerate vision applications in manufacturing for the near future.

From the project performed, it was obvious that machine vision technology and Vision tools together can be used for sorting objects in a factory production line. It was confirmed that out of many machine vision tools, the pattern-matching algorithm could be applied for the object sorting purpose. Also, it was clear that a simple webcam could be used for performing machine visions tasks. Because, a webcam was used for pattern matching, it is not for sure that it can be used for different machine vision applications. But, if the application is independent of different image processing tasks, it might be possible to use webcams instead of other industrial cameras.

The pattern matching was done at different times of the day; every time the score generated by the vision assistant needed adjustment for the correct pattern matching. This shows that pattern matching is based on direct correlation matrix algorithm. The score generated for the image template was 900. If the score was increased over 900, none of the objects matched the pattern; below 900 patterns matched, but if the score was below certain score, the objects which tend to be of the same pattern also matched. In that case, the aim of pattern matching failed.

Although pattern matching is not affected by lighting, it was seen that shadow formation of some other objects over the analyzed object hindered to match the pattern stored in the pattern template. So to say that pattern matching is independent of lighting might be somewhat unrealistic. It might be said that pattern matching not affected by lighting directly, but there might be some other indirect cause relating to light that affects pat-tern matching.

It is also confirmed that PLC could be integrated with MATLAB using OPC communication protocol; communication was enabled using an earphone port in this thesis. The integration of semantic PLC was illustrated in this thesis but almost all the PLCs can be integrated with MATLAB using NI OPC servers; provided there is an OPC driver for the PLC.

In this thesis document it is possible to present only a simple pattern recognition technique for the object sorting. Although the objective of sorting object using machine vision tool was met, it was realized that geometric matching tool would be more robust for sorting objects. The objects used in the project were all similar; defining only one parameter could be enough in such condition to get the result. But the case would not be the same always. The objects may have different shapes and sizes; in such cases, it is not enough to match only the pattern of the object. Measuring distances between two points, measuring diameters, etc. could be added to the application to make it more powerful and error-free.

6.2 Future Scope

Faster running hardware, more intelligent tools, much better application software development and deployment environments, these all will enable a broader and deeper proliferation of machine vision in manufacturing.

However, through recent positive advances in price, its performances, the robustness and the ease of use, machine vision technologies now have reached a point very close to what the industries and market place projected as a distant promise a few years ago.

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APPENDIX A

Code in MATLAB to acquire, compare and process the image of the object.

```
v=videoinput('winvideo', 1, 'YUY2_640x480')
v.FramesPerTrigger= 1;
preview(v);
start(v);
pause(2.0);
im=getdata(v);
imshow(im)
ImageFileName = fullfile(pwd, 'myfirstimage.jpg');
imwrite(im,ImageFileName);
a=imread('untitled_68.jpg');
b=imread('myfirstimage.jpg');
a1=im2double(a);
b1=im2double(b);
a2=rgb2gray(a1);
b2=rgb2gray(b1);
hn1 = imhist(a2)./numel(a2);
hn2 = imhist(b2)./numel(b2);
subplot(2,2,1);subimage(a)
subplot(2,2,2);subimage(b)
subplot(2,2,3);plot(hn1)
subplot(2,2,4);plot(hn2)
f = sum((hn1 - hn2).^2);
disp(f);
if (f>0.3)
[road,fs]=wavread('road.wav');
size(road)
left=road(:,1);
right=road(:,2);
soundsc(left,fs);
else
disp(0);
%if (f<0.7)
%disp(0);
%else
end
```

APPENDIX B

NPN transistor BC547 Characteristics:

NPN Epitaxial Silicon Transistor

Absolute Maximum Ratings T_a=25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CBO}	Collector-Base Voltage : BC546 : BC547/550 : BC548/549	80 50 30	V V V
V_{CEO}	Collector-Emitter Voltage : BC546 : BC547/550 : BC548/549	65 45 30	V V V
V_{EBO}	Emitter-Base Voltage : BC546/547 : BC548/549/550	6 5	V V
I_C	Collector Current (DC)	100	mA
P_C	Collector Power Dissipation	500	mW
T_J	Junction Temperature	150	°C
T_{STG}	Storage Temperature	-65 ~ 150	°C

Electrical Characteristics T_a=25°C unless otherwise noted

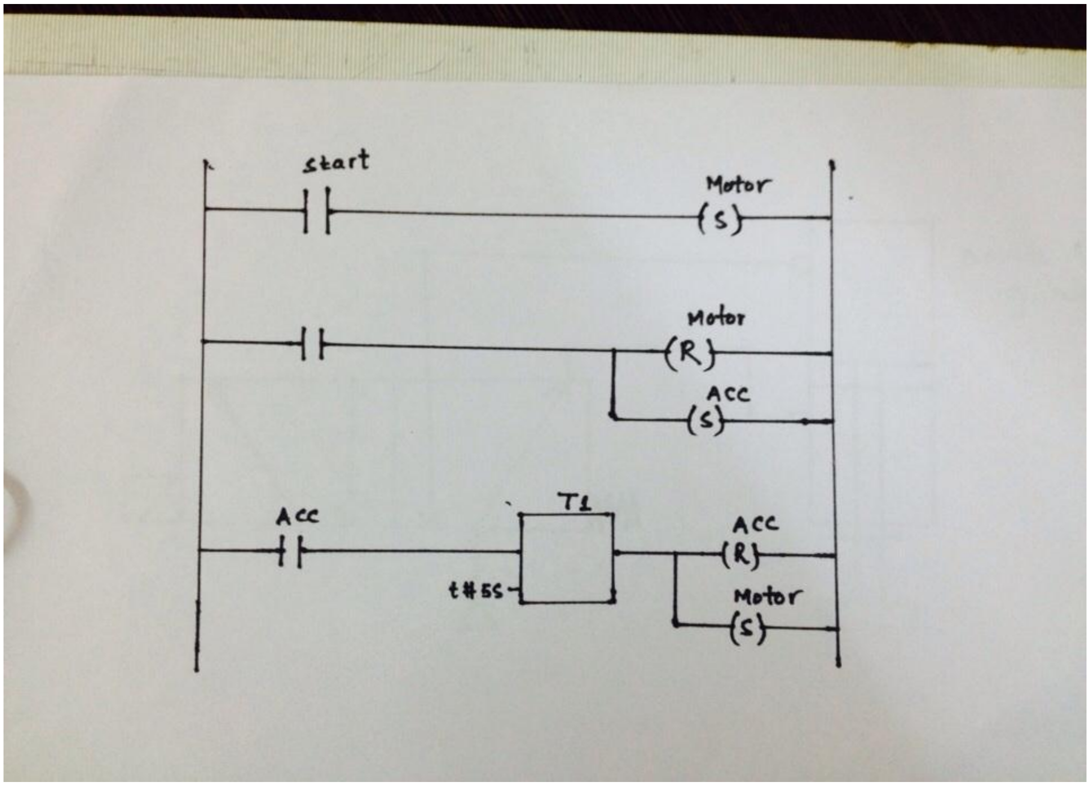
Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Units
I_{CBO}	Collector Cut-off Current	V_{CB}=30V, I_E=0			15	nA
h_{FE}	DC Current Gain	V_{CE}=5V, I_C=2mA	110		800	
V_{CE} (sat)	Collector-Emitter Saturation Voltage	I_C=10mA, I_B=0.5mA I_C=100mA, I_B=5mA		90 200	250 600	mV mV
V_{BE} (sat)	Base-Emitter Saturation Voltage	I_C=10mA, I_B=0.5mA I_C=100mA, I_B=5mA		700 900		mV mV
V_{BE} (on)	Base-Emitter On Voltage	V_{CE}=5V, I_C=2mA V_{CE}=5V, I_C=10mA	580	660	700 720	mV mV
f_T	Current Gain Bandwidth Product	V_{CE}=5V, I_C=10mA, f=100MHz		300		MHz
C_{ob}	Output Capacitance	V_{CB}=10V, I_E=0, f=1MHz		3.5	6	pF
C_{ib}	Input Capacitance	V_{EB}=0.5V, I_C=0, f=1MHz		9		pF
NF	Noise Figure : BC546/547/548 : BC549/550 : BC549 : BC550	V_{CE}=5V, I_C=200μA f=1KHz, R_G=2KΩ V_{CE}=5V, I_C=200μA R_G=2KΩ, f=30~15000MHz		2 1.2 1.4 1.4	10 4 4 3	dB dB dB dB

h_{FE} Classification

Classification	A	B	C
h_{FE}	110 ~ 220	200 ~ 450	420 ~ 800

APPENDIX C

Here is a ladder logic for the segregation process in INDRA WORKS Engg.



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