MACHINE VISION BASED
MATERIAL TENDING PROCESS

A PROJECT REPORT

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ABSTRACT

This thesis demonstrates an industrial assembly task of classifying the objects moving on a conveyor by getting the vision information from the developed machine vision system. This setup is made from an industrial robot centered flexible manufacturing cell which consists of conveyor and a material loading station with vice. Without the sensing capabilities, most of the assembly cells lack flexibility and cannot act intelligently in recognizing the workpieces. This flexibility for assembly cells was achieved through the integration of vision sensing. For this work, an assembly cell is made with ABB IRB 1410 industrial robot equipped with a two fingered gripper and a camera mounted perpendicular to the conveyor belt. In order to recognize the workpieces, low level object recognition algorithms were developed in GUI based LabView. The whole assembly cell is controlled by a PLC station and integrated with the robot. Once the workpieces are identified by the vision system, the robot will execute the predefined sequence of assembly operations controlled by PLC. The tests conducted on the developed system showed that the vision system localizes the workpieces regardless of their initial position and orientation. A simple and reliable PLC communication was developed in order to connect the components of the assembly cell and to provide a flexible process execution.

Keywords: Vision system, flexible assembly cell, LabView, Plc

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LIST OF ABBREVIATIONS

VI   -   Virtual Instrumentation

VGR   -   Vision Guided Robotics

2D   -   2 Dimensional

3D   -   3 Dimensional

MV   -   Machine Vision

VGRBP   -   Vision guided robotic bin picking

CCD   -   Charge-coupled Device

CMOS   -   Complementary Metal Oxide Semiconductor

RGB   -   Red Green Blue

USB   -   Universal serial bus

IMAQ   -   Image Acquisition

CHAPTER 1

INTRODUCTION

Industrial robots are usually designed to perform material handling, painting, welding in a flexible manufacturing workplace. The working conditions and the environment behind the operation of these tasks are well defined. If the working condition is altered, the industrial robot may not function properly. So some external sensors are necessary to enhance the robot's functionality to work in a dynamic environment. A Vision sensor is one which enhances robot's functionality in these working conditions. The images of objects of interest can be extracted from their environment, the information from these images can be computed to control the robot. The control that uses the images as feedback signals is called as vision based control. The vision system developed here involves machine vision to analyze the scene, identify and locate the specified object and provide feedback to the robot arm for subsequent operations.

In the pick and place systems using industrial robots there is a need to automate the pick and place process basically comprising of picking intended objects and placing them to a desired location. The automated pick-and-place systems mainly consist of robotic arms and sensors.

The machine vision camera is used as sensor and the primary function of them is to drive the robotic arms to the right location of desired object for picking and placing according to the robot's degrees of freedom.

The requirements for the design and development of a successful machine vision system vary depending on the application domain and are related to the tasks to be accomplished, environment, speed etc. For example, in machine vision inspection applications, the system must be able to differentiate between acceptable and unacceptable variations or defects in products, while in other applications, the system must enable users to solve guidance and alignment tasks or, measurement and assembly verification tasks.

It is a responsibility of the processing and classification units to maintain system reliability, but the effectiveness of classification depends also on the quality of the acquired images. An industrial vision system must also be robust. Thus, it should adapt itself automatically and achieve consistently high performance despite irregularities in illumination, marking or background conditions and, accommodate uncertainties in angles, positions etc.

Robust performance is difficult to achieve. High recognition and classification rates are obtained only under certain conditions of good lighting and low noise. Finally, an industrial vision system must be fast and cost efficient.

Typically, an industrial inspection system computes information from raw images according to the following sequence of steps:

1. ***Image acquisition***: Images containing the required information are acquired in digital form through cameras, digitizers etc.

2. ***Image processing***: Once images have been acquired, they are filtered to remove background noise or unwanted reflections from the illumination system. Image restoration may also be applied to improve image quality by correcting geometric distortions introduced by the acquisition system (e.g., the camera).

3. ***Feature extraction***: A set of known features, characteristic for the application domain, is computed, probably with some consideration for non-overlapping or uncorrelated features, so that better classification can be achieved. Examples of such features include size, position, contour measurement via edge detection and linking, as well as and texture measurements on regions. Such features can be computed and analyzed by statistical or other computing techniques (e.g. neural networks or fuzzy systems). The set of computed features forms the description of the input image.

4. ***Decision-making***: Combining the feature variables into a smaller set of new feature variables reduces the number of features. While the number of initial features may be large, the underlying dimensionality of the data, or the intrinsic dimensionality, may be quite small. The first step in decision making attempts to reduce the dimensionality of the feature space to the intrinsic dimensionality of the problem. The reduced feature set is processed further as to reach a decision. This decision, as well as the types of features and measurements (the image descriptions) computed, depends on the application.

For example, in the case of visual inspection during production the system decides if the produced parts meet some quality standards by matching a computed description with some known model of the image (region or object) to be recognized.

The decision (e.g., model matching) may involve processing with thresholds, statistical or soft classification.

Vision systems however are expensive to be used in applications that needs accuracy and fast response. But for tasks involving simple material handling like sorting it does not need an accurate system. So it is necessary to develop feasible vision systems for the robot to manipulate different tasks based on the application.

In the past two decades, a number of technological advancements have been made in the development of flexible manufacturing systems (FMS). A FMS can be described as a system consisting of one or more handling devices like robotic manipulators along with the robot controllers and machine tools, arranged so that it can handle different family of parts for which it has been designed and developed.

A flexible manufacturing system is a

"**Highly automated group technology (GT) machine cell, consisting of a group of workstations, interconnected by an automated material handling and storage system and controlled by a distributed computer system [Groover, 2000]**."

The flexible robot assembly cell used for this thesis consists of:

- An Industrial robot whose movements can be controlled by programming.
- A PLC station to control the overall operations
- Machine vision system which identifies the required objects from different objects on the conveyor and sends the information to the industrial robot.
- Machining center with loading through bench vice.
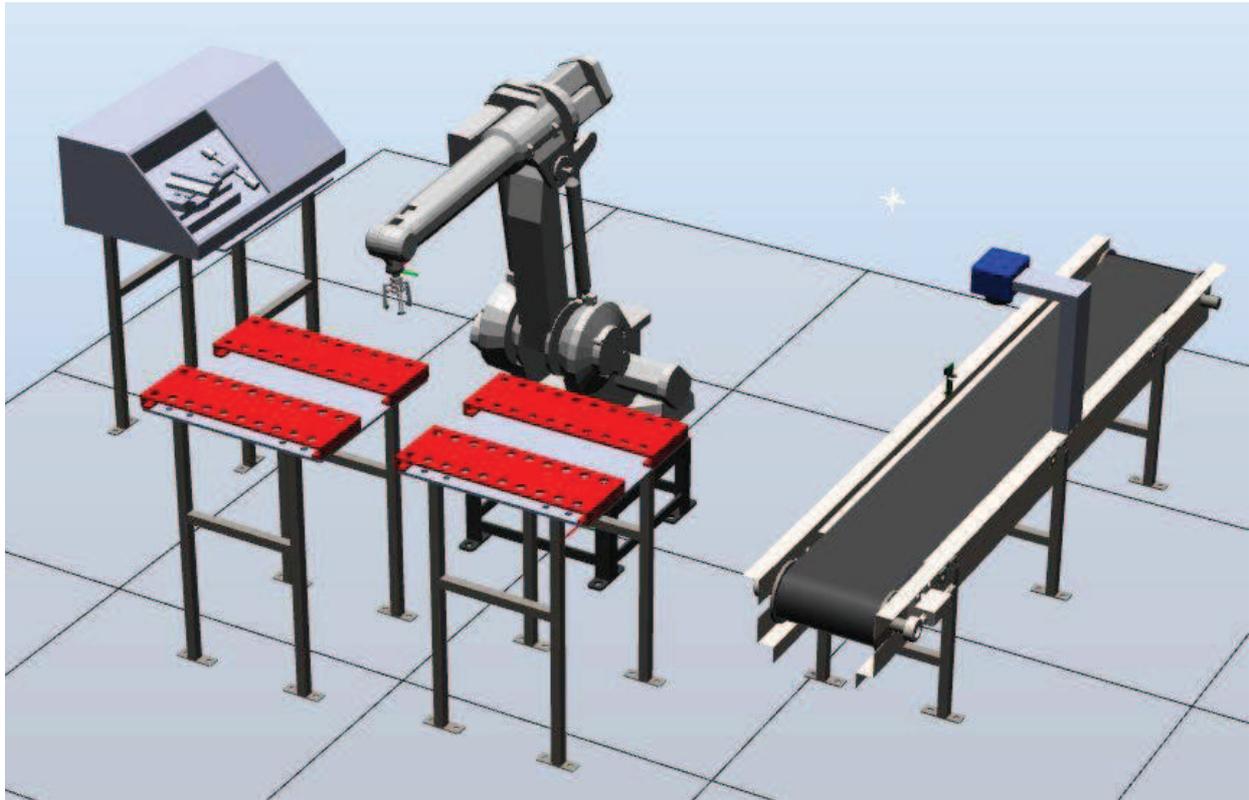
Figure 1.1 Simulated view of Robot centered FMS

Our main objective of this project is to develop a cost effective vision system using simple integration of a virtual GUI process control software (LabView) and an industrial robot system to carry out various tasks.

In order to work with less accurate tasks like sorting, picking, material handling a 2D vision system is sufficient.

Here, a 2D based low level vision control to carry out pick and place operation is developed and is used to perform some tasks based on object recognition and localization.

CHAPTER 2

LITERATURE REVIEW

SIFT BASED APPROACH: OBJECT RECOGNITION AND LOCALIZATION FOR PICK-AND PLACE SYSTEM [1]

Girish.P & Devendra S. Chaudhari. (2013)

Object recognition and localization are the basic processes of the robotic vision. A wide range of information composed of various techniques applied for the object recognition and localization is known. According to application perspective, the initiating work utilized the basic image processing techniques such as thresholding, segmentation to identify and to locate the grasping point which was the center of gravity for that object. Further it describes about the method which was **SIFT – Scale invariant transform feature** which is a feature based segmentation technique. But since there is a limitation of image acquisition through a standard webcam, they decided to recognize and localize the object based on either *Pattern matching or Edge detection*

DESIGN OF A ROBOTIC ARM FOR PICKING AND PLACING AN OBJECT CONTROLLED USING LABVIEW [13]

Shyam.R.Nair. (2012)

This paper explains about the control of robot arm for pick and place operation. It involves the conversion of coordinates into real-world coordinates using LABVIEW. The LABVIEW is designed to input the coordinates of object in the real time environment. To select the real time object, the corresponding coordinate is inputted. The action of picking or placing is also given through the LABVIEW panel. Once the robot gets the coordinates, it uses the inverse kinematics to calculate the required rotation.

TWO-FINGERED GRASP PLANNING FOR RANDOMIZED BIN PICKING [2]

Dupuis, Donna, etal (2008)

This paper involves a two fingered grasp generation and target selection for bin picking of randomized parts. They presented a way to use the evaluated list of generated grasps in the context of Vision Guided Robotic Bin picking VGRBP to (1) increase the number of pickable candidate parts, and (2) select the best part to pick from a bin of different objects.

3D VISION BASED CONTROL ON AN INDUSTRIAL ROBOT [3]

Saedan, Mana, and Marcelo H. Ang Jr(2001)

This paper investigates the relative target object (rigid body) pose estimation for vision based control. In this paper, a position-based approach is presented. The advantage of this approach is that the servo control structure is independent from the target pose reconstruction.

INFERRING GENERALIZED PICK-AND-PLACE TASKS FROM POINTING GESTURES [4]

Blodow, Nico(2006)

In this paper a simplified approach to instruct the robots to perform pick and place tasks is presented. This is achieved by inferring additional information about the environment and locations in it and based on semantic knowledge .They used the Kinect RGB-D camera mounted on a PR2 robot and the human tracking.

VISION BASED ROBOTIC INTERCEPTION IN INDUSTRIAL MANIPULATION TASK [5]

Denker, Ahmet, and Tuğrul Adigüzel (2007)

In this paper, a solution is presented for a robotic manipulation problem in industrial settings. The problem is sensing objects on a conveyor belt, identifying the target, planning and tracking an interception trajectory between end effector and the target. Such a problem could be formulated as combining object recognition, tracking and interception. For this purpose, they integrated a vision system to the manipulation system and employed tracking algorithms .The control approach is implemented on a real industrial manipulation setting, which consists of a conveyor belt, objects moving on it, a robotic manipulator and a visual sensor above the conveyor.

TOWARDS REAL TIME VISION BASED MANIPULATION OF WORKPIECES [7]

Nagel, H (1994)

This work demonstrated a combination of machine vision system and a robot that picked work pieces from a moving conveyor belt at the IITB in 1979. An area on the conveyor belt used for carrying components is illuminated by a flashlight. The location and orientation of the work pieces are determined by processing captured images. The images are thresholded and binary masks are obtained. The binary masks are compared with the specified 2D models. The position of a recognized component is revised by considering the time interval between recording the image and the picking operation

DEVELOPMENT OF A COLOR MACHINE VISION METHOD FOR WOOD SURFACE INSPECTION [8]

Kauppinen, Hannu (1999)

This paper discusses the development, implementation and performance analysis of a colour based visual surface inspection method for wood properties. In this study, defect detection and recognition methods based on colour histogram percentile features are proposed. The colour histogram percentile features were noticed to be able to recognize well wood surface defects with relatively low complexity.

ROTATION-INVARIANT PATTERN MATCHING USING COLOR RING PROJECTION [9]

Tsai, Du-Ming, and Ya-Hui Tsai (2002)

This paper demonstrates the need to develop an efficient colour matching technique so that the detection of coloured objects in a complex background can be effective and fast. For solving the problem of arbitrary orientation, they proposed a rotation-invariant representation of coloured patterns based on the colour ring-projection transformation. This represents the methods to perform colour matching based on varying colour backgrounds.

CHAPTER 3

METHODOLOGY

The block diagram of our developed machine vision system is given below

3.1 BLOCK DIAGRAM OF DEVELOPED MACHINE VISION SYSTEM
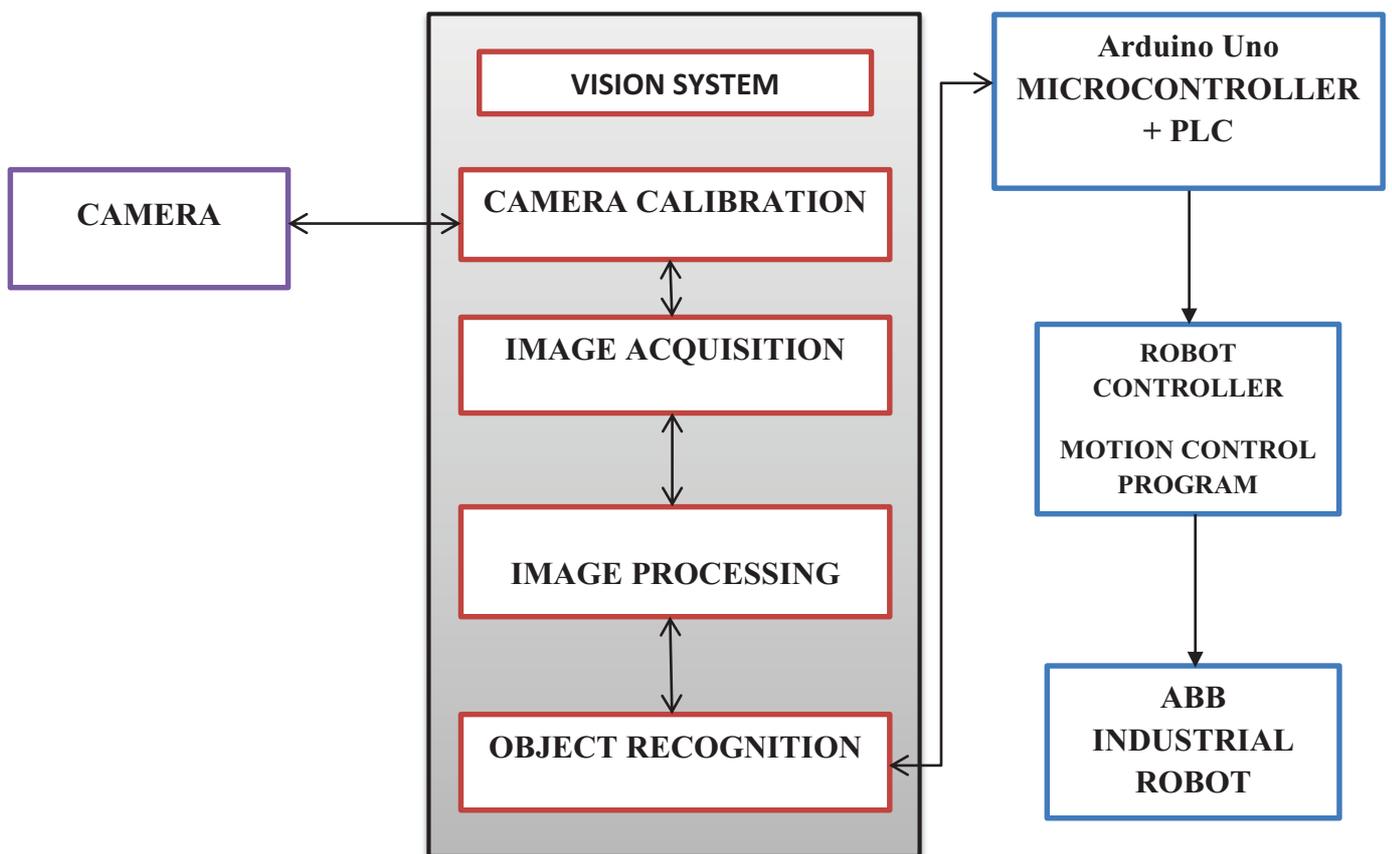
Figure 3.1 Block Diagram of Machine vision system

3.2 PROCESS FLOW CHART

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┌─────────────────────────────┐
│   VISION GUIDED ROBOTICS     │
│                              │
│         2D VISION            │
└─────────────────────────────┘
                │
                ▼
┌─────────────────────────────┐
│    CHOOSING AN IMAGE         │
│   ACQUISITION DEVICE         │
└─────────────────────────────┘
                │
                ▼
┌─────────────────────────────┐
│ CAMERA CALIBRATION FOR OBJECT│
│  DETECTION AND RECOGNITION   │
└─────────────────────────────┘
                │
                ▼
┌─────────────────────────────┐
│  IMAGE PROCESSING ALGORITHM  │
│                              │
│  PATTERN MATCHING OR EDGE    │
│         DETECTION            │
└─────────────────────────────┘
                │
                ▼
┌─────────────────────────────┐
│    SENDING INFORMATION TO    │
│ MICROCONTROLLER THROUGH SERIAL│
│ DATA COMMUNICATION AND FURTHER│
│ INFORMATION TO THE INDUSTRIAL │
│ ROBOT THROUGH PLC            │
└─────────────────────────────┘
                │
                ▼
┌─────────────────────────────┐
│   PICK AND PLACE OPERATION   │
│  DONE BY USING ABB IRB1410   │
└─────────────────────────────┘
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Figure 3.2 Flow Chart

3.3 WORKING PRINCIPLE OF MACHINE VISION BASED MATERIAL TENDING PROCESS

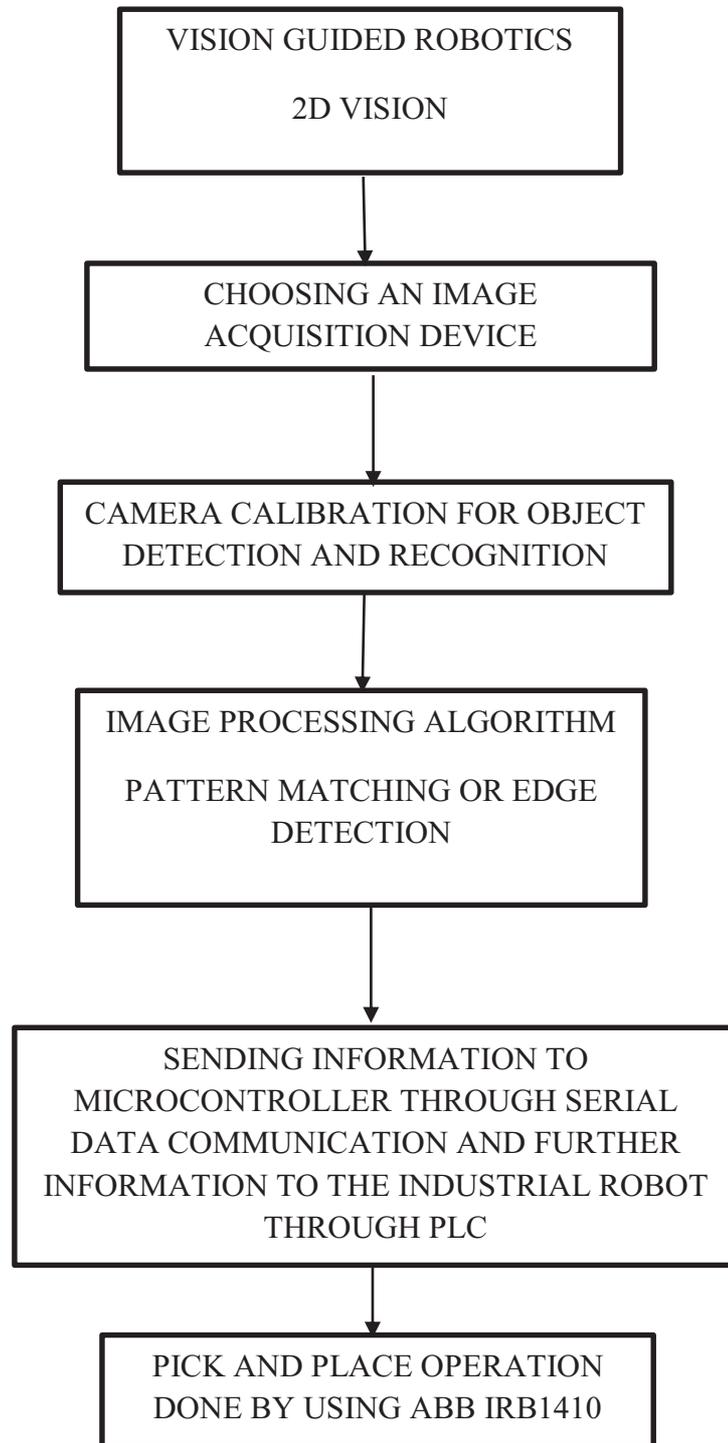The basic principle behind the working of Machine Vision Based Material Tending Process is Machine Vision. Machine Vision (MV) is the process of applying a range of technologies to provide imaging-based automatic inspection, process control and robot guidance in industrial applications. A generally accepted definition of machine vision is "**The analysis of images to extract data for controlling a process or activity".** The primary uses for machine vision are automatic inspection and robot guidance. The main categories into which MV applications fall are quality assurance, sorting, material handling, robot guidance, calibration etc.

Here in this project 2D vision system using LabView was developed. The object passed on color template matching is analyzed for detection and recognition and was done for sorting. Initially the camera was calibrated from a fixed position perpendicular to the object to be analyzed. The image is acquired and undergoes a pattern matching algorithm and would produce the output coordinates. This information is sent to Arduino microcontroller board via Serial Data Communication. Further from arduino microcontroller the control is given to the ABB Industrial Robot controller via Plc system. The data from the Labview is sent to plc through any one of the communications like Modbus, TCP/IP etc. The object is picked and placed in a position specified once after the given set of instructions get executed.

CHAPTER 4

DESCRIPTION OF VISION SYSTEM

4.1 COMPONENTS OF MACHINE VISION SYSTEM

A machine vision system typically consists of machine vision software (machine vision tools) and a camera (image acquisition device). Once the image processing is done it is necessary to communicate with control devices like microcontroller, plc etc. From that control system the control is given to the industrial robot to carry out the material tending process.

4.1.1 ILLUMINATION

Illumination refers to the light sources that are available around the object being analyzed. It is significant that the object(s) under analysis be clearly visible to the image acquisition device. It ensures that much of the information is retained in the acquired image, and no much image processing needs to be done.

The light sources may be fluorescent lights or LED lights or halogen lights, etc. LED lights are more preferred over the other types of light sources, because of their long life and less energy consumption. Depending upon the arrangement of lights, illumination can be direct or indirect.

Direct illumination involves illuminating specific regions of the object(s) being analyzed such that those regions can be identified clearly. These regions may be the Centre or edges of the object. Direct lighting can be obtained using ring lights, low angle ring lights or bar lights.

High-density LED ring lights are perfect for illumination if central region or the edges of the object needs to be analyzed.

Fig 4.1 given below is an example of direct illumination.

Figure 4.1 Direct illumination with ring lights[14]

4.2 VISION SYSTEM

THEORY OF IMAGE FORMATION

An image is a two-dimensional pattern of brightness. During the image formation process, three-dimensional scene is projected onto a two dimensional image plane.

Each point on the image plane has an image intensity and an image location. In order to understand image formation, it is necessary to find a geometric relation between points in the scene and points in the image and to explain what determines the brightness at a particular point in the image.

A digital image is composed of pixels. A pixel is the smallest picture element in an image. In grey scale images, a number represents the intensity value of the pixel. For an 8-bit digital image, pixel values can be any integer value between 0 and 255. 0 corresponds to black color while 255 corresponds to white color.

The other values are used to represent the other tones of gray. A grey scale image is represented below in Fig 4.2

Figure 4.2 Colors in 8-bit grey scale image[15].

4.3 DEVELOPMENT OF INDUSTRIAL VISION SYSTEM

Today's machine vision systems can be regarded as consisting from standard platform components. The migration to standard PC-based platforms also standardized networking, backup and storage technologies. Powerful Graphical User Interface (GUI) environments running on PCs coupled (if necessary) with image processing accelerators provide the core technologies necessary for building powerful, user-friendly machine vision environments at moderate cost. System development involves integration of software and hardware tools into a complete application. [6] Today's machine vision systems are offering far easier integration of various components originating from various software and hardware vendors.

Even conventional programming environments such as C and C++ allow for software components to be embedded into a single system. With the advent of new hardware for sensors, grabbers and computers, machine vision for industrial inspection tackles even more sophisticated problems. High complexity algorithms can nowadays be implemented for real time vision and new sensors (e.g., CMOS sensors) offering high dynamic range allow for more reliable, flexible and faster image acquisition than traditional CCD sensors, even under poor lighting conditions.

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At the same time, image-processing software has become user friendly and powerful utilizing software libraries implementing some of the most popular image processing and analysis algorithms. Most of these environments support both, visual programming in combination with flexible GUI interfaces and traditional programming.

Both programming practices can be combined to facilitate application development. Visual programming can be employed to accelerate application's prototyping whereas the final application can be implemented and optimized using standard programming methods and languages.

The current trend in industrial vision is to use commercial products instead of customized. This reduces the effort and risk in developing new products and allows for immediate exploitation of new hardware. When higher performance is needed, specialized DSP processors can be used. The selection of the appropriate software tools is of crucial importance. A software tool must have the following desirable features:

• *Multi-processing level support*: The type of processing in an industrial vision system varies from low level (e.g., filtering, thresholding), to medium level (e.g., segmentation, feature computation) and high level (e.g., object recognition, image classification etc.). An image software package must support all levels of functionality. Otherwise, different software tools must be adopted and integrated into the same system.

• *Ease of manipulation*: Graphical user interfaces, visual programming and code generation are typical features facilitating application development. Image functions must be categorized by type and scope so that even a non-expert may choose the appropriate function based mostly on what it does rather than on how it is done.

• ***Dynamic range and frame-rate support***: New types of sensors (e.g., CMOS sensors) offer high dynamic range and faster image acquisition (e.g., 16 bits per pixel instead of 8bits per pixel). Image software must support the processing of such high dynamic range images at variable frame rates.

 • ***Expandability***: The software package must be able to accommodate new or better algorithms substituting old ones. In addition, the software package must easily adjustable to new requirements of the running application without major programming effort.

• ***Dedicated hardware support***: The software package must be able to work in collaboration with hardware (e.g., DSPs, ASICs, or FPGAs) to alleviate the problem of processing speed in the case of computationally intensive applications

4.4 SELECTION OF IMAGE SENSOR

The performance of industrial vision systems are enhanced by advancements in imaging sensors . Solid-state technology has allowed the elimination of thermionic technology from the capturing of images, which was inappropriate for such applications due to slow frame rates, increased device volume, increased noise etc.[6] The introduction of solid state technology in image capturing has led to some breakthroughs in industrial vision, since they offer a number of advantages as opposed to the predecessor technology. Some of these advantages are smaller device sizes, robustness against EM noise, higher resolutions, asynchronous triggering (capturing the image the time it is needed), stop-motion techniques (capturing fast-moving objects), on-chip signal processing, robustness against changes of lighting conditions etc.

The most important technologies used in integrated imaging sensors are the Charge-Coupled Device (CCD), Charge-Injection Device (CID) and Complementary MOS (CMOS). Data bit resolution is increasing and the technology moves from the 8-bit era to the 16-bit era.

Color cameras are also advancing their capabilities mostly using CCD sensor technology. Commercially available cameras use single CCD sensor of size ¼'', 1/3'', or even ½'' chip for standard PAL/NTSC video quality.

Digital cameras are also becoming available at affordable prices, using 3 CCD chips for 24 bit true color acquisition separating the image into Red, Green and Blue channels. Using advanced CCD imager with 680K pixel capacity, they achieve high DV picture quality. Digital color cameras capture still images in standard JPEG format, whereas interconnection, communication and video transmission is often performed through the IEEE 1394 interface, also known as FireWire, which tends to become a standard.

The integration of IEEE 1394 interface into the computer's operating system is achieved via available device drivers. Camera systems achieving 640x480 frame acquisition with 24bit true color are becoming of widespread use, while megapixel cameras are gaining their share in today's market. Several criteria are used to evaluate image sensors, the most important being the following:

 a) **Responsivity**, which is a measure of signal level per unit of optical energy. CMOS sensors are slightly better than CCD in this category, due to the fact that gain elements are easier to place on their chip.

b) ***Dynamic Range*** defined as the ratio of a pixel's saturation level toits signal threshold. CCD sensors are better because they have less on-chip circuitry, which reduces the noise and increases the sensitivity of the sensor.

c) ***Uniformity***, indicating the consistency of response for different pixels under identical illumination conditions. Circuitry variations affect the uniformity of pixels on an image sensor. CMOS sensors are more sensitive to these variations because of the more additional circuitry on sensor. Newer CMOS devices have added feedback to the amplifiers to compensate these variations, but this only works well under illuminated conditions. CCD has better uniformity because the lack of any amplification in the sensor itself.

d) ***Speed of operation***, with CMOS sensors operating faster because most of the circuitry is on board. Thus, the signals communicate less distance and don't have to be piped to other chips on the printed circuit board. CCD imagers still operate adequately fast for most applications, but anticipated demanding applications will consider CMOS sensors instead.

e) ***Reliability***, in which respect CMOS sensors are superior to CCDs because of the high level of integration contained on the chip. More integration means less external connections that are susceptible to corrosion and other problems associated with solder joints in harsh environments.

Overall, CCDs offer superior image performance and flexibility at the expense of system size. CMOS imagers offer more integration, lower power dissipation, and smaller system size at the expense of image quality and flexibility.

For next-generation applications, CMOS evolves in order to get around the low–quality problem. Improvements are incorporated by the use of micro-lenses, which are small lenses manufactured directly above the pixel to focus the light towards the active portion, and the minimization of the space circuitry in the CMOS pixel.

On-chip A/D conversion and signal processing have been enabled from the advances in semiconductor technology, thus eliminating the need for separated chips. The trend is to move from the imaging sensor to the image processing sensor, with on-chip capabilities for image processing algorithms such as low-pass filtering, velocity measuring, edge detection, smoothing etc.

Although CCD is a mature technology that is commonly used in industrial vision applications, the potential of the alternative technologies (CID and CMOS) is very high, considering their on-chip intelligent and autonomous post-processing. Many applications in industrial vision require stand-alone operation, which means that there is a need for intelligent cameras providing fast processing capabilities inside the camera.

The major challenge in this direction is to maintain an easy-to-program feature by providing the end-user with commercial image processing libraries. The integration of a general-purpose processor or a DSP inside the camera offers such features, since compiling tools are widely available for these kinds of architectures.

General schematic of CCD and CMOS sensors is given below in Fig & Fig respectively.
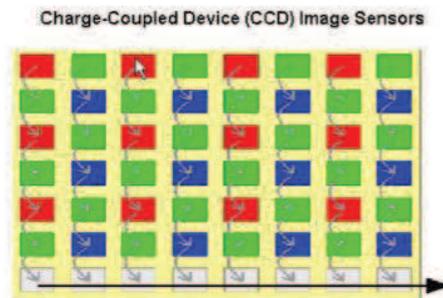

Figure 4.4.1 CCD IMAGE SENSOR[17]
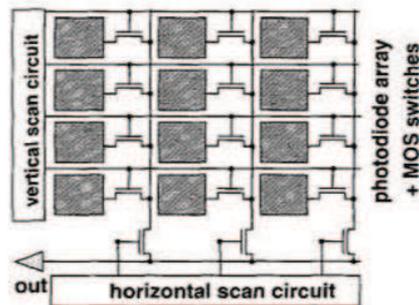

Figure 4.4.2 CMOS IMAGE SENSOR[17]

CMOS image sensors have wide advantages over CCD sensors because these sensors help to capture images at very high frame speed of more than 1000 frames/second, low cost and low power consumption.

So we chose a simple CMOS based webcam for image acquisition. This camera is well suited for machine vision applications and is well suited for integration with image processing GUI like Labview unlike CCD cameras.

4.5 DESCRIPTION OF SOFTWARES AND HARDWARE USED

LABVIEW

NI LabView is a graphical program development environment from National Instruments. Programs written in LabView are called VIs (virtual instruments). It is a powerful tool used by engineers and scientists for different kind of measurements, process controls and R&D (Research and Development). It can easily be integrated with most of the hardware, provided the driver of the hardware is installed into the computer.

4.6 NI VISION BUILDER FOR AUTOMATED INSPECTION

NI Vision Builder for Automated Inspection gives us an easy way to configure, benchmark, and deploy a system that addresses vision applications from pattern matching to code reading and presence detection to precision alignment and classification. An interactive menu-driven development environment replaces the complexities of programming, making the development and maintenance process simple without sacrificing performance or range of functionality.

4.7 ARDUINO UNO MICROCONTROLLER

An Arduino board consists of an Atmel 8-bit AVR microcontroller with complementary components to facilitate programming and incorporation into other circuits. Official Arduino's have used the megaAVR series of chips, specifically the ATmega8, ATmega168, ATmega328, ATmega1280, and ATmega2560. Most boards include a 5 volt linear regulator and a 16 MHz crystal oscillator

4.8 GENERAL DESIGN OF VISION SYSTEM

    The flow chart given below in Fig 4.5 is the general steps for designing a vision system as given by National instruments.
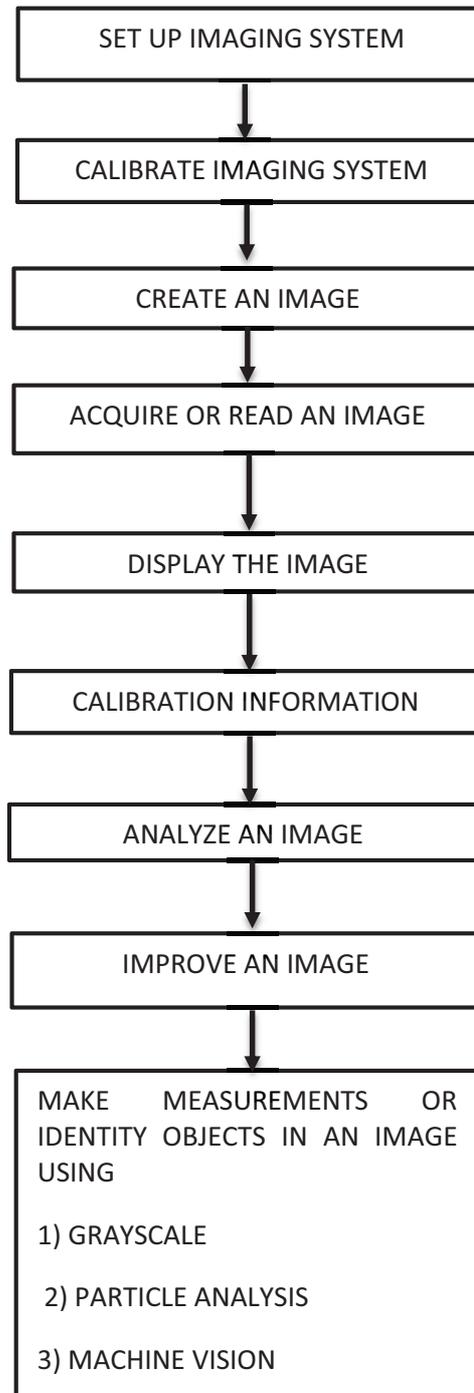
```
┌────────────────────────────────┐
│      SET UP IMAGING SYSTEM      │
└────────────────────────────────┘
                 │
                 ▼
┌────────────────────────────────┐
│    CALIBRATE IMAGING SYSTEM     │
└────────────────────────────────┘
                 │
                 ▼
┌────────────────────────────────┐
│         CREATE AN IMAGE         │
└────────────────────────────────┘
                 │
                 ▼
┌────────────────────────────────┐
│     ACQUIRE OR READ AN IMAGE    │
└────────────────────────────────┘
                 │
                 ▼
┌────────────────────────────────┐
│        DISPLAY THE IMAGE        │
└────────────────────────────────┘
                 │
                 ▼
┌────────────────────────────────┐
│     CALIBRATION INFORMATION     │
└────────────────────────────────┘
                 │
                 ▼
┌────────────────────────────────┐
│        ANALYZE AN IMAGE         │
└────────────────────────────────┘
                 │
                 ▼
┌────────────────────────────────┐
│        IMPROVE AN IMAGE         │
└────────────────────────────────┘
                 │
                 ▼
┌────────────────────────────────┐
│  MAKE  MEASUREMENTS  OR         │
│  IDENTITY OBJECTS IN AN IMAGE   │
│  USING                          │
│                                 │
│  1) GRAYSCALE                   │
│                                 │
│   2) PARTICLE ANALYSIS          │
│                                 │
│  3) MACHINE VISION              │
└────────────────────────────────┘
```

Figure 4.5 General Steps For Designing A Vision Application

CHAPTER 5

EXPERIMENTS AND RESULTS

This chapter discusses some of the main experiments that were used to test and develop the vision system . One of our key objective was to perform color pattern matching for various coloured objects moving on a conveyor belt. To carry out the experiments the experimental setup and calibration was performed.

The general setup and calibration is given below,

5.1   SETTING UP THE IMAGING SYSTEM

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 5.1
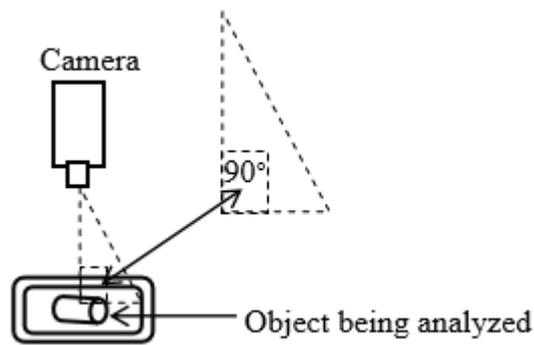
Figure 5.1 Camera installation

5.2 CALIBRATING THE IMAGING SYSTEM

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. ***Point-point coordinates calibration*** is performed.

NI Calibration involves to match image coordinates in pixels to real-world coordinates in physical units like inch.The calibration is done using an A3(420*297mm) calibration grid.
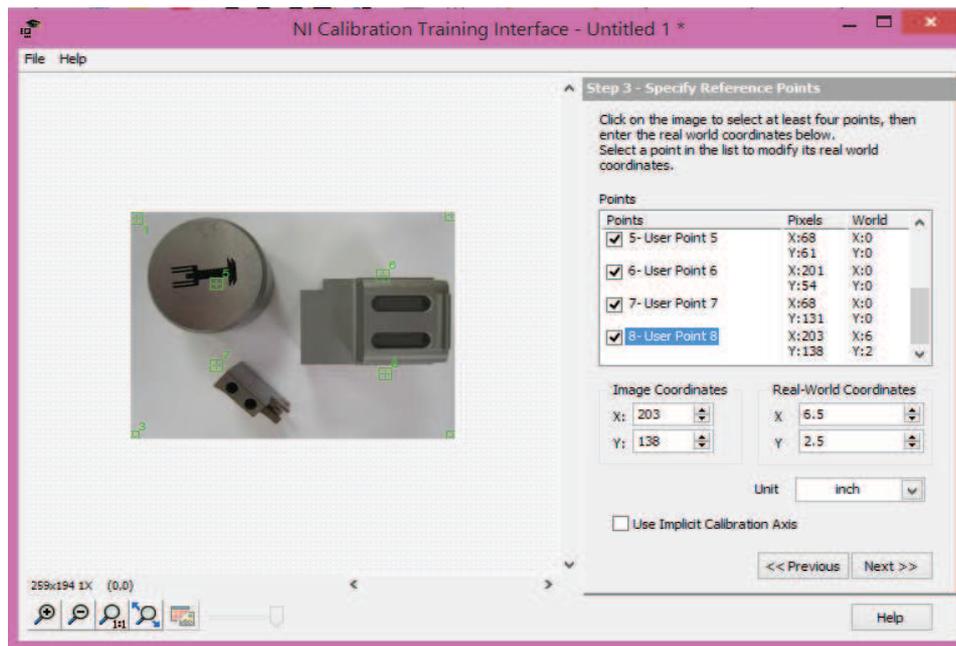
Figure 5.2 NI Calibration Training Interface

5.3 EXPERIMENTS TO TEST THE SYSTEM

The following experiments were carried out to verify certain important aspects for machine vision like presence of color, pattern of an object and the results to be verified with help of image processing using *LabView*, *NI Vision assistant*, *NI Vision builder* for automated inspection software and the result sent to *PLC* module through *Arduino Uno* controller.

5.4 COLOR PRESENCE IN A SCENE

The presence of color in an environment or scene was important to be observed in a camera used for vision system. So the camera was connected to image acquisition and it was checked for presence of color in LabView. A simple LabView VI was developed to identify different colors.

Several colors like blue, red, green, yellow, etc., were verified with image processing and webcam was eligible for performing color matching.
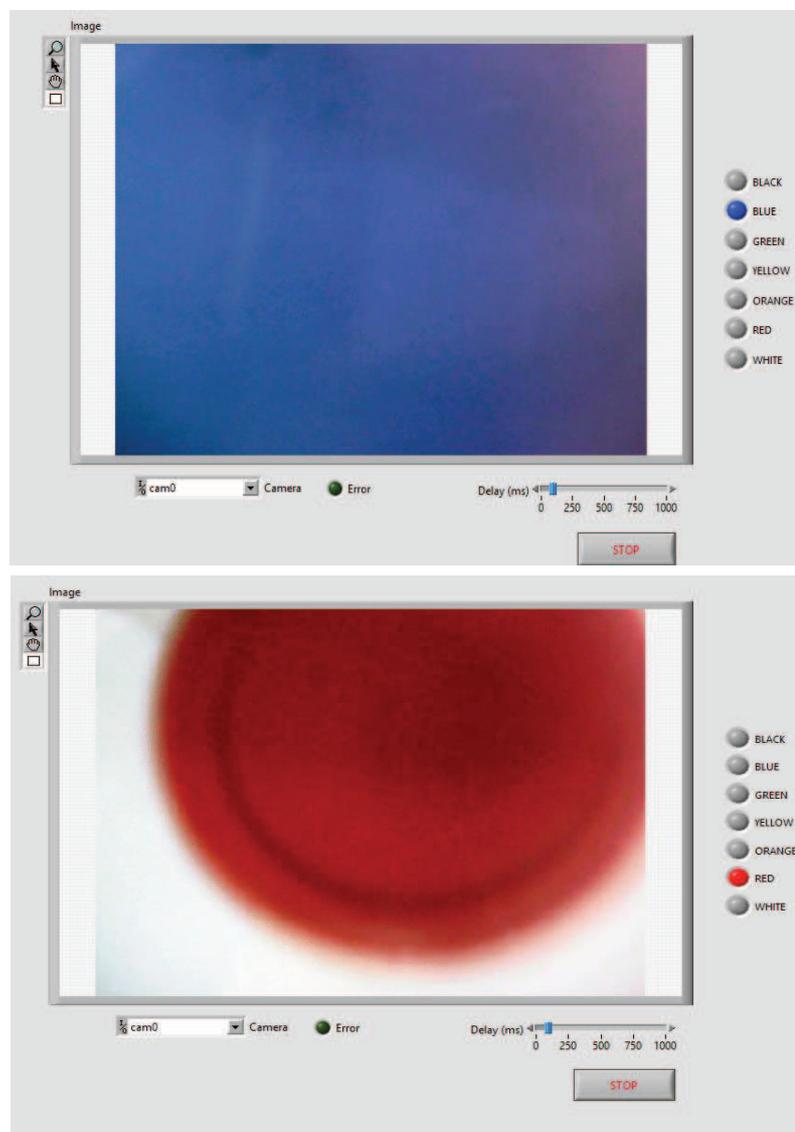

Figure 5.4 Color Matching Front Panel

5.5 CHECKING FOR PATTERN

The pattern matching algorithm was developed in Vision Builder and LABVIEW software for automated inspection and it was verified for performing image processing tasks. Once the inspection was verified it was essential to send necessary control for getting the output.

The output was either given to a microcontroller or plc. Here the output was given to Arduino Uno microcontroller and a specific output pin was accessed to trigger a 5v.

This 5v are used to trigger LED to show the inspection pass or fail. The 5v produced here as output is amplified to 24v by connecting it to relay box. This 24v can be given as input to the plc and set of executions were performed.
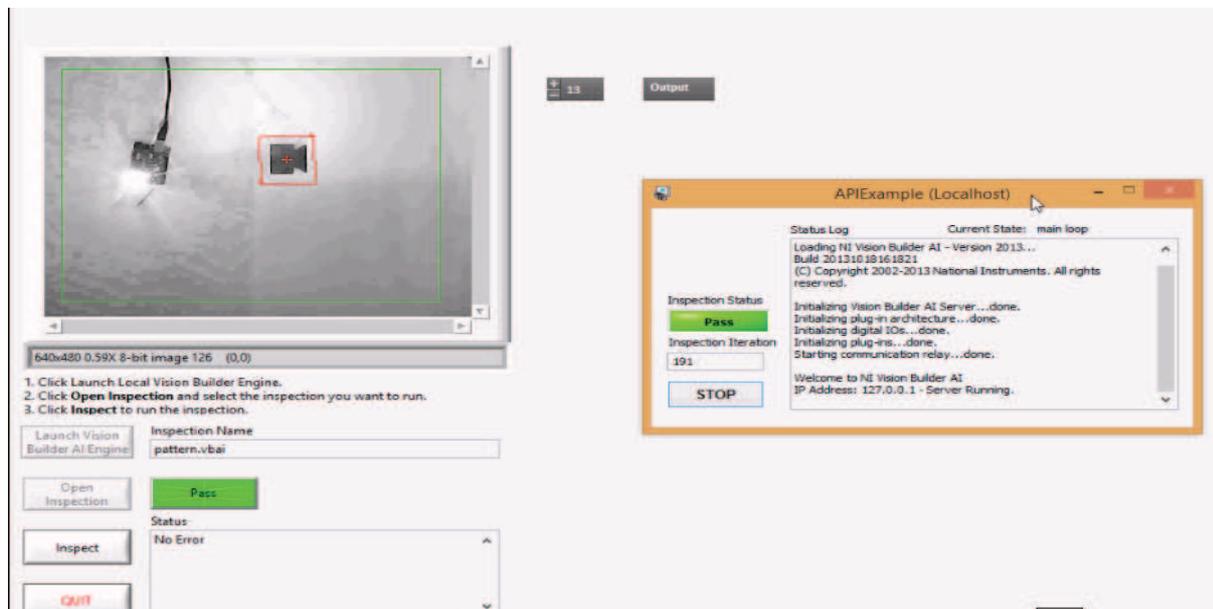

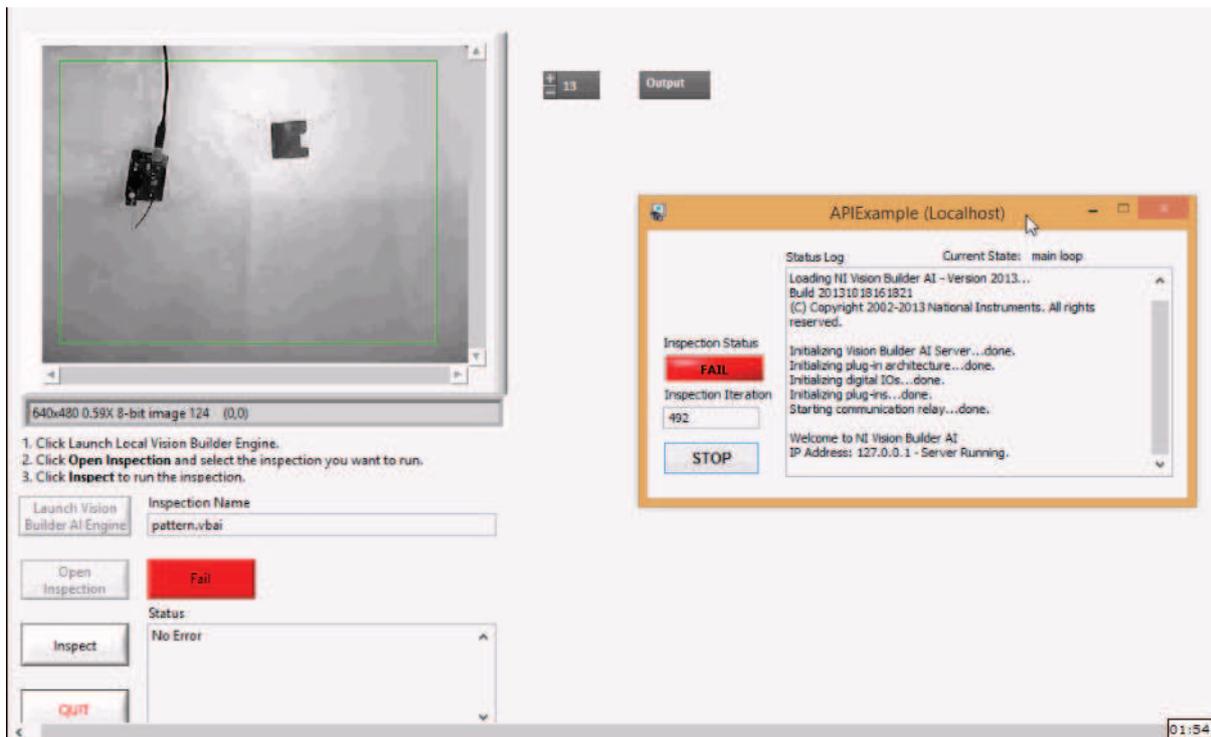**Figure 5.5.1 Pattern Matching Pass Condition**

Figure 5.5.2 Pattern Matching Fail Condition

5.6 SUMMARY

The above experimental results were helpful in conducting the final application. The final machine vision application was developed in GUI based software. An inspection in VBAI, image is acquired from a standard CMOS webcam, then the color pattern matching which includes thresholding, region selection, template creation was developed and the matching limits in the inspection was set to pass or fail based on the previous template matching state and our requirements. Then the VBAI inspection was imported into the created Labview VI. The created Labview front panel and block diagram are shown in fig 5.6.

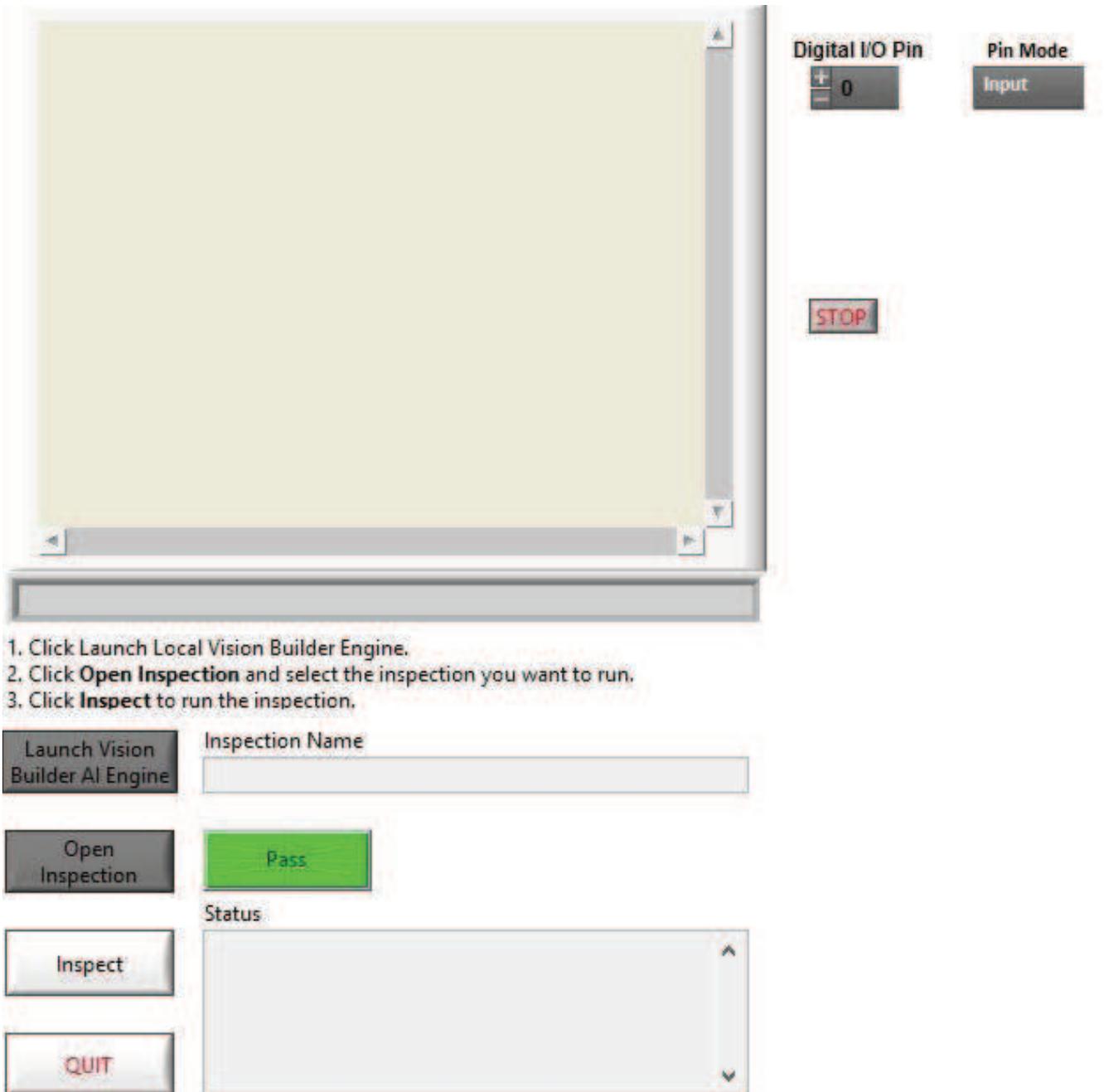## 5.7 THE FRONT PANEL OF THE CREATED LABVIEW VI INVOLVING MACHINE VISION

Figure 5.7 Front Panel of Machine vision VI

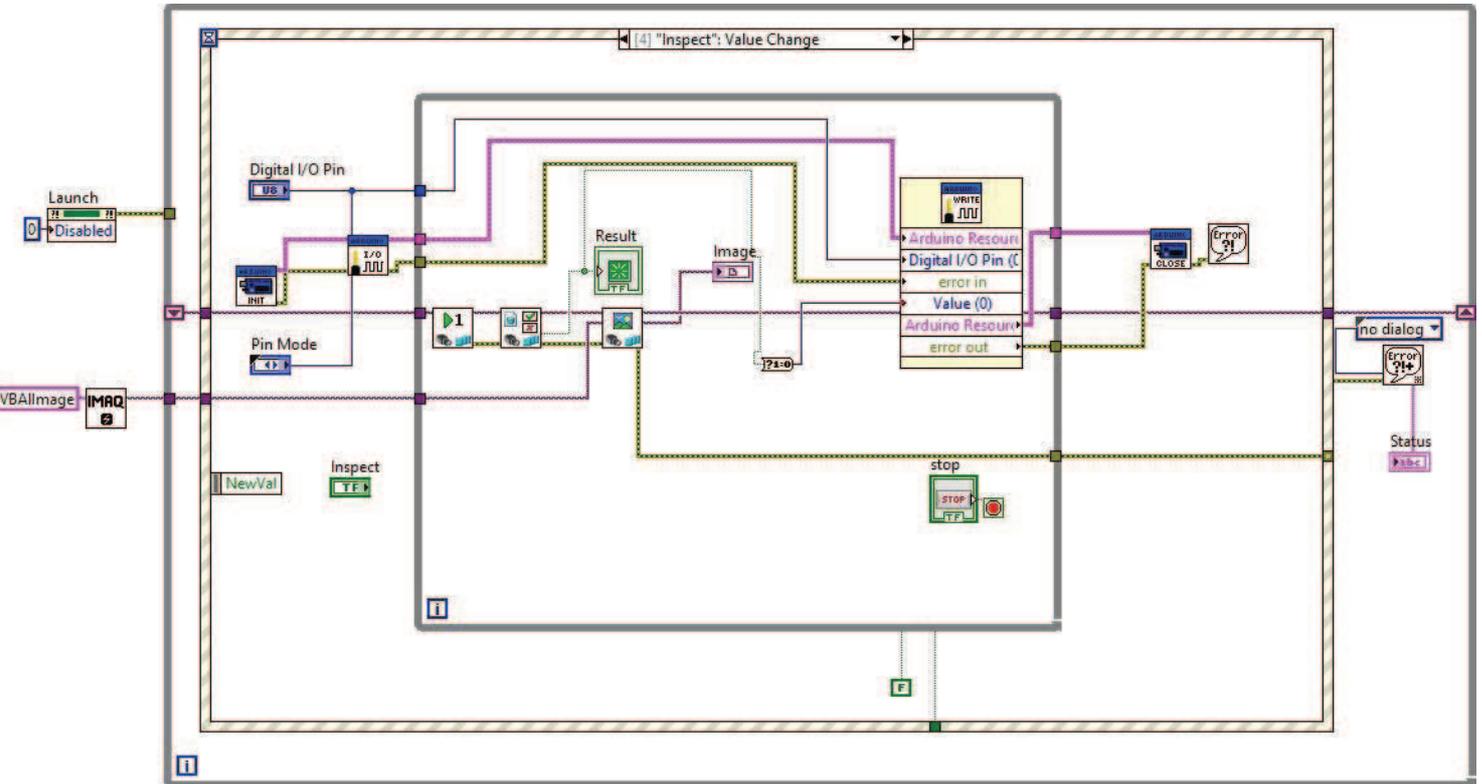## 5.8 THE BLOCK DIAGRAM OF THE MACHINE VISION VI IS GIVEN BELOW

Figure 5.8 Block Diagram of Machine Vision VI

RESULT

1) The experiment to verify whether the camera was eligible to perform color matching and it was checked by different color object.

2) The experiment to conduct pattern matching in LabView, NI Vision builder for automated inspection, Vision Assistant and sending the output to controller was verified.

3) The final experiment on the developed system was verified successfully.

CHAPTER 6

CONCLUSION

This main objective of this thesis was to develop a cost effective machine vision system that was built from low-level vision algorithms developed in Labview and Vision Builder for Automated Inspection from National Instruments. The developed vision system is used for material tending operations involving an ABB industrial robot. The whole assembly tasks were controlled by a plc system. The output from the vision system through GUI is communicated to the plc using reliable communication using several methods like digital input to the plc, Modbus RTU protocol, TCP/IP communication. The developed vision system is flexible to recognize, manipulate and assemble different types work pieces through the conveyor. The vision system successfully grasps and assembles various workpieces regardless of their initial position and orientation.

Different objects were inspected during experiments and colour pattern matching algorithm was well implemented and found to have desired results. The pick and place operation of different objects moving on a conveyor belt was performed using ABB IRB 1410 industrial robot using the developed machine system.

FUTURE WORKS

The following advancements can be made into the developed machine system,

- Stereo vision system can be developed to extract depth information from the objects which is used to work with 3D vision.

- Blob detection algorithm which compensates the background subtraction technique can decrease the vision system limitations.

- Developing trajectory planning to automatically grasp objects using the vision system.

- The camera can be mounted on the end effector to integrate the vision system with the industrial robot.

- When the end effector of the robot is close enough to the object, proximity sensors attached to the end effector of the robot can be used to determine the exact location of the object.

- Since the objects are moving, "Shape from motion" technique can be used to determine the depth. In this technique, one camera is used and the frames of the moving objects are acquired at the different time.

- The same system architecture can also be used to detect defected parts on the conveyor belt. In this case, the robot can be used to remove the defected parts from the belt.

- Using calibration information, different inspections can be done and dimensional measurements were calculated.

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APPENDIX A

Source Code For Labview Arduino Integration

```
/***************************************************************************

**  Functions

***************************************************************************/


// Writes Values To Digital Port (DIO 0-13).  Pins Must Be Configured As Outputs Before Being Written To

void writeDigitalPort(unsigned char command[])

{

  digitalWrite(13, (( command[2] >> 5) & 0x01) );

  digitalWrite(12, (( command[2] >> 4) & 0x01) );

  digitalWrite(11, (( command[2] >> 3) & 0x01) );

  digitalWrite(10, (( command[2] >> 2) & 0x01) );

  digitalWrite(9, (( command[2] >> 1) & 0x01) );

  digitalWrite(8, (command[2] & 0x01) );

  digitalWrite(7, (( command[3] >> 7) & 0x01) );

  digitalWrite(6, (( command[3] >> 6) & 0x01) );

  digitalWrite(5, (( command[3] >> 5) & 0x01) );

  digitalWrite(4, (( command[3] >> 4) & 0x01) );

  digitalWrite(3, (( command[3] >> 3) & 0x01) );
```

```
  digitalWrite(2, (( command[3] >> 2) & 0x01) );

  digitalWrite(1, (( command[3] >> 1) & 0x01) );

  digitalWrite(0, (command[3] & 0x01) );

}

// Reads all 6 analog input ports, builds 8 byte packet, send via RS232.

void analogReadPort()

{

  // Read Each Analog Pin

  int pin0 = analogRead(0);

  int pin1 = analogRead(1);

  int pin2 = analogRead(2);

  int pin3 = analogRead(3);

  int pin4 = analogRead(4);

  int pin5 = analogRead(5);

  //Build 8-Byte Packet From 60 Bits of Data Read

  char output0 = (pin0 & 0xFF);

  char output1 = ( ((pin1 << 2) & 0xFC) | ( (pin0 >> 8) & 0x03) );

  char output2 = ( ((pin2 << 4) & 0xF0) | ( (pin1 >> 6) & 0x0F) );

  char output3 = ( ((pin3 << 6) & 0xC0) | ( (pin2 >> 4) & 0x3F) );

  char output4 = ( (pin3 >> 2) & 0xFF);

  char output5 = (pin4 & 0xFF);

  char output6 = ( ((pin5 << 2) & 0xFC) | ( (pin4 >> 8) & 0x03) );
```

```
  char output7 = ( (pin5 >> 6) & 0x0F );

  // Write Bytes To Serial Port

  Serial.print(output0);

  Serial.print(output1);

  Serial.print(output2);

  Serial.print(output3);

  Serial.print(output4);

  Serial.print(output5);

  Serial.print(output6);

  Serial.print(output7);

}

// Synchronizes with LabVIEW and sends info about the board and firmware (Unimplemented)

void syncLV()

{

  Serial.begin(DEFAULTBAUDRATE);

  i2cReadTimeouts = 0;

  spiBytesSent = 0;

  spiBytesToSend = 0;

  Serial.flush();

}
```