FIRAT UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
TÜRKİYE

DESIGN AND SORTING OF AN OBJECT IDENTIFICATION ON MACHINE VISION BY USING LINE SCAN CAMERA

Zeravan Mosa MOSA

Master's Thesis

DEPARTMENT OF COMPUTER ENGINEERING
Program of Graduate School of Natural and Applied Sciences

JULY 2021

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Title:	Design And Sorting of An Object Identification On Machine Vision By Using Line Scan Camera
Author:	Zeravan Mosa MOSA
Submission Date:	27 May 2021
Defense Date:	02 July 2021

THESIS APPROVAL

This thesis, which was prepared according to the thesis writing rules of the Graduate School of Natural and Applied Sciences, Fırat University, was evaluated by the committee members who have signed the following signatures and was unanimously approved after the defense exam made open to the academic audience.

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Chair:	Assoc. Prof. Dr. İlhan AYDIN Firat University, Faculty of Engineering	Approved
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This thesis was approved by the Administrative Board of the Graduate School on

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Assoc. Prof. Dr. Kürşat Esat ALYAMAÇ
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DECLARATION

I hereby declare that I wrote this Master's Thesis titled " Design And Sorting of An Object Identification On Machine Vision By Using Line Scan Camera" in consistent with the thesis writing guide of the Graduate School of Natural and Applied Sciences, Firat University. I also declare that all information in it is correct, that I acted according to scientific ethics in producing and presenting the findings, cited all the references I used, express all institutions or organizations or persons who supported the thesis financially. I have never used the data and information I provide here in order to get a degree in any way.

02 July 2021

Zeravan Mosa MOSA

PREFACE

I would like to dedicate this dissertation to my family. A special dedication to my mother and my father, who encouraged me to further my study and career, and who also, taught me to never stop setting and reaching newer and bigger goals. I dedicated to my dear supervisor Prof.Dr. Erhan AKIN

Zeravan Mosa MOSA
ELAZIG, 2021

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ABSTRACT

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This research represents designing a system to identify objects on a conveyor belt using machine vision. In the present study, a machine vision based on one line scan sorting was developed, the purpose being to sort objects based on various stages of maturity. Many different methods are available for object identification. But it design a system that separates and counting them. Different objects placed on the conveyor belt moves along, and a camera placed above the belt takes real-time video and feeds it to the MATLAB software for processing the object to compare with the basic template object. The vision camera understands an object based on its physical attributes, such as shape and size, to effectively control the hardware, which will be used in this work. Besides, the number of objects of a particular section that cross the conveyor to demonstrate the identification of moving objects is counted and displayed. For identifying a good object, the wavelength data is used, while determining how to match the geometric patterns and identify the dimensions, and edge detection is applied. The ability to count specific attributes of objects is tested in different test paths. The sorting of objects using machine vision was performed using an algorithm of pattern matching. A pattern image template was built and stored in a computer's memory. The vision application investigates the image and transfers it to the classifier if the received image matches the model image or not matches. In the conclusion part of the thesis, the results are discussed over the experimental data.

Keywords: Machine vision, Object sorting, Line scan camera, Design, MATLAB software

ÖZET

Çizgi Tarama Kamerası Kullanarak Makine Görmesi Üzerine Bir Nesne Tanımlamasının Tasarlanması Ve Sınıflandırılması

Zeravan Mosa MOSA

Yüksek Lisans Tezi

FIRAT ÜNİVERSİTESİ
Fen Bilimleri Enstitüsü

Bilgisayar Mühendisliği Anabilim Dalı
Fen Bilimleri Enstitüsü
Temmuz 2021, Sayfa: xii + 68

Bu araştırma, makine görmesi kullanarak, konveyör bant üzerindeki nesneleri tanımlamak için bir sistem tasarımı sunmaktadır. Mevcut çalışmada, çeşitli olgunluk aşamalarına göre nesneleri sıralama amacı ile tek çizgi tarama sıralaması bazlı bir makine görme geliştirilmiştir. Nesne tanımlaması için birçok farklı yöntem mevcuttur. Fakat nesneleri ayıran ve sayan bir sistem tasarlanmıştır. Konveyör bandı üzerine yerleştirilen farklı nesneler hareket ederler ve bandın üstüne yerleştirilmiş bir kamera gerçek zamanlı video çekip, nesneleri temel şablon nesneleri ile karşılaştırmak için MATLAB yazılımına aktarır. Görüş kamerası, bu çalışmada kullanılacak olan donanımı etkili bir şekilde kontrol etmek için objeyi şekil ve boyut gibi fizikler özelliklerine bağlı olarak anlar. Ayrıca, hareketli nesnelerin tanımlanmasını göstermek için konveyörden geçen belirli bir bölümdeki nesneler sayılır ve görüntülenir. Bir nesneyi tanımlamak için dalga boyu verileri kullanılırken, geometrik desenlerin nasıl eşleştirileceğini ve nesnelerin boyutlarını tanımlamak için kenar algılaması uygulanır. Nesnelerin belirli özelliklerini işleme alma yeteneği farklı test usulleriyle test edilmiştir. Makine görme kullanarak nesnelerin sıralanması, bir model eşleştirme algoritması kullanılarak gerçekleştirilmiştir. Bir desen görüntü şablonu inşa edilmiş ve bilgisayar belleğinde depolanmıştır. Görme uygulaması görüntüyü inceler ve eğer model görüntü ile eşleşirse veya eşleşmezse, sınıflandırıcıya aktarır. Tezin sonuç bölümünde deneysel veriler üzerinden sonuçlar tartışılmıştır.

Anahtar Kelimeler: Makine görmesi, Nesne sıralama, Çizgi tarama kamerası, tasarım, Dizayn, MATLAB yazılım

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ABBREVIATIONS

AIA	: Automated Imaging Association
CCD	: Charge-Coupled Device
CMOS	: Acute Myeloid Leukemia
COTS	: Commercial Off-The-Shelf
DOF	: Depth o Field
DPI	: Dots per Inch
DSC	: Digital Still Camera
FF	: Full Frame
FFT	: Fast Fourier Transform Filter
FOV	: Field of View
FT	: Frame Transfer
GUI	: Graphic User Interface
JIT	: Just-In-Time
LPI	: Line per Inch
MV	: Machine Vision
OCR	: Optical Character Reader
PPI	: Pixel per Inch
SNR	: Signal-to-Noise Ratio
SPI	: Sample per Inch
TDI	: Time Delay and Integration
WIP	: Work-In-Process

1. INTRODUCTION

Machine vision gives the computer with eyes and ears. The eyes are the most critical organs of the human body, and our abilities depend mainly on our ability to see, distinguish, and separate objects. Most professions depend on our vision. Machine vision does not mean design and sketch; indeed, it identified with the innovation of view; it made sense. Cameras offer PCs or devices the ability to see and distinguish and recognize elements or circumstances and decide the right options in the same way. Study progress of strategies and methods that allow the machines to translate digital images into m / c vision [1].

Machine vision refers to the mechanical use of visual innovation. It represents the understanding of the images acquired to control the forms of creation. In a few of previous years, it has become one of the fundamental innovations in mechanical computerization, which is used as part of all assembly industries. Occasionally, the term artificial vision is also used to indicate applications of non-mechanical. A feasible framework of vision should represent the scene with an available management time as in recognition of biometric examples [2].

Over the past 15 years, innovation in machine vision has improved rapidly, becoming essential and, more often than not, a necessary device for robot assembly. Nowadays, machine vision applications are obtainable in several commercial companies, containing semiconductors, pharmaceuticals, packaging, car, products for the shopper and gadgets [2].

The use of machine vision for the separation of objects is not an unknown concept. The detection of objects in transport is a widespread industrial problem. Model-based recognition methods can use if all objects are the same or with few differences. Recycling plants, bottles, plastics, and other materials require classification. Inspect the objects of the fixed chamber mounted on the transport system used. One has to agree if a pixel fits to an object or a background [3].

Line-scan cameras, as 2-dimensional imaging devices, have characteristics of high resolution and high frame rate. These characteristics provide new possibilities for the measurement of high-speed continuous moving objects with higher accuracy. Therefore, line-scan cameras have been widely used in vision measurement instead of matrix cameras, especially in real-time applications [4].

The image detection process is defined as the identifying and recognition of the object or the feature in the video and digital video. In other words, it is the technique of computer vision for locating the objects instances in any images or videos. This can be done by using the Leverage machine learning and deep learning algorithms, which produces final results. When a human looks at an image/ picture or any video, we recognize and identify the object in just a glance. But now this can be done by using the computer software i.e. MATLAB [5].

As we use machine learning or machine vision, so it is defined as the approach for identifying the image or picture from video, in which the key features or factors are extracted from the image and these keys factors are provided to a machine vision for a new model. This approach is very effective for image identifying or detection or recognition because this approach includes a technical computing environment for the analysis of the data, and data visualization, and development of the algorithm [2].

Machine vision is the utilization of PC vision to industry and assembling. Two significant determinations in any vision framework are the affectability and the goal. The better the goal, the more bound the field of vision. Affectability and goal are related. All different elements are held consistent, expanding the affectability lessens the goal, and improving the goal decreases the affectability. One of the most widely recognized utilization of Machine Vision is the review of produced merchandise, for example, semiconductor chips, autos, food, and drugs.

Machine vision is designed to process images in real-time. This means that image processing occurs concurrently with the acquisition of the image. As a result, it provides a real-time representation of a real world image. It removes the three-dimensional datum about an object from its two-dimensional image.

Additionally, device and software communications are commonly used in industries. Through the advent of communications and networking technologies, various computers, tools, and applications used in various industries can now be related. Today, various networking protocols, such as Ethernet, are used in different industries.

1.1. Aim & Objectives

This thesis performs to illustrate machine vision tools like (Line scan camera) for sorting objects and using MATLAB software to capture a pattern-matching image used to objects of sorting. The first step in a machine vision application is pattern matching. In this study project needs just two requirements; damaged objects and correct objects for sorting of objects. So, if the patterns of the objects are only matched it should be enough. Pattern matching is simple to implement since it is not disturbed by illumination, motion, or noise, as experts have said.

This thesis aims to create code in MATLAB that can be used to classify objects with varying refers for example shape and size. The work's primary objectives involve the following:

- The objects on a conveyor belt need to be identified and shown as indicators with a component count index using a vision camera.
- Size and shape need to be recognized using a variety of image recognition techniques, such as edge detection and pattern matching.

- Separating objects into different categories.
- Counting subject.
- Counting the total number of objects.

1.2. Problem Statement

There are some technical reasons for this problem. The first one is that as object dries some wrinkles and crease appears on the outer surface of the object. The second reason seems while passing through the machine two or more objects stuck to each other or overlap. The third problem refers to a type of object contamination. The last one related to the faults originated by machine vision systems refers to the nature of the aflatoxin.

1.3. Literature review

Literature review deals with image detection, image identifying and recognition as well and applications of image detection using the technique of machine learning or machine vision. It is describing that the literature survey on MATLAB especially based on image detections/ identifying as a vast number of applications in the machine world. Many articles and papers in the open literature about the use of vision systems in object sorting and identification operations in the industry are available. The next is a sampling of the literature in this field.

Automated date fruits sorting device study focused on different aspects of its capacity to satisfy customer needs. The system took the form of a conveyer belt in which dates were transported and a camera to capture their image. An appropriate actuator is driven by an engine operated as the sorting framework [6].

A machine vision-based method proved for classifying and sorting aquatic products. The visual quality of fish, fish fillets, and a variety of other marine items were determined using machine vision (scallop, oyster, and shrimp) [7].

Vision-based task selection and placement strategy. The CCD camera is used to capture images all the time the conveyor goes a short distance. Next image preparation of the images, position, and states of items was dead set, and the target following technique was used to do a sorting process [8].

A method for measuring the fat content of poultry meat using a vision system. Chicken and turkey bodies were selected at random, and comparisons between the content of white spots obtained through vision framework and solid substance determined via the reference Soxhlet method were produced [9].

An automatic removal method of fruit vision. The system is based on improving the threshold algorithm OHTA color space. The organic product articles were naturally strategy and the yields were demonstrated as binary images [10].

The basic and simple object detection system was purposed. Different toolboxes and functions are used at various points during the research and implemented and using simple MATLAB code to detect the image as a result. This research also helps with future work and helps new researchers as well [11].

In this research it is proposed that the color of the image is properly found not following the required then it will be rejected and if the color is properly found in the image according to the requirements then this image is selected. In this research, the machine vision camera shows better resolutions, and the capacity of clearness and zooming property helps us to sort or detect the image or picture according to the requirements [12].

In this paper developed a technique of fuzzy which is based on the algorithm detection of the edge. In which "Image processing" is the main concept used as artificial intelligence. In this research, a comparison was also made between the Fuzzy Ruled-based technique and the Sobel edge detection techniques [13].

2. MACHINE VISION TECHNOLOGY

In the world of science and technology, machine vision (MV) is a relatively new specialty. It has been gaining popularity as a valuable industrial tool for approximately 20 years and is accelerating its development [14]. Machine vision has traditionally been used in industries for measurements, counting, quality management, item sorting, and robotic guidance. It has been a valuable method in product inspection and review due to its potential to significantly minimize costs, commitment, and time while maintaining a high degree of accuracy and reliability.

Machine vision processing advancements are inextricably linked to the development of optical technologies. The late 1800s saw the introduction of modern time optics, whilst the 1980s saw the emergence of a new period of optics known as optical image processing and machine vision systems.

Automated Imaging Association (AIA) defines machine vision as both applications of non-industrial and industrial in which a mixture of software and hardware guides devices in performing their functions centered on the capturing and analysis of images [15]. Although industrial machine vision employs many of the same algorithms and methods as educational/academic and military/governmental computer vision implementations, the restrictions are distinct.

Industrial vision systems need higher levels of robustness, durability, and flexibility than academic/educational vision systems and are usually often less expensive than those used in military/governmental applications. While also, machine vision of industrial entails low prices, reasonable precision, good robustness, high durability, and excellent mechanical and thermal flexibility. Figure 2.1; represent the basic structure of machine vision.

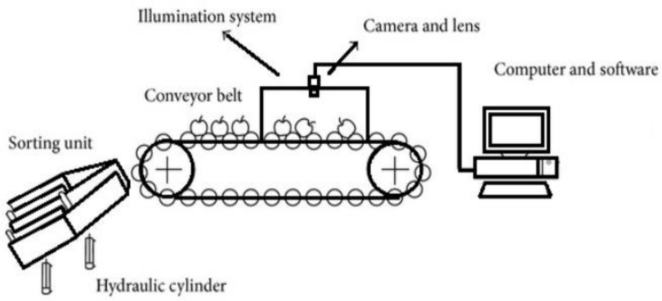

Figure 2.1. The basic structure of machine vision

2.1. Machine vision system

The typical configuration of a machine vision device is depicted in Figure 2.2, which is to be seen bottom-up. This figure is purposefully formed like a pyramid centered on the image acquisition technique. This level's acceptability and consistency are critical for the entire sequence of visual inspection activities.

The quantity and quality of information present in acquired image data are dependent entirely on the image acquisition step. Without this stage, information that is not obtained can be retrieved only with difficulty, if at all, through subsequent image processing measures, regardless of how much work is expended on them. Numerous visual inspection systems that have failed in operation have violated this basic guideline [16].

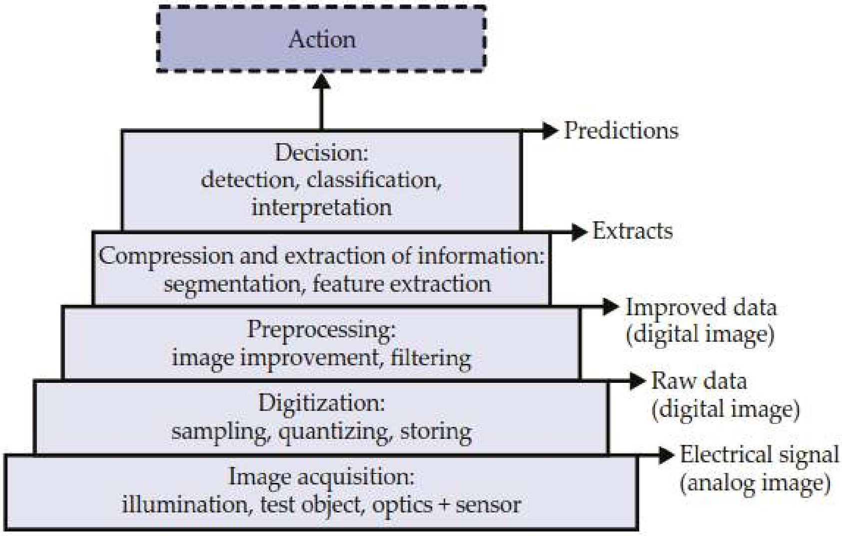

Figure 2.2. The processing chain of machine vision systems[16]

The light released by the light source communicates with the test sample, travels through the imaging optics, and then arrives at the sensor where that is converted to an electrical signal. This analog signal, which is usually a voltage, is discretized and constrained in terms of both space and amplitude. It can be stored as a digital image and handled by a machine in this form. However, in addition to the details required for visual analysis, this raw data also includes undesirable and irrelevant components such as noise, homogeneities, and so on. The resulting image reconstruction procedure attempts to preserve pertinent details whilst compensating for the insignificant signal components.

As a result, enhanced image data is collected that is segmented into meaningful regions (segmentation) and/or analyzed to retrieve task-relevant parameters (features). Finally, based on this simplified knowledge, judgments may be taken about defect identification (e.g., classification of various objects), or perception (e.g., assumption of output parameters), depending on the visual inspection mission.

Following that, a direct step may be taken in response to and per the verdict, including discarding or holding the test object, or selectively modifying output conditions, for instance.

It cannot be emphasized enough how a well-designed image acquisition system may have a significant effect on an automated visual inspection system's capability. The enormous number of optical and geometrical degrees of freedom inherent in the image acquisition setup (light source, test object, optics, and sensors) creates a vast design area of numerous possibilities, however, can be utilized systemically only with the requisite information and a concept that is appropriately tailored to the issue at hand. The effort invested at this point is usually a successful investment in the visual inspection system's final capability. For certain tasks, it is also possible to acquire images that are so expressive and readily interpretable throughout the retrieval phase that the resulting image processing measures are nearly negligible. Three instances will demonstrate this.

To capture images, machine vision systems rely on secure digital sensors and special optical equipment in industrial cameras, thus allowing computer hardware and software to process, evaluate, and calculate various functions to make decisions.

View a brewery's fill-level inspection scheme as an example Figure 2.3. Each bottle of juice is inspected by a sensor, which activates a vision device to flash a strobe light and photograph the bottle. After capturing and saving the picture in memory, vision software analyses or analyzes it and generates a pass-fail answer depending on the bottle's fill stage. If the device identifies an incorrectly filled container as a miss, a diverter is notified to refuse the bottle. On a display, an operator will monitor rejected bottles and current process statistics.

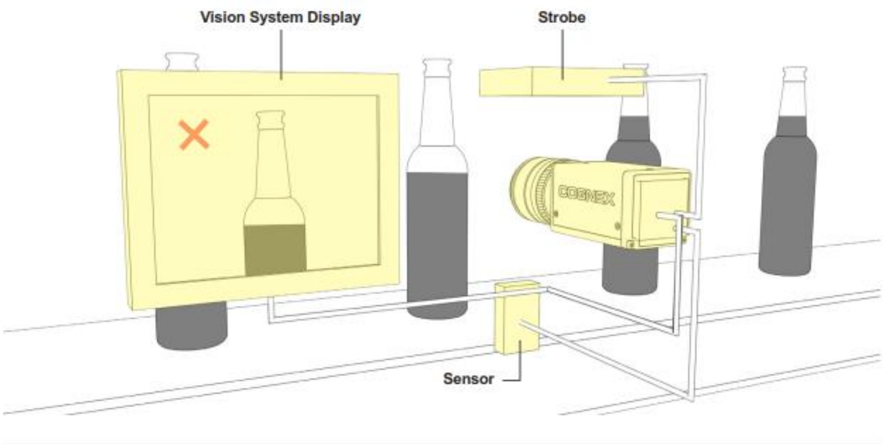

Figure 2.3. Inspecting the amount of filling in a bottle as an illustration

In this case, the fill-level inspection method allows for only two potential answers, defining it as a system of binary:

- Pass when the product is of high quality .
- If the product is bad, Fail.

Systems of machine vision may also conduct objective calculations, such as calculating the distance between two spark plugs or guiding a robot in aligning components during a production operation. Figure 2.4, illustrates how a machine vision device can be used to determine if oil filters pass or fail (right) and to determine the width of a bracket's middle tab (left).

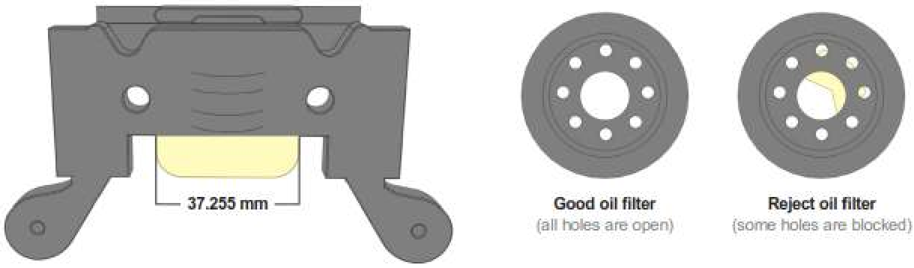

Figure 2.4. Real-time measurements and inspections like a machined bracket (left) or oil filters (right)

2.2. Machine vision application

Through recent technological advancements, computer vision can be used to identify various properties of artifacts such as their heights, areas, and so on. Machine vision used in security, automotive, and medical applications. A machine vision application developed for one purpose can be used for another yet related purpose; for example, an application developed for object sorting might be used for object detection or identification of geometric [2][16]. Table 2.1, illustrates many machine vision implementations in a variety of areas.

Table 2.1. Application of machine vision

Fields of Medical	Fields of Industrial	Fields of Security
Diagnosis of dermatological	Sorting of object	Face recognition
Treatment of skull abnormalities in children	Guidance of robotic	Object tracking
	Detection of object	Security administration
	Object inspection	
	Edge and Pattern detection	

The word "machine vision" is a broad one. Numerous mathematical theories, image acquisition, interpretation and image processing, among others, comprise the whole field of computer vision. As a result, identifying machine vision is a daunting challenge when these factors are taken into account. Various pages may be published for any of these distinct subjects [16]. As a result, the thesis document's primary focus was on developing a basic machine vision program utilizing the platform. MATLAB was used to complete this thesis project.

Usually, the first stage of any machine vision application, whether it is a straightforward assemblage verification or a sophisticated three-dimensional robotic bin-picking, is for pattern matching technology to locate the target or function of interest inside the camera's field of view. Locating the desired object often dictates performance or loss. If the software tools of pattern matching are unable to specifically locate the component inside the image, they would be incapable of guiding, identifying, inspecting, counting, or measuring the part. While locating a component can seem straightforward, variations in its presence in real manufacturing environments may render this process incredibly difficult Figure 2.5. Though vision systems are trained to identify objects based on their patterns, even the most tightly regulated processes allow for some variation in the presence of a part Figure 2.6.

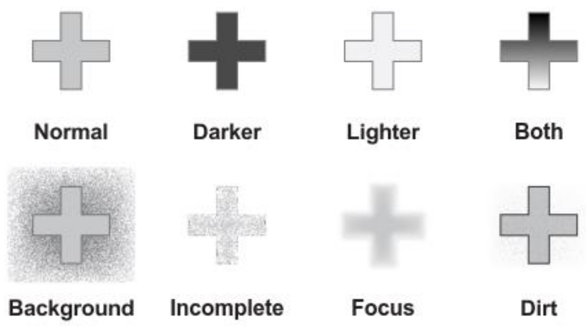

Figure 2.5. Changes in appearance caused by lighting or occlusion may render it difficult to locate a part

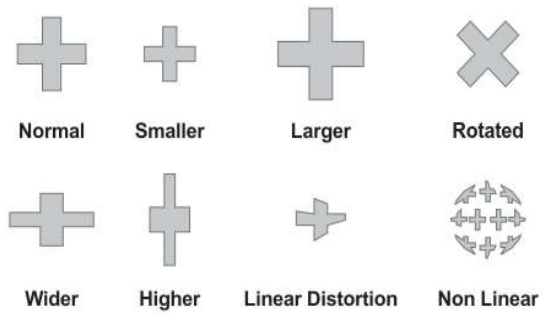

Figure 2.6. Component display or pose distortion effects may make it difficult to locate an element

2.3. Machine vision features

Machine vision systems are characterized by developed flexibleness and automation. In some unsafe working environments not suitable for standard work or where artificial vision is complex to meet the requirements. At the same time, in the large-scale industrial production process, manual visual inspection is used to control product quality with low capability and low precision [17]. Machine vision inspection methods can significantly improve production efficiency and automation of production. Moreover, machine vision is easy to implement information integration and is the primary technology to realize computer integrated manufacturing.

2.4. How machine vision works

The detection of machine vision system uses a CCD camera to transform the detected object into an image signal and transmits it to a dedicated image processing system and transforms it into a digitized signal based on the pixel division, brightness, color, and the like and the image processing system performs various operations on these signals. Extract the characteristics of the objective, such as area, number, position, length, and then generate the results based on the pre-established allowed degree and other conditions, including dimensions, angle, number, approved/failed, presence/absence [18].

A typical industrial machine vision system includes a light source, lens, camera (including CCD camera and COMS camera), and an image processing unit (or image capture card), image processing software, monitor, communication/input, and output unit.

2.5. Different types of machine vision

Machine vision systems are classified into three wide categories: 1D, 2D and 3 Dimension.

2.5.1. One-Dimension vision system

1-Dimension vision analyzes a digital signal one line at a time rather than the whole image at once, for example, by calculating the difference between the most current group of ten obtained lines versus an older group [18]. As shown in Figure 2.7, this method is often used to identify and classify defects in products produced in a continuous phase, such as paper, metals, plastics, and other non-woven sheet or roll goods.

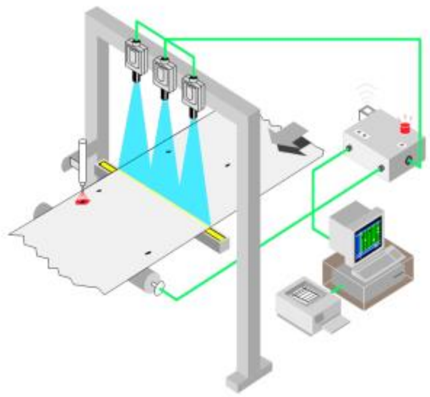

Figure 2.7. When the operation is running, 1-D vision devices check one line at a time

2.5.2. Two-Dimension vision system

As shown in Figure 2.8, the majority of typical inspection cameras conduct area scans by taking 2-D snapshots at different resolutions.

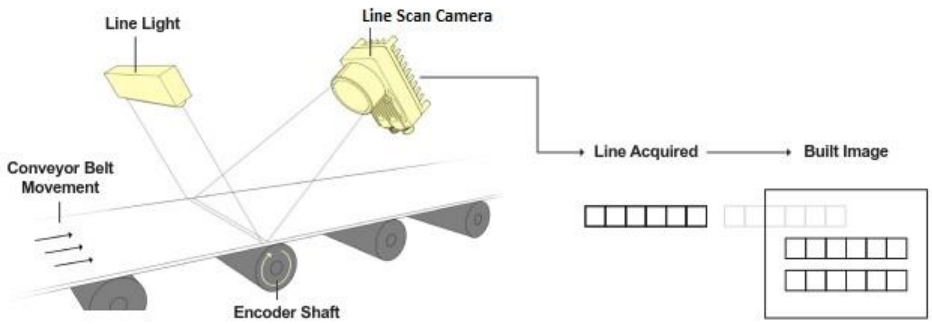

Figure 2.8. Line scan techniques construct the 2-Dimensional image one line at a time

2.5.3. Three-Dimension vision system

Usually, 3-Dimensional machine vision systems as shown in Figure 2.9 consist of several cameras one or two laser displacement sensors. Multi-camera 3D vision is used in robotic direction applications to provide the robot with knowledge about the direction of the parts [18]. These systems use several cameras positioned in various locations to "triangulate" on an objective point in 3-dimensional space.

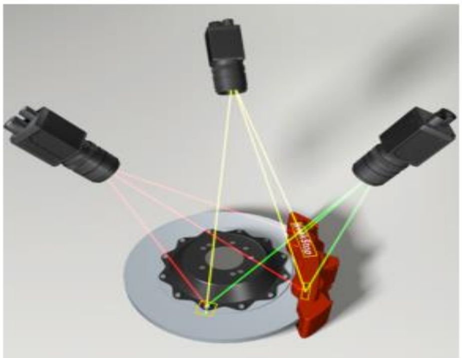

Figure 2.9. Multiple cameras are commonly used in 3-D vision systems

For comparison, 3D laser displacement sensor implementations usually require surface inspection and volume estimation, with as little as a single camera delivering 3D data. A height map is created by displacing the position of the reflected lasers on an individual. Similar to line scanning, the object or camera must be rotated to scan the whole product. Isolation sensors can quantify parameters such as height of surface and planarity with a precision of up to 20 µm when used in conjunction with a calibrated offset laser.

2.6. Machine vision systems benefits

Machine vision systems directly support suppliers and manufacturing line operations in a variety of ways. Among the advantages of using machine vision technologies are the following:

- Defect reduction.
- Increased production gain.
- Reduced downtime.
- Increased capability for tracking and tracing components and goods in a manufacturing process.
- Facilitation in conformity with applicable legislation for particular product classes

Decreased errors equate to less product recalls due to problems including mislabeling, which occurs where the product's label does not fit the product's contents. Manufacturers incur costs as a result of recalling and replacing mislabeled stock. The effects of these recalls may entail disruption to the manufacturer's brand's perceived integrity, as well as problems affecting customer welfare, like mislabeled pharmaceuticals or items containing additives to which certain people might be allergic [19].

Increased yield is directly related to the potential to detect inaccurate or defective components before their incorporation into larger assemblies. The earlier faulty products are identified and withdrawn from a manufacturing chain, the less loss occurs, allowing for the conversion of a greater proportion of the raw material utilized in the process into finished objects that can be marketed. Scrapped materials and reworked components are costly in terms of time and resources and the result of lower yields in manufacturing processes.

Machine vision systems' ability to identify the location and alignment of components on a production line enables misaligned parts to be identified and withdrawn from the operation until they jam a unit, resulting in downtime for that process line. This removes the possibly significant costs associated with downtime in manufacturing.

Since machine vision systems can instantly interpret the symbology on parts and pieces, they can significantly aid in the monitoring and tracing of components used in the assembly and device manufacturing processes. This capability allows more accurate Work-In-Process (WIP) monitoring and a greater perception of part usage rates, allowing for the implementation of Just-In-Time (JIT) production practices that eliminate the need for large inventory inventories, avoid part shortages, and shorten delivery times [12].

As opposed to manual supervision and inspection processes, automatic machine vision systems are simpler, more diligent, and provide more reliable outcomes than human inspection might. As human inspectors fatigue, their error rates rise, and they often have a propensity to adjust their examination standards over time, resulting in less accuracy in performance.

2.7. Line scan technology

Appropriate, line scanning technology is very suitable for applications that capture; high-speed or high-resolution objects that need excellent images or need immediate corrections to pixel responses. The camera contains one line of pixels, the thing or camera moving vertically on the pixel line to make a two-dimensional image of the object to realize high brightness focus line lights wherever the camera scans the lines for the object read. The most extended exposure time square measure is given through time delay and integration (TDI) to move pixel lines in conjunction with object movement electronically. Applications that have tried that online scanning cameras square measure the most effective possibility, as well as checking the materials within the network, like within the paper or plastic business, and analyzing "objects" like road and road scrutiny, or requiring high-quality images also as print scrutiny. When using line scanning, care should be there in use to synchronize camera acquisition with object movement. The initial prices could also be on top of the frame cameras. However, the scanning technology resolves issues that cameras cannot merely solve or solve at all [20].

Line scan technology is using in several areas, particularly in vision-based fields. They are additionally extensive use in producing companies wherever they are used to find errors once checking their products in real-time. Several researchers have designed a special automotive to get 3D models. While driving, buildings square measure created in 3D and captured images square measure used to create texture maps.

2.7.1. When to use line scanning technology

Line scanning technology is ideal for applications that require high-resolution, large or high-speed image capture, such as continuous web applications for textiles, glass, paper or metal tape, road or rail inspection, surface topography, or satellite imagery line scanning is ideal for free-falling items such as steel, molten glass, and postal sorting. Line measurements are often useful for a host of functions, including inspecting flat panel displays, silicon chips, printed, solar cells, circuit boards and medical diagnostics, among others [20].

So when a product is moving so quickly, the scanning camera is preferable to the camera. This is because the camera's limited exposure period can be accounted for by utilizing time delay and integration (TDI) and concentrated illumination to maximize the number of photons "harvested" by the camera. When the scanning camera performs a camera offset correction and gain, the area scanning camera uses the VISION module to calculate the correction, so the speed is much slower.

2.7.2. Line scan sensor

The line scan camera is ready with a line sensor, and the area scan camera is ready with an array sensor. The purpose of creating an image using a line scan is to generate a two-dimensional image using this one-dimensional line sensor. General-purpose equipment using this technology has been in use for many years. Typical examples are computer scanners, copiers, and facsimile.

2.7.3. Imaging by line scan

Figure 2.10, captures data from the line scan line sensor and keeps it in the image (or frame) buffer; it shows the process of forming a 2D image by existence. This frame buffer is a machine it can use for vision processing. The camera sensor always determines the width and height of the resulting image is horizontally placed, the image width is equal to the resolution of the camera sensor, and the height of the image is equal to the number of lines stacked in the frame.

The image width is constant, and it depends on the resolution of the camera. The program sets the height it is set up like a ram, and it depends on the application. Area scan cameras can capture images regardless of the motion of objects, but line scan to generate an image, movement of the object is necessary.

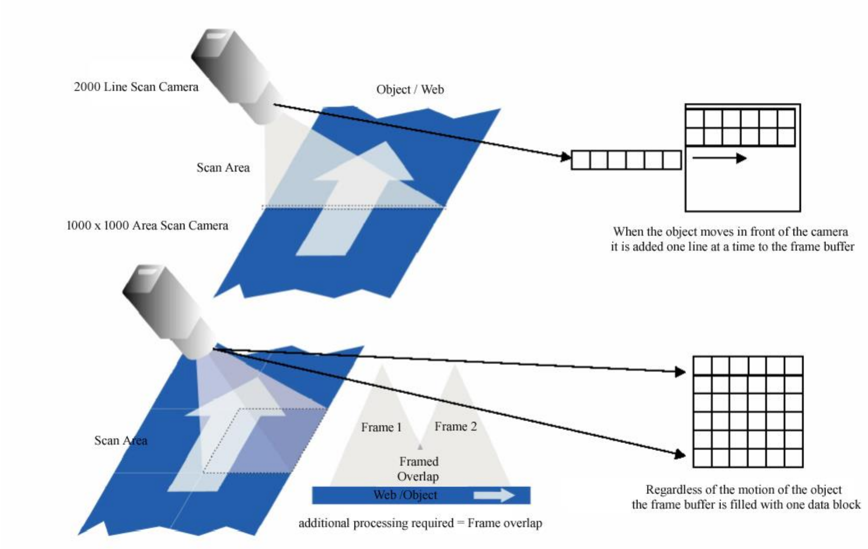

Figure 2.10. Captures data from the line scan line sensor and keeps it in the image (or frame)

3. MACHINE VISION COMPONENTS

A machine vision system's main components Figure 3.1 include a lens, illumination, vision processing, image sensor and communications. The lighting illuminates the component being examined, highlighting its characteristics so it can be identified by the camera. The lens captures the image and transmits it by light to the sensor. A machine vision camera's sensor transforms this light into a digital image that is then submitted to the processor for processing.

Vision processing is comprised of algorithms that examine an image and collect the necessary details, perform the necessary inspections, and make a decision. Finally, connectivity is usually achieved by the use of a discrete I/O data sent or signal via a serial link to a device that is logging or utilizing the data. The following sub-sections address the critical components in detail.

The majority of hardware components used in machine vision, such as illumination systems, cameras, and processors, are readily available commercially (COTS). Machine vision systems may be built using commercial off-the-shelf components or bought as an optimized system with all parts included in a single device [18].

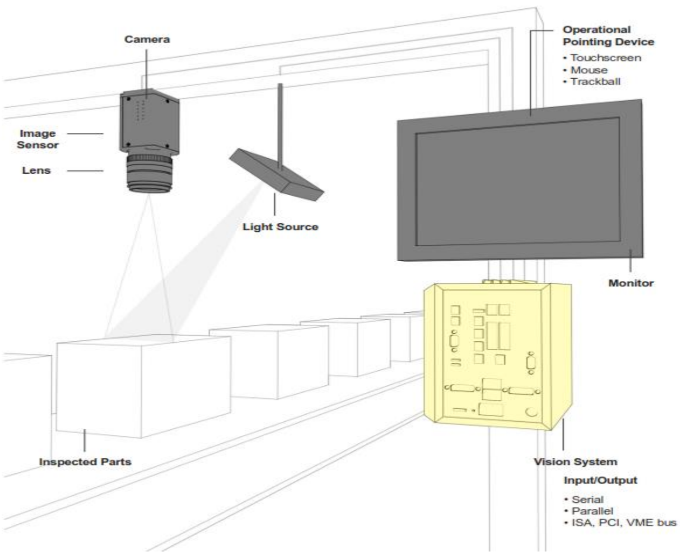

Figure 3.1. A machine vision system's main parts

3.1. Lighting

The term "illumination" applies to the light sources surrounding the target being examined. Notably, the image acquisition system may see the object(s) under study. It means that the acquired image retains the majority of the details and that no image processing is required; this simplifies the development of the machine vision application.

Illuminating an object(s) may not imply the presence of an abundance of light surrounding the object; it relates to the lights being correctly calibrated. Proper lighting necessitates the use of the appropriate strength and path of lighting. It can be performed in such a way that shadow forming is minimized and optimal contrasts are obtained from the object's area of interest (s).

Halogen lights or Fluorescent lights, LED lights are also examples of light sources. Due to their long existence and low energy usage, LED lights are favored over other forms of light sources. Direct or indirect lighting is determined by the configuration of the lamps.

An application for a line scan camera at the end requires only a thin line of light as lighting, as the sensor only detects a line of one pixel at a time. However, it is essential for all linear scanning camera applications that the light is as bright as probable and has an extremely high frequency to prevent flicker.

One key to efficient machine vision outcomes is illumination. Through observing an object's mirrored light, and not by analyzing the object itself, systems of machine vision generate images. A lighting technique requires a source of light and its location to the part and the camera. A specific technique of lighting can improve an image in such a way that it negates certain characteristics and improves others, by silhouetting a portion that obscures surface details to enable its edges to be measured, for example.

3.1.1. Incident light illumination

- Using line scanning cameras is the standard way to scan the surface as shown in Figure 3.2.
- Much light as possible is detected in this way, the camera and lighting can structure in such a way that the camera is at the opposite angle of illumination (reflection angle = angle of clarity) [21].
- In the case of reflective material, this works particularly well. Bright and dark areas appear this way.
- If the corners of the surface structures are not aligned correctly but are tilted, they also appear dark in the camera image.

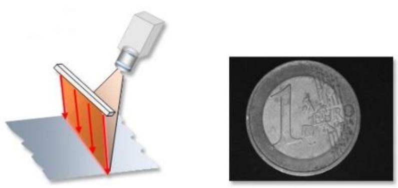

Figure 3.2. Incident light illumination for line scan camera

3.1.2. Dark-field illumination

- To provide a dark-field effect, line scan cameras may be used to do this, the light is not aligned at the point of reflection, but rather at a flatter angle as shown in Figure 3.3.
- The immediately reflected light does not hit the camera. An image field appears dark.
- The camera detects only the faint stray light; therefore, much light requires for this technique.

  Scratches, slots, elevations, and embossments look white because their irregular surface reflects light.

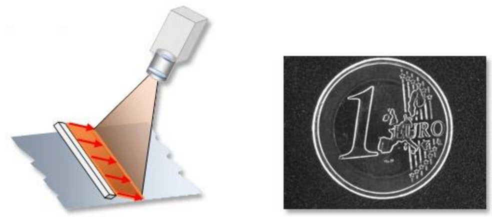

Figure 3.3. Dark-field illumination for line scans cameras

3.1.3. Backlight illumination

- In this illumination scenario, a camera and illumination are precisely opposite of each other and the test object is right in between as shown in Figure 3.4.
- The contours of non-translucent materials become apparent in this way, edge chippings can detect, and the component can be measured.
- In the case of transparent objects (same glasses and foils), this method can use to create bubbles or cracks in the material or edge chippings apparent.

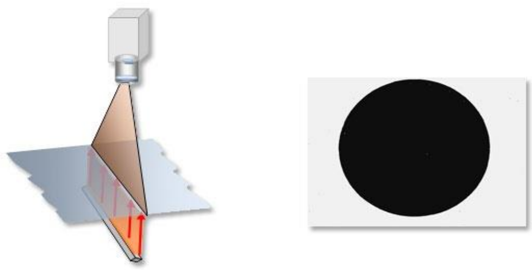

Figure 3.4. Backlight illumination for line scan cameras

3.1.4. Axial diffuse lighting

Axial diffuse illumination introduces light from the side onto the optical direction (coaxially) as illustrate in Figure 3.5. A half-transparent mirror illumine from the side brings to light the element downward. The component inverted light to the camera through the half-transparent mirror, resulting in a picture that is very uniformly lit and uniform in appearance [18].

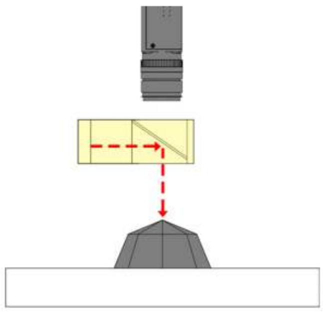

Figure 3.5. Axial diffuse lighting

3.1.5. Light of structured

Lighting of structured is the reflection of a light pattern (grid, plane or more complicated shape) onto an object at a certain angle as shown in Figure 3.6. It can be extremely valuable for providing contrast- separate surface inspections, gathering dimensionality, and measuring length.

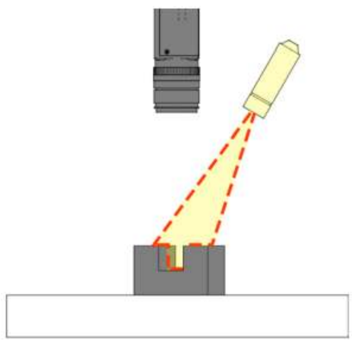

Figure 3.6. Light of structured

3.1.6. Bright-field illumination

High-contrast applications benefit from bright-field lighting. High-pressure sodium and quartz halogen light sources, on the other hand, can cast harsh shadows and do not offer clear lighting throughout the entire field of view. As a result, and provide even illumination in a bright area, hot spots and specular reflections on glossy or reflective surfaces can necessitate a more light of diffused source as shown in Figure 3.7.

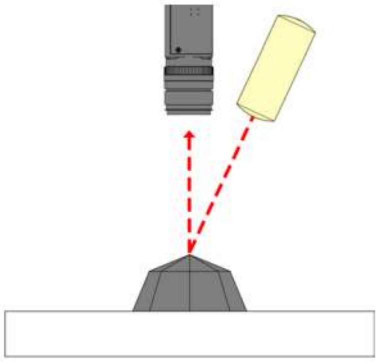

Figure 3.7. Bright-field illumination

3.1.7. Lighting of diffused dome

Diffused bubble lighting provides the generality uniform illumination to important features which may obscure non-important inconsistencies that might be distracting to the scene as demonstrate in Figure 3.8.

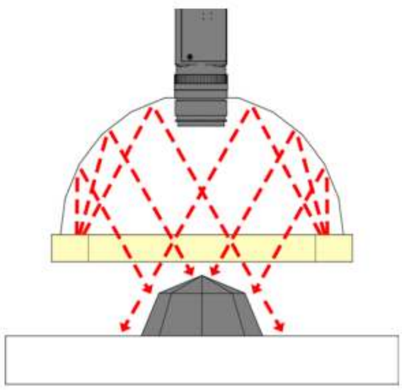

Figure 3.8. Diffused dome lighting

3.2. Image acquisition

The acquisition of images is a critical component of every computer vision device. It entails using a camera to capture an image of the material to be studied. For image acquisition, various styles of cameras can be used; these may include a traditional standard digital camera, mobile camera or even a webcam. However, industrial cameras are also accessible. The multiple cameras may be divided into two groups based on the sensor technologies used:

- CCD (Charge-coupled Device) cameras.
- CMOS cameras

Sensors can be matrix or line sensors. A sensor transforms an optical image into an electrical signal.

Choosing a machine vision camera may be challenging. However, when purchasing one, sensitivity, the resolution, and form of camera-monochrome or color must be considered. Additionally, the camera's contact interface should be discovered. USB, Ethernet, and Firewire are also usable interfaces.

3.2.1. CCD (Charge Coupled Device)

The word CCD means (Charge-Couple Device) and is an electronic module that is able of transporting electronic charges [22]. A charge-coupled device image sensor CCD, which is made using a high-speed semiconductor material, can light into electric charge, the chip by an analog into a digital signal, a digital signal compressed by the camera after the internal flash memory or internal hard disk card saved, so data can easily be transferred to the computer, and the image can be modified as needed and imagined using computer processing.

In a CCD sensor, the light (charge) falling on the sensor pixels carried from the chip within one output node or only a few output nodes. The contents are converted into voltage levels, buffered, and sent as an analog signal. This signal amplifier was changed to numbers using an external A / D converter to the sensor [21].

In general, there are three types of CCD sensor layouts as follows.

In Full Frame (FF) CCD, Once the sensor array has been exposed for some time, a sequence of sampling pulses is implemented using parallel shift registers to pass pixel signals one row at a time to serial shift registers. The feedback amplifier then collects each row in the serial registers. Since both the imaging and readout processes exist on each pixel, the exposure is monitored by a mechanical shutter or strobe to ensure the integrity of the signal (i.e. all pixels have the same exposure time). The benefit of Full Frame CCD is that it has the best resolution and density due to its basic construction. The imaging time used to capture a single frame is equal to the exposure time plus the readout time.

Without the use of a shutter or coordinated strobe, the Frame Transfer (FT) CCD enables continuous photography. The concept is to use a computing array to cache the imaging array's readout. When the exposure phase is complete, the whole picture array's pixel values are read into this non-light-sensitive storage array. Then, similar to the Full Frame CCD, the whole storage collection is read out. Simultaneously, the imaging array will begin acquiring the next frame. This parallel design increases the sensor's frame rate. The downside is that during data migration from the imaging arrays to the storage array, a "smear" effect can occur. Since the sensor components are exposed and interpreted simultaneously, each pixel has a slightly different exposure period. Meanwhile, Frame Transfer CCD has a lower resolution and density than Full Frame CCD due to the addition of a silicon circuit.

Interline (IL) CCDs are a form of CCD that addresses the issue of image "smear" in Frame Transfer CCDs. Each pixel on the sensor is composed of two components: a photodiode and a shift register. Instantaneously after the exposing operation, the photodiode's charge is moved to the move log.

It has a higher frame rate than Frame Transfer CCD due to the quicker readout operation. The downside is comparable to that of the Frame Transfer CCD. There is a trade-off between resolution and light quality. Interline CCDs benefit from this property because they do well in real-time imaging and motion pictures Fıgure 3.9 shows line scan and area scan CCD sensor.

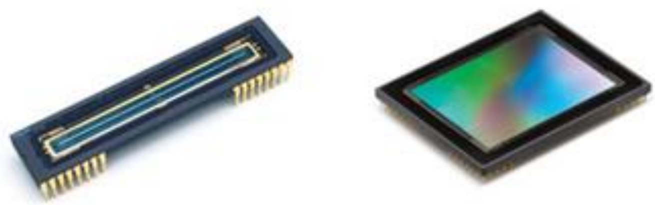

Figure 3.9. CCD sensors

The advantages and disadvantages of CCD sensor technology:

CCD sensor advantages

- Low level of noise.
- Full-well capacity is very high.
- Fill factor 100%.
- High uniformity.
- Ripe technology.

CCD sensor disadvantages.

- Slow readout.
- Pixel blooming.

- Specialized fabrication.
- Low functionality.

3.2.2. CMOS (Complementary Metal-Oxide Semiconductor)

CMOS means "Complementary Metal-Oxide-semiconductor" and describes a specific type of electronic circuit [22]. Like CCD sensors, these sensors are based on the photoelectric effect and convert incident photons into electrical charges. The difference with CCD sensors is how to transmit this information Fıgure 3.10 shows line scan and area scan CMOS sensor.

Beginning on, ordinary CMOS chips used for imaging targets, but the image quality reduced because of their inferior light sensitivity. The latest CMOS sensors using more specialized technology, quality, and light sensitivity of the sensors have quickly developed in recent years. Table 3.1 shows the main comparison between CCD and CMOS image sensors.

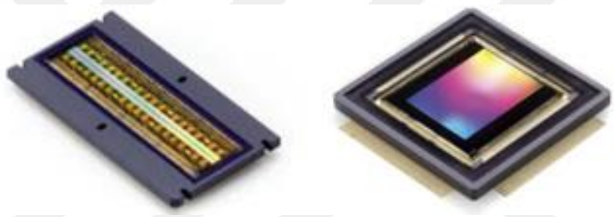

Figure 3.10. CMOS sensors

The advantages and disadvantages of CMOS sensor technology as follows:

CMOS sensor advantages

- Readout at a high rate.
- Access is granted at random.
- Intelligence on a single chip.
- Power use is low.

CMOS sensor disadvantages

- Increased read-out noise.
- Diminished dynamic range.
- Uniformity of reduced.
- fill-factor Reduced.
- Cost is high.

Table 3.1. The main comparison of CCD and CMOS image sensors

CCD	CMOS
Lower noise	Lower power consumption
Smaller pixel size	Single power supply
Lower dark current	High Integration capacity
100% Fill Factor	Lower cost
Higher sensitivity	Single master clock
Electronic shutter without artifacts	Random access

3.2.3. Linear CCD Image sensors

The sensor components in linear CCD image sensors are arranged in a single row. Additionally, these sensors provide change registers and output amplifiers for data reading. In flatbed scanners and paper copiers, linear picture sensors are often used. They are also used in advanced digital imagery and space imaging scan-backs. Linear sensors with a single row are monochrome. Color linear sensors are typically composed of three rows of sensors, each with a distinct primary color. Kodak produces a 14,400-pixel trilinear color image sensor with an ultrahigh resolution for use in high-end color scanning systems [23].

To conclude, various image sensors each have their share of benefits and drawbacks. In digital imaging, the type of sensor to use is determined by the device and the cost-benefit ratio. Relevant parameters for evaluating today's picture sensors include sensitivity, data speeds, and noise level. Controlling exposure and preventing blooming is often critical.

3.2.4. Color for Sensors

Due to the sensor element's inability to perceive color, it can only have the sum of light striking its surface. To obtain a full-color picture, the majority of sensor elements look at the light through filters that correspond to their three primary colors. Since recording the three shades, they are combined to produce the full-color range used by the human eye. Three color channels may be recorded in a digital camera in a variety of ways.

3.3. Line-scan camera

A line-scan camera has one row of pixel sensors, instead of a matrix. Frames square measure fed down to a computer that joins and creates an image permits to capture clear images of objects that have exceeded the camera at high speed. Sports racing typically uses this kind of camera to require pictures, that is, to work out the winner once several competitors cross the finishing line at the same time. These cameras will use as industrial tools for speedy operation analysis [24].

Line scan cameras mainly have the following features:

- Easy high resolution can be obtained (even for inexpensive image scanner 10000 dots or more).
- A compact optical system (space for expanding the original can be made unnecessary).
- Unlimited image size in the longitudinal direction (Seamless processing of long subjects can do continuously).

Based on these features, line scan cameras mainly use for the following items. Line sensors are a common but essential electronic device as well as area sensors:

- Copy machine.
- Image scanner.
- Facsimile.
- Machine vision (Surface inspection of elongated items such as rolls and cylindrical items).
- Satellite (ground picture familiar with Google Maps).
- Start / Goal judgment (race).
- Used for sorting mail items, reading bar codes, QR codes, text (OCR), and other codes. Allows delivering parcels and letters to the correct recipients quickly.

3.3.1. Understand line scan camera applications

This thesis defines the advantages of scanning cameras, as well as the power to get large object images and high-resolution images. One line of pixels in a line scans camera images through an object. A 2-Dimensional image of the object is formed by moveable the object or camera vertically on the pixel line Figure 3.11 shows compare between line scan camera and frame camera.

This might seem to be a fancy way to show an object compared to border cameras that take 2-Dimensional images ("frame"). However, once the task needs high-resolution or high-resolution images, or if the object is large and moving endlessly, the scanning camera is typically a higher possibility than the framing camera [24].

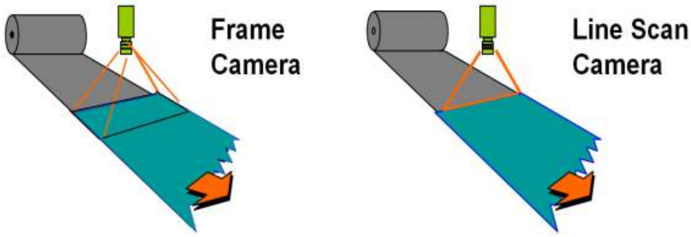

Figure 3.11. Compare between line scan camera and frame camera

As users use 4 large frame cameras mounted on the side through the mesh material, this has many disadvantages. The first one, large-frame cameras usually contain hidden, broken pixels by filling the pixel value of adjacent pixels, the activity the defects that users are trying to discover. In the second one, the exposure time of the framing camera ought to be short to avoid the opacity caused by the movement of the material. Short exposure requests high-intensity illumination throughout the image space to realize a satisfactory image. It is often a turned encoder output that activates the acquisition of synchronal images for all cameras. Moreover, the third one eliminating differences in gain and displacement in pixel responses, necessary to discover low distinction defects, needs much time using frame cameras.

3.3.2. Principle of line scan camera

The setup depicted in Figure 3.12, consists of a single line scan camera and a range between them. The camera records a single image line in rapid succession. Motion is necessary for addition to the inspection for 2-Dimensional image acquisition: either the item to be shot is passed through a conveyor belt or the camera is moved along the stationary object.

Because the image in the Y-direction is created as a result of the conveyor's movement, this must be an incredibly uniform motion. However, this is theoretically difficult to do since the feed must be aligned with an encoder to prevent image distortions [4].

Individual artifacts on a conveyor may also cause the picture acquisition: a photoelectric barrier sends a signal to the image capturing hardware. Only then are the lines distributed, allowing for the avoidance of the test object spreading through two image blocks.

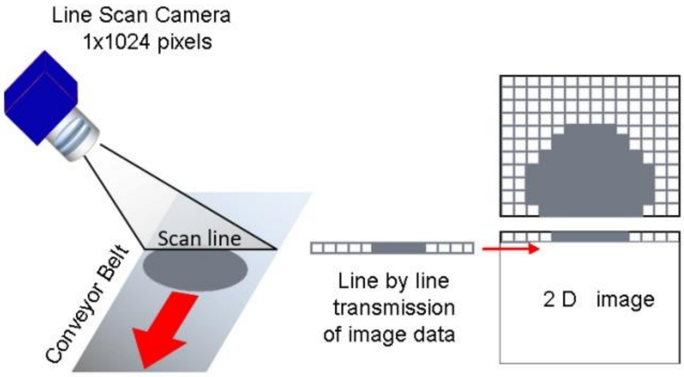

Figure 3.12. Principle of image acquisition using line scan camera

3.3.3. How line scan camera works

The customary field of application for line scan cameras contains a situation where continuous materials require to be analyzing see Figure 3.13.

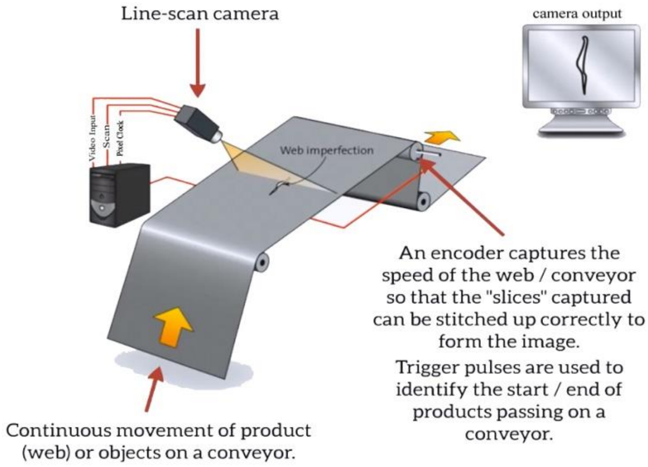

Figure 3.13. The structure of a line scan camera application with possible error location indicate

The reason why line scan cameras are more appropriate than area scan cameras in these continuous operations is explained by the fundamentally different design of the two technologies.

Depending on the type of camera, area scanning cameras bring a static (synchronous) or variable (asynchronous) series of a moving object. In apply; the continuous capture of continuous materials is achieved by taking overlapping images. When done, programs require completely cutting person images, removing distortion, and assembling images in the correct sequence.

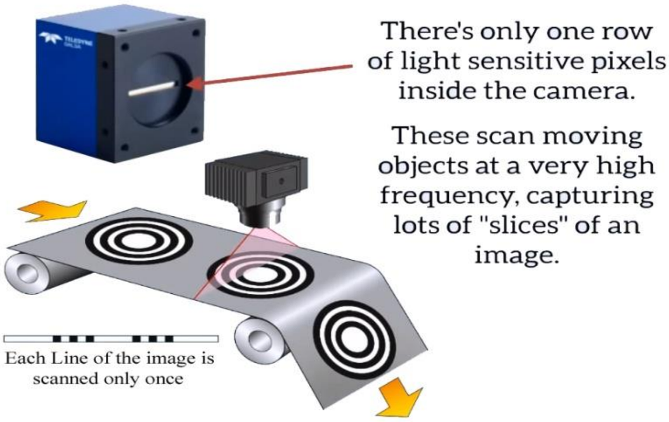

Figure 3.14. Each Line of the image scanned only once

On the other hand, line scan cameras have only one line of light-sensitive pixels as shown in Figure 3.14, which continuously scan moving objects at an excellent line frequency. Typically, the resolution of line cameras varies between 512 and 12,888 pixels. Sensors with pixel lengths of 7µm, 10µm, and 14µm are usually available in the market. In very high resolution, smaller pixels are used in the sensor design to take the optics into account, since the 8000-pixel sensor and a 10µm length, for example, can be "detected" only without distortion by a lens with at least a diameter of images About 8 cm [20].

3.3.4. Color line scan cameras

In-kind of a color line scan camera, rows of sensor pixels with common color filters or pixels of various color filters are used to track illuminate of different wavelengths. Although filters are typically perceived as green, blue, and red (RGB) as shown in Figure 3.15,3.16, certain applications, like satellite remote sensing, need a greater variety of filters [24].

Figure 3.15. Each line contains trilinear sensor pixels with Red, Green, and Blue filters

Figure 3.16. Green and contrasting Red and Blue filters on bilinear camera pixels

Color scanning cameras, in particular, aid in the capture of images of written material. You'll use a "trilinear" camera with one kind of filter per row for this job, which ensures that each pixel in the picture contains a full collection of RGB measurements. Since the color sensor's varying pixel lines are delayed in time, they all see a similar portion of the source from which the image is created [24].

Lenses should be color balanced for color line scanning cameras to avoid significant aberration. Aberration occurs when a lens fails to concentrate the light of varying wavelengths within the similar focal plane, and it appears as colored lines along the intensity's edges.

If the camera is normal, which is vertical to the object's surface, there may be a perspective distortion. Perspective distortion is proportional to 1 / distance from the object. This means that with a pixel shape and size slightly different from those projected onto the object's surface, this can cause errors in high-precision color measurements. You need to make sure that the camera is perpendicular to the object on the surface, which is a good idea, even if the color is not used.

3.3.5. Area scan vs. line scan cameras

The camera scanning area, an imaging lens focuses on the object to be displayed in the sensor array, and the image is sampled at the pixel level for reconstruction Figure 3.17. This useful if the image does not move rapidly or if the object is not very large. Known point-and-shoot digital cameras are examples of area scanning devices. With linear scanning cameras, the pixels are arranged linearly, allowing very long arrangements. Extended arrangements are exemplary due to the amount of information that needs to read from the exposure decreases substantially and the reading speed increases due to the absence of registers or column displacement multiplexes; In other words, as the object passes through the camera, the image is acceptable line by line and rebuilt with the software [25].

Area scan cameras are composed of a matrix of pixels that provide an image of a scene. They are more versatile than line scan cameras which need less configuration and orientation time. Area scan cameras are optimal for applications in which the target is stationary, even if only for a brief moment.

Area scan cameras have a set resolution, which simplifies the implementation in situations where rotating cameras or artifacts are not desirable or feasible. It is capable of rapidly imaging a given region, while a line scan camera should be passed across the area to generate a comparable image. With area scan cameras, greater versatility is possible since a single image may be segmented into several regions of interest to scan for individual objects rather than needing to process the whole image.

Line scan cameras have a single row of pixels and are used to rapidly collect data. When an entity passes in front of the eye, a full picture may be reproduced line by line in software. Line scan systems are most effective in applications including the high-speed transmission or fast-moving conveyor lines.

Line scan cameras use a single row of pixels to create continuous images that are not constrained by vertical resolution. This enables far higher resolutions than are possible for area scan cameras. Unlike field scan cameras, a line scan camera may expose a new image when the data from the previous image is still being transferred. This is since the readout of the pixels is quicker than the exposure of the camera. When constructing a complex image, the line scan camera may either pass over an entity or be faced with moving items. Line scan cameras need to get really of production/camera motion and image acquisition timing, but they need just easy illumination. Table 3.2 represents the comparison of area scan cameras and line scan cameras.

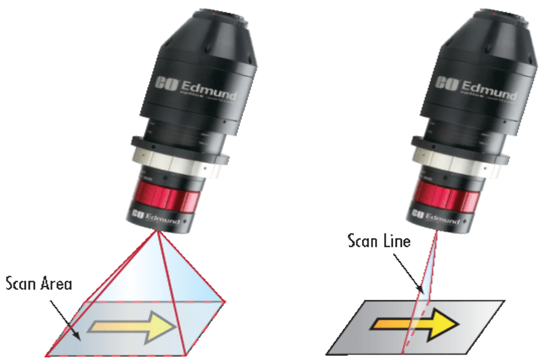

Figure 3.17. Design of area scanning and line scanning technique

Table 3.2. Comparison of Area Scan Cameras and Line Scan Cameras

Area Scan Cameras	Line Scan Cameras
4:3 (H: V) Ratio (Typical)	Linear Sensor
Large Sensors	Larger Sensors
High-Speed Applications	High-Speed Applications
Fast Shutter Times	Constructs Image One Line at a Time
Lower Cost than Line Scan	Object Passes in Motion Under Sensor

Wider Range of Applications than Line Scan	Ideal for Capturing Wide Objects
Easy Setup	Special Alignment and Timing Required; Complex Integration but Simple Illumination

3.4. Camera Calibration

One of the main purposes of camera calibration is to find out the position of the camera relative to the scene in the photo. Suppose you have taken a picture of a large room with a grid floor, and you have placed a chair and a table in that room. Then, you have input this image into the modeling program and built a 3D model around the scene. Then, any number of other virtual objects can be placed in the scene, such as modeled characters or other props that interact with the scene [26].

However, the rendering program also uses the camera, even though it is virtual. For the modeled object to correctly interact with the object as the photo, we need to ensure that the virtual camera is in the same position as the real camera when the initial photo was taken. Camera calibration accomplishes this by using a formula to essentially work backward and subtracting the position of the real camera relative to the scene.

Calibration of the camera may often be used to ascertain additional camera-related details about the scene. For instance, formulas may be used to determine the focal length of a scene. Additionally, it will determine the image's skew factor and any lens distortion that could have been added, resulting in a pincushion effect. Additionally, it will determine if the camera's pixels are circular, as well as the pixels' horizontal and vertical scaling factors.

3.4.1. Area-based camera calibration

There have been several remarkable advancements in the field of area-based camera tuning. Numerous methods to camera calibration were defined, including the conventional photogrammetric process, computer vision, and self-calibration [27].

Calibration for photogrammetry was initially designed for aerial photography and surveying. Brown concentrated on close-range photogrammetry to prepare for lens distortion heterogeneity [28]. This technique employs the observational plumb line procedure to verify the truth of the hypothesis by allowing for the difference of distortion with object distance. This technique was stated to be extremely convenient to use and capable of producing reasonably reliable outcomes. However, photographic cameras have been mostly supplanted by video cameras in recent times [29].

With regards to the computer vision method, the procedure can be distributing into two groups based on the disparity in measurements of the calibration objects: 3d shape calibration and 2-dimensional directional object calibration.

The planar pattern may be displayed on a laser printer with precisely defined points. It was unnecessary to be familiar with the plane's motion. The suggested approach contained a closed-form solution that was refined nonlinearly according to the maximum probability criterion. Both computer simulation and real-world data were used to generate the test effects. In comparison to more traditional methods that need costly tools, his method is more adaptable and straightforward to execute.

3.4.2. Line-scan camera calibration

Though there have been several publications discussing area-based camera calibration and the field of study is relatively advanced, line-scan camera calibration is seldom discussed [28][30]. In comparison to two-dimensional matrix cameras, one-dimensional cameras are more effective and precise at measuring, and one-dimensional imagery is simpler and quicker to process than two-dimensional pictures. Line-scan cameras are increasingly being used for measuring in a variety of fields, and we used line-scan cameras to collect cloth photographs for our fabric defects inspection.

Given the scarcity of knowledge on linear camera tuning, the solution suggested by Horaud et al [31], is beneficial for future studies in this area. They suggested a procedure for calculating the exterior parameters using a multiline calibration. Three parallel lines formed the calibration sequence, with a fourth line overlapping the three parallel lines and forming a curve with the direction of three. They will obtain the geometric orientation of the camera relative to the pattern and hence the matrix of the camera's external parameters using this pattern architecture. The article published by Luna et al [30], proposed a procedure focused on the methodology of multiple line calibration [31], Using a calibration pattern consisting of two parallel planes separated by four parallel lines. They will explain the lines on the pattern using pattern geometry.

3.5. Lens optics

Machine vision cameras are built on the pin-hole camera model. The perspective beams are assumed to travel through an infinitesimally narrow aperture at the front of the camera in this model. However, the aperture should be wider in practice to admit more illumination. Lenses are inserted into the aperture to package rays from every point on the scene to the image's identical point, as shown via viewpoint projection's geometry. A lens collects more light, which enables the camera to operate for less artificial light or a quicker speed of shutter, but the depth of field is small [32].

Calculating the depth of field might be important when selecting a camera lens for a specific machine vision application. This formula needs the image resolution and the lens equation. The following paragraphs include an overview of the lens equation and image resolution.

3.5.1. Lens equation

The lens equation describes the relationship between the camera plane's distance z' (image distance) from the lens's core (optical root, O), the object distance z (object distance) from a point in the image, and the focal length Fl of the lens [32] as shown in Figure 3.18.

The critical variables in optical systems are the f-number, focal length, aperture size, luminance, the field of vision, and depth of field.

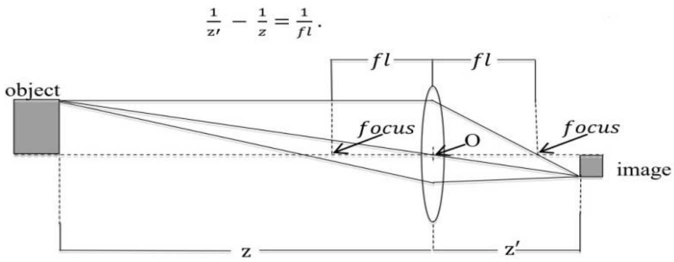

Figure 3.18. The general mechanism of image formation by the lens

3.5.2. F-number

The term 'f-number' refers to the ratio of the focal length to the diameter of the aperture; an aperture is simply an opening in the lens that enables light to penetrate. Typically, As shown in Figure 3.19, lenses have an interchangeable diaphragm., which alters the scale of the aperture, thus limiting the goal size or aperture size [33].

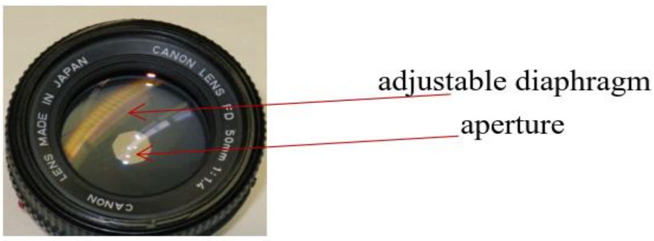

Figure 3.19. An adjustable diaphragm

3.5.3. Field of view

The field of view (FOV) of a camera can be described as the area through which it can view the real-world image in an instant. It is determined by the lens's focal length. The point of vision is increased for a shorter focal range. This enables the lens to capture a larger portion of the scene.

The graphical diagram of the FOV is seen in Figure 3.20. The area enclosed by the scene's height and width is considered to be inside the FOV.

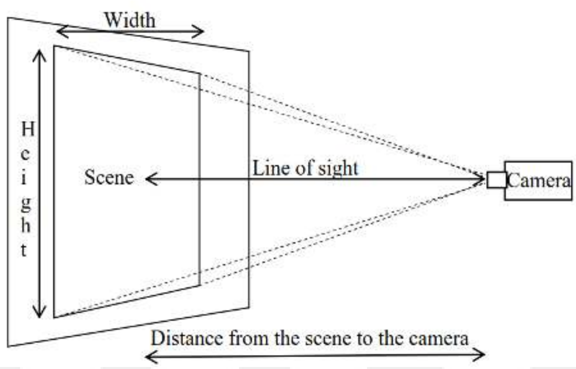

Figure 3.20. A frame lens's range of view Field depth

3.5.4. Depth of field

Field depth (DOF) is a term that refers to the distance seen between closest and furthest objects in a scene which can be recorded by the camera while remaining passably sharp in the shot. The DOF of a lens is depicted in Figure 3.21 [34].

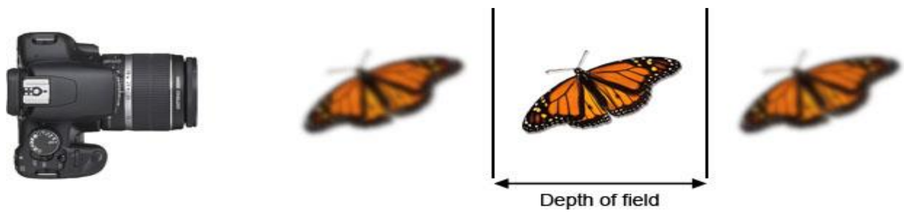

Figure 3.21. Depth of field of a camera

The area inside the DOF appears sharp in Figure 3.21, while the areas in front and behind it are fuzzy. It is dependent on the imaging device's focal length and aperture size.

And although lens will focus on a single point at a time, the sharpness gradually decreases on both sides of the focus point. Thus, under normal circumstances, the un-sharpness inside DOF is unstable.

3.5.5. Resolution of image

Image resolution shows how an image can be seen. In other terms, the minimum distance in an image between two lines is such that the image is visibly resolved. It is possible to describe image resolution in various methods, such as spatial resolution and pixel resolution.

The image resolution is a measurement basis used to describe the level of detail in digital images. The unit is PPI (pixels per inch), which means the number of pixels per inch. High resolution means fine image quality, and low resolution means image quality. Rough, because the source of the digital image is often obtained through a scanner or digital camera, that is, the color of the physical image or scene is sampled, it is sometimes called SPI (samples per inch), which means every The number of sampling points in inches. According to the definition, there is the following relationship between the image resolution, the number of pixels of the digital image, and the corresponding physical image size.

Image resolution = number of image pixels / physical image size

In other words, if you want to obtain a high-resolution image with fixed physical image size, the number of image pixels sampled should be very high. On the contrary, if the pixels per unit length are not enough, the image quality will be poor and cannot show many details of the entity. As shown in Figure 3.22, the left image is a low image resolution image, the right image is a high image resolution image, and the sampling of the left image is insufficient.

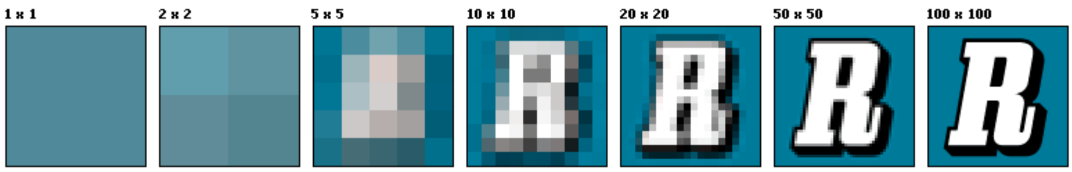

Figure 3.22. Comparison of effects when images of different resolutions are displayed in the same size

Another related metric relative to image resolution is device resolution (device resolution), or physical resolution. The two are often confused and used because digital images need to pass through devices such as displays, printers, and printers. These output devices use light or ink dots to display the color of the image. The basic unit of color performance of monitors and printers is dotted, so the unit of resolution is DPI (dots per inch), which means the number of light points or ink points contained in each inch, the printing machine uses the screen line to express the color, so the resolution unit is LPI (lines per inch), and usually, the mechanical characteristics of the printing machine make LPI equal to half of DPI. Generally, the device resolution of a personal computer screen is 72 DPI, and the resolution of printers and printers may be as high as 1200 DPI.

The resolution of the device is a characteristic that has been determined when the device is manufactured, and generally cannot be used. Adjusted, this is different from the image resolution; the two need to be used in conjunction with each other to show the perfect image output quality.

When using a computer as an input and output tool for physical images, ideally the following relationship between image resolution and device resolution should be observed:

PPI x input entity image size = DPI x output entity image size

The significance of this equation is that the number of pixels sampled during input capture should be equal to the number of pixels required during output, that is to say, following the resolution and size requirements of the output device, enough image pixels are provided so that the desired expression can be presented Image details.

3.6. Communications of device

After acquiring and processing the image of the entity being evaluated, the machine should be able to initiate output(s) to the output device(s) and (or) generate an input signal from the input device (s). This includes coordination between computer vision tools, image acquisition devices, input devices like proximity sensors, and output devices like valves. The schematic depiction of computer interactions between the various components of a machine vision system is shown in Figure 3.23.

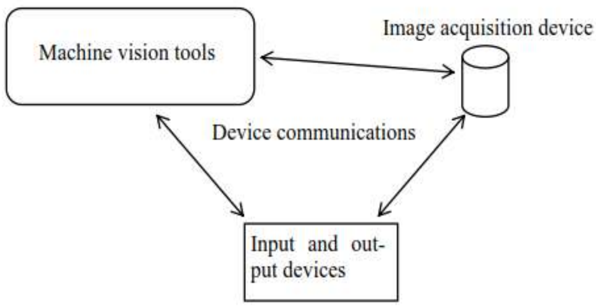

Figure 3.23. Device communication diagrams in a machine vision system

3.7. System application

Line scan systems are mostly used for continuous content inspection. Additionally, they are well-suited for applications involving extreme resolution or speed, as well as for inspecting cylindrical or spinning materials.

3.7.1. Continuous Image Capture

There is a limit on the size in the longitudinal direction of the line scan camera image as an example of utilizing the absence, steel sheet surface defects in the steel line Inspection equipment, foreign matter inspection equipment such as tape and film, etc. is there. For example, even steel plates longer than 1 000 m can have the same total length it can be inspected with a resolution. Image capturing continues in a short cycle Therefore, simultaneous processing of image capture and examination is performed. High speed / high speed in order to respond finely, there are many devices in which a plurality of cameras are arranged Figure 3.24 [35].

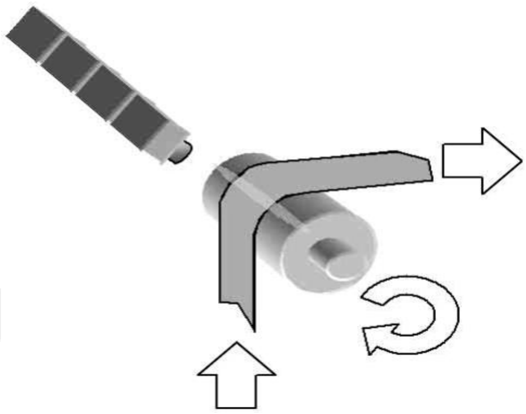

Figure 3.24. Pattern matching inspection of cutting paper

3.7.2. Pattern Inspection

Imaging high resolution and moving in line scan camera as an example using the function to perform pattern inspection of printed matter there is a device. Making a moving device to obtain a high-resolution line may be captured with a scanning camera. Master picture Compare images and information with camera images to find differences perform a survey. Because comparison with a pattern is necessary, it is synchronized with the trigger signal at the pattern start and the movement pulse of the device Figure 3.25 [36].

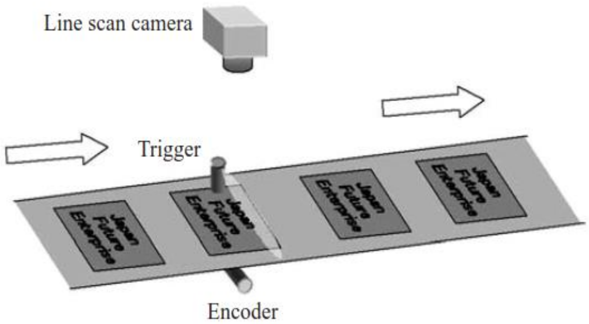

Figure 3.25. Pattern matching inspection of cutting paper

3.7.3. Microscopic Examination

Use high resolution and continuous acquisition of line scan camera defects such as the wafer surface using a microscope there is an inspection system. Shoot the area camera in the stopped state, Therefore, to capture images that can cover the whole float up, it is required to repeat movement/stop of the tag for each screen yes. The time is taken to move/stop this stage is related to imaging It takes dozens of times longer than the time to be taken, in addition to eliminating the missing part of the image [37], It is necessary to overlap the imaging range. On the other hand, when shooting with a line scan camera, the stage is stopped It only stops when it reaches the edge of the wafer, Overall inspection can be done many times faster than.

4. PROCESS OF MACHINE VISION

The processes involved in machine vision applications can be broadly classified into three categories:

3.1 Image Acquisition.

3.2 Processing of Image.

3.3 Output.

4.1. Image acquisition

Image acquisition is the process of acquiring an image acquiring device, a camera. While the acquiring device captures an image, the image would lose much information. This loss might be due to harmful light exposure, wrong angle adjustment, noise in the surroundings. So, to retrieve and recover the missing data, the images must be farther analyzed using image processing and computer vision techniques to provide a higher-quality performance.

In image processing, image acquisition can be generally characterized as the process of extracting an image from a database, typically a hardware-based source, so that it can be transferred through whatever subsequent processes are required. In image processing, image acquisition is often the first phase in the workflow series since processing is impossible without an image. The obtained picture is entirely unprocessed and represents the output of whatever hardware was used to produce it, which may be critical in certain areas to provide a clear baseline on which to operate. One of the ultimate aims of this technique is to provide an input source that functions under such precise and regulated parameters that the same image can be almost accurately replicated under identical circumstances if possible, making anomalous variables simpler to detect and remove [22].

Depending on the field of operation, a significant element in image collection and analysis is occasionally the original configuration and long-term servicing of the hardware used to take the photographs. The hardware system itself will range from a small laptop scanner to a large optical telescope. If the hardware is not calibrated and aligned correctly, visual artifacts may be created, complicating the image processing process. Additionally, improperly configured hardware can produce images of such poor quality that they cannot be salvaged even after comprehensive processing. Both of these components are critical in some fields, such as comparative image processing, which is concerned with identifying subtle distinctions between image sets.

Real-time camera capture is a technique used in image processing. This usually entails downloading photographs from a source that captures images automatically. Continuous image acquisition generates a flood of files that can be stored dynamically, queued for later processing, or stitched together into a single media format. One of the most often employed technologies of real-time image processing is called background image acquisition, which refers to both software and hardware that can rapidly retain the artifacts that flow through a system Figure 4.1.

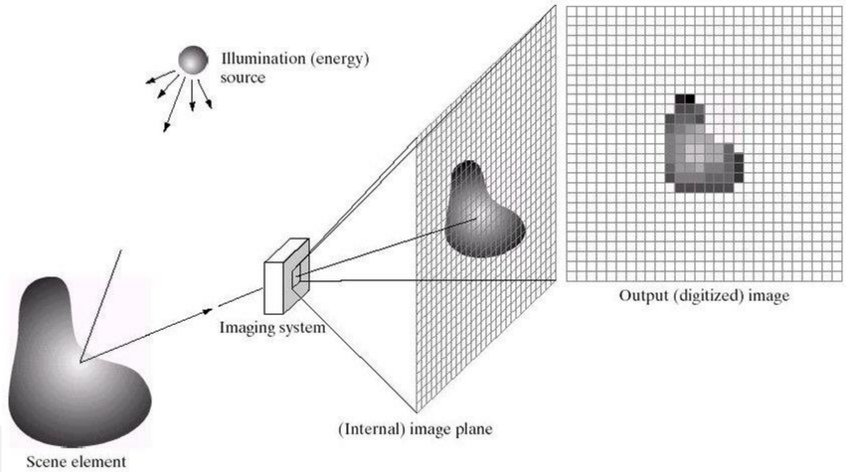

Figure 4.1. Image Acquisition Model

4.2. Processing of image

The acquired image must be farther analyzed using image recognition techniques to recover the detail that was lost during retrieval. The following are several of the most often used image recognition techniques for machine vision applications:

i. Pixel counts: Pixel counting is a very common image processing technique. It entails counting the number of light or dark pixels in an image. It can be analyzed using a histogram, which depicts an image's grayscale distribution.

ii. Thresholding: This is the easiest method of segmenting an image. It is used to convert a grayscale picture to a binary image, separating the area of interest from the context. It needs sufficient contrast between the area of interest and the context. Figure 4.2 illustrates an image before (a) and after (b) thresholding [38].

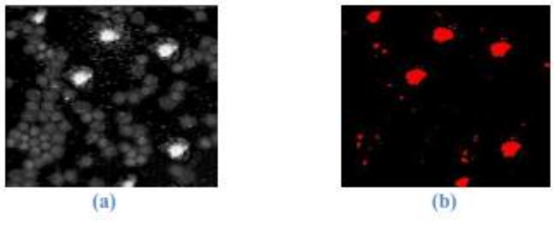

Figure 4.2. Stained biological cells (a) after thresholding (b)

iii. Image filtering: Various image filters may be used to process images. There are pre-built filters available, as well as the ability to build user-customized filters. Linear filters, spatial filters, and FFT (Fast Fourier Transform) filters are all examples of filters [39], are a few of the image processing filters. This research does not involve the algorithms for the image processing filters. However, much of the time, the program used for computer vision includes the majority of the traditional filters. Figure 4.3, depicts the binary picture after applying a filter to eliminate the noise in Figure 4.2 (b).

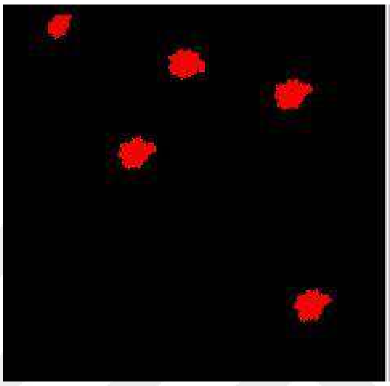

Figure 4.3. Filtered Image

4.3. Image Output

In every operation, the output is critical. Everything is achieved in exchange for something more. Additionally, machine vision implementations provide a final output. Generally, computer vision systems provide Pass/Fail outputs. However, additional attributes for Pass/Fail outputs may be specified, such as the number of passed/failed objects, the setting of an alarm if an object fails, and so forth. It is determined by the application's purpose. However, it is often necessary to specify the attributes for subsequent R&D activities. Figure 4.4, depicts an intuitive depiction of output in a machine vision program, beginning with image acquisition.

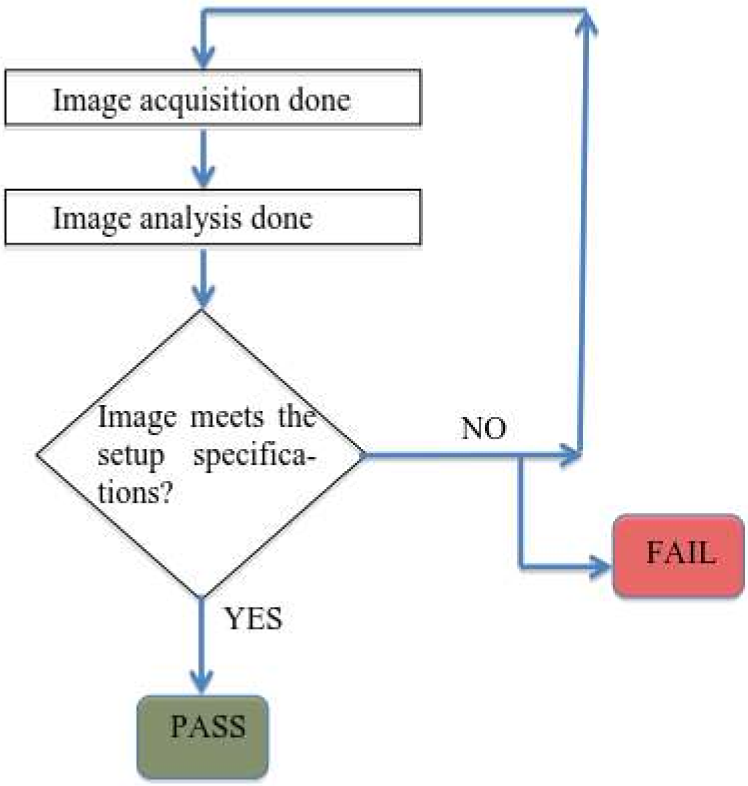

Figure 4.4. Illustrates of output starting from image acquisition in an application of machine vision

5. OBJECT RECOGNITION MACHINE VISION SYSTEM

Sorting objects is a critical phase of factory production lines. Various faulty or defective goods are generated during the manufacturing phase. These goods are unlikely to be used or deployed into the industry, and the path must be cleared.

Sorting such ineffective goods manually is time-consuming, expensive, inefficient, and tiresome. The use of machine vision allows this mission to be completed with a greater degree of precision in a relatively short amount of time, with minimal labor, and at a low cost. However, technological difficulties do occur on occasion [12].

Various machine vision software packages and cameras are available on the market today. Since the program is so useful, pre-configured programs for automatic inspection also exist. The consumer is only required to provide inputs to the app. Users, on the other hand, may create their apps. One advantage of scheduling their framework is the cost savings associated with the ready-made use. A machine vision technology is comparable in both theoretical and functional terms.

Additionally, the more user experience, the more meaningful the program. Various approaches can be used to develop machine vision systems, depending on the requirements. However, this document discusses only a few methods for object sorting.

5.1. Object sorting of machine vision methods

Sorting objects has evolved as a common technique in many sectors. Machine vision applications in object sorting may be important because they improve product accuracy and minimize redundancy. Based on the materials and requirements, various vision screening techniques may be used for object sorting.[40] Various algorithms prepared for inspection through machine vision by different diligent programmers and software firms are available. Customers may select from pre-built algorithms or build their own using the software's features. Several methods for object sorting are stated in the following sub-sections.

5.2. Pattern matching

Pattern matching is the process where a template image is defined and stored in the memory. This template image also refers to as a reference image. When the real-world photos; for example, a picture of products in a factory production line are acquired using the 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 [41] [42]. A rectangular box around the image often indicates pattern matching. Pattern matching is a vital 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 like missing parts or components from a product), and product alignment (determining the position and (or) orientation of a known object by locating fiducially.

The method of pattern matching is divided into two stages: matching and learning. During the learning period, the vision system removes the gray value from the saved blueprint and stores it in such a manner that it is easily accessible during the quest or inspection phase. The matching stage of the algorithm looks for patterns that correspond with the highest cross-correlation in the newly acquired picture (for inspection). In certain programming languages, tree patterns are used as a general method for processing data based on its composition. The matching of patterns is a vital aspect of machine vision.

Types of pattern matching:

- Guarded pattern matching.
- Structural pattern matching.
- Heuristic pattern matching.
- Ordered pattern matching.

5.3. Edge detection

Edges are critical in assessing the object's composition. Typically, edges appear when two regions of an object are separated by a boundary see Figure 5.1. Thus, edges are used to identify significant changes in an image. These regional variations are understood in the strength of various regions within an image. Changes or discontinuities in strength may result in the forming of phase edges or line edges [32], ramp edges, or roof edges.

Figure 5.1. Demonstrates the initial picture (left) and the edge-detected image (right)

When the amplitude suddenly switches from one value on one side of the discontinuity to the opposite value on the other side, step edges exist see Figure 5.2.

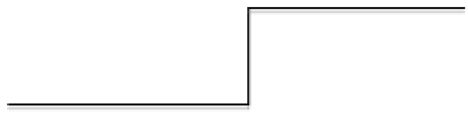

Figure 5.2. Demonstrates the phase edge forming action of an image's strength

Line edges appear where the intensity suddenly varies then quickly returns to its original meaning see Figure 5.3.

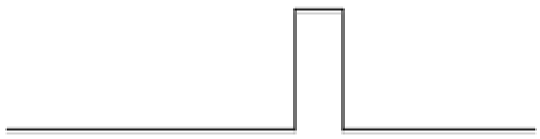

Figure 5.3. Shown the line edge formation behavior

However, in real-world photographs, stage and line edges are uncommon. The actions of a phase edge transitioning to a ramp edge and a line edge transitioning to a roof edge are depicted in Figure 5.4(a) and (b) (b).

Figure 5.4. Ramp edges (a) and roof edges (b)

Usually, edge detection algorithms are used in three distinct fields in computer vision applications: target gauging, object orientation and object geometric transformations.

5.4. Geometric matching

Geometric matching identifies areas in a grayscale image that complements a reference pattern's template, or blueprint. Geometric and pattern matching methods are somewhat similar. Additionally, it is insensitive to changes in brightness, [43] blur, chaos, and geometric transformations are both included in this work. Additionally, the phases are very identical. As with pattern matching, a sample picture is generated that serves as a guide for the geometric matching method to browse through the acquired images.

6. MATERIAL AND METHOD

Object detection is a computer vision technique for recognizing and locating objects in images, videos, and real-time. Object detection can be used to count objects in a scene, determine and track their precise positions, and mark them specifically using this identification [44].

This project involves object detection from a conveyor belt. Different objects placed on the conveyor belt moves along, a camera placed above the belt takes real-time video and feeds it to the MATLAB software.

The MATLAB software using different techniques from image processing and machine vision to detect the object and matches it to the predefined image of the object.

6.1. System setup and structure

This section describes the hardware and software design for the study. All experiments result was using a LAPTOP with an i5 processor, 8 GB memory, and Windows 10 64-bits. Besides, MATLAB R2019b software was used for performance evaluation of the network's architecture. Moreover, an image processing Toolbox has been utilized, which allows a framework to design and implement.

To select appropriate illumination and capturing devices, one type of illumination source was used, namely, Power LED 12 V DC and combination with one model of camera 'Basler Runner ruL1024-57gm' monochrome. It is a line scan CCD series that combines high-quality line scan technology with Gigabit Ethernet (GigE) interface technology and the sensor size is 1024 pixels. A Nikon F-mount lens with an effective focal length of 28 mm is used. The runner family's validated image quality and clear GigE interface make it suitable for a wide range of applications. To transport the plastic objects, a conveyor belt system was prepared. The approximate speed is 10 sec. In this paper, we use a sport conveyor belt to classification plastic objects. Figure 6.1, represented a model of the CDD camera and Figure 6.2 represented the system structure of the study.

Figure 6.1. Basler Runner ruL1024-57gm monochrome line san camera

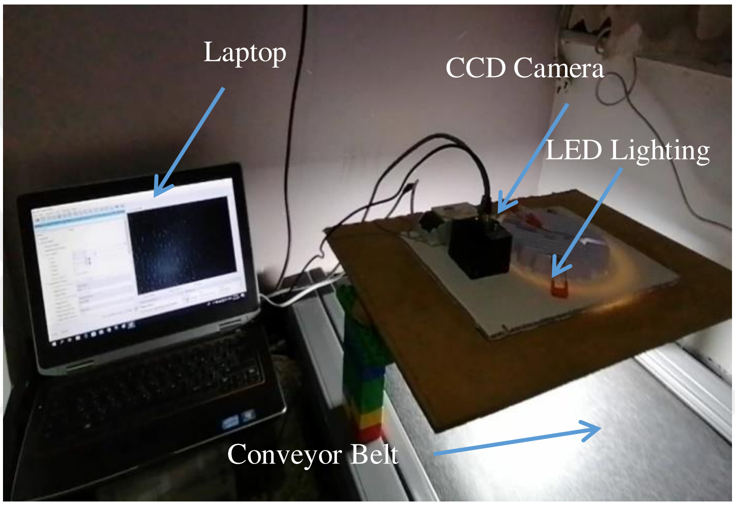

Figure 6.2. The System Structure

6.2. Image setting

To accept structures with varying characteristics, small plastic models with varying parameters such as shape and size brought (large, small, cracked, and different). Allowing these blocks to travel through a conveyor belt system was permitted. A sensor captured the image in real-time. The backdrop of the environment has been held completely white to allow for better object detection. Standard light was used to provide illumination. The following table lists several of the artifacts that were included in the current work.

Three types of objects are used for demonstration as shown in Table 6.1. Based on shape one type is to be separated.

Table 6.1. Sample plastic objects

Objects	Size	Resolution
	2 cm	1024*664
	1.5 cm	1024*664
	2.524	1024*664

6.3. Detection algorithm

The sorting of objects using machine vision was performed using an algorithm of pattern matching named (Normalized Cross-Correlation) of machine vision. A pattern image template was built and stored in a computer's memory. When the object is sorting the application run, the camera receives the image of the object into MATLAB. The vision application investigates the image and transfers it to the classifier if the received image matches the model image or not matches [14].

While cross-correlation can be accomplished effectively in the transformation domain, the normalized type of cross-correlation used in feature matching applications lacks a simple frequency domain expression. As a consequence, the spatial domain normalized cross-correlation is determined.

Correlation between two signals (cross-correlation) is really a widely used strategy for detecting features and is often a part of more advanced techniques. Correlation textbook presentations explain the convolution theorem and the implication of efficiently computing correlation in the frequency domain through the fast Fourier transform [45][46]. Regrettably, the desired normalized type of correlation (correlation coefficient) in template matching lacks an equivalently easy and efficient frequency domain expression. As a result, the spatial domain's normalized cross-correlation has been calculated. Due to the computational expense of convolution of spatial domains, many imprecise yet quick spatial domain matching methods have been created [47]. This thesis discusses a newly introduced algorithm for extracting normalized cross-correlation from convolution of the transform domain. In certain instances, the modern algorithm significantly accelerates the calculation of normalized cross-correlation in the spatial domain.

Normalized 2-D cross-correlation algorithm uses the following general procedure:

- ✓ Calculate cross-correlation in the spatial or the frequency domain, depending on the size of images.
- ✓ Calculate local sums by precompiling running sums.
- ✓ Use local sums to normalize the cross-correlation to get correlation coefficients.

The implementation closely follows the formula from:

$$\gamma(u,v) = \frac{\sum_{x,y}\left[f(x,y) - \bar{f}_{u,v}\right]\left[t(x-u,y-v) - \bar{t}\right]}{\left\{\sum_{x,y}\left[f(x,y) - \bar{f}_{u,v}\right]^2 \sum_{x,y}\left[t(x-u,y-v) - \bar{t}\right]^2\right\}^{0.5}} \quad (6.1)$$

Where

- ❖ f is the image.
- ❖ $\bar{t}$ is the mean of the template.
- ❖ $\bar{f}\ u, v$ Is the mean of $f\ (x, y)$ in the region under the template.

6.4. Template matching by cross-correlation

The use of cross-correlation for template matching is motivated by the distance measure (squared Euclidean distance).

$$\mathrm{d}_{\mathrm{f,t}}^2(\mathrm{u,v}) = \sum_{\mathrm{x,y}} [\mathrm{f(x,y)} - \mathrm{t(x-u,y-v)}]^2 \quad (6.2)$$

Where f is the image and the sum is over x, y under the window containing the feature t positioned a t(u, v). In the expansion of d^2

$$\mathrm{d}_{\mathrm{f,t}}^2(\mathrm{u,v}) = \sum_{\mathrm{x,y}} [\mathrm{f}^2(\mathrm{x,y}) - 2\mathrm{f(x,y)t(x-u,y-v)} \quad (6.3)$$

$$+\mathrm{t}^2(\mathrm{x-u,y-v})]$$

The term $\sum t^2(x-u, y-v)$ is constant. If the term $\sum f^2(x, \bar{y})$ is approximately constant then the remaining cross-correlation term

$$\mathrm{c(u,v)} = \sum_{\mathrm{x,y}} \mathrm{f(x,y)t(x-u,y-v)} \quad (6.4)$$

Is a measure of the similarity between the image and the feature?

There are several disadvantages to using (6.2) for template matching:

- ❖ If the image energy $\sum f^2(x, y)$ varies with position matching using (6.1) can fail. For example, the correlation between the feature and an exactly matching region in the image may be less than the correlation between the feature and a bright spot.
- ❖ The range of $c(u, v)$ is dependent on the size of the feature.
- ❖ Eq. (2) is not invariant to changes in image amplitude such as those caused by changing lighting conditions across the image sequence.

6.5. Implementation

The implementation of the object sorting method is described in this section. First, we need to determine the duration of the exposure. The length of the exposure and the amount of noise in the recorded images are a trade-off. Long exposure times trigger motion blur when the speed of a dynamic scene is high. By reducing the exposure time this effect can be reduced; Short exposure times result in lower SNR (Signal-to-Noise Ratio), which affects the precision of the estimated surface standard. As a result, we determined the target dynamic scene and devised a sufficient exposure time. Then we designed the camera lighting system and created the light sources. The light sources are typically located far apart from the target object to be considered parallel light rays. The real light strength, on the other hand, is reduced according to the inverse square law. For instance, as the distance doubles, the light intensity is reduced to one-quarter of its original value, resulting in noise in the captured images.

Also, we tested the system with a vision camera (Line Scan Camera). Later on, the design system will also test to assist its ability under different practice settings. The vision camera instantly recognizes an object based on its shape and size.

6.5.1. Exposure Duration (objects speed and line scan speed relation)

From intensity shifts in captured images and lighting directions, the normalized cross-correlation method will estimate the normal map for a target object. We suggested using a CCD image sensor to capture several images under various lighting conditions nearly simultaneously.

However, there is an issue with motion blur when capturing dynamic scenes. For the normalized cross-correlation, we need to set an exposure time that is long enough to capture the detailed intensity changes in the captured images.

Also, this reduces the SNR (Signal-to-Noise Ratio), resulting in a noisier captured image. Thus, it is important to consider the length of the exposure time. Since object speed varies, we must design exposure durations that are appropriate for specific dynamic scenes.

The following equation defines the relationship between object speed and line speed time taken to acquire the single image:

$$v_{max} = \frac{d}{f}\frac{s}{e'} \qquad (6.5)$$

Where v_{max}, f and e are the maximum speed of the object, the focal length of the camera lens, and the total exposure time. The distance between the image sensor and the scene is represented by d, and the pixel size of the image sensor is represented by s. We may disregard the motion of a target dynamic scene if the target object is projected in the same image sensor pixel over time, according to this equation. We used a CCD image sensor with pixel dimensions of 10 µm x 10 µm in our implementation. The relationship between the relevant object speed and the exposure time is shown in Figure 6.3, with a camera lens focal length of 25 mm, we measured the applicable object speed to get the results. By moving the target object further away from the image sensor or reducing the exposure time, we can capture multiple images from a faster dynamic scene.

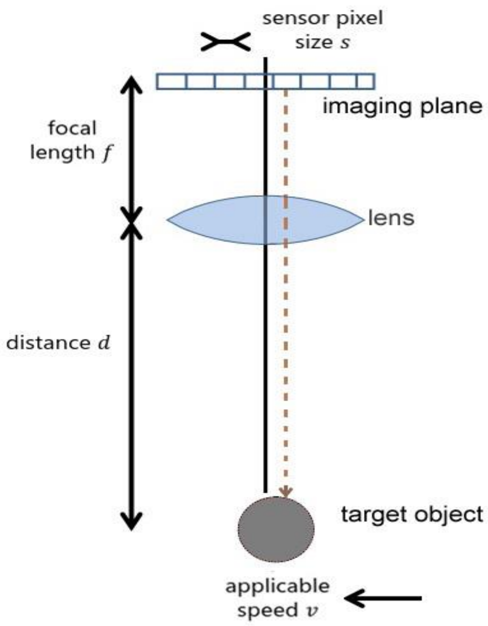

Figure 6.3. Relationship between the exposure time and object speed (Equation (6.5))

As shown in Figure 6.3, the relevant object speed at which we can disregard the difference in direction of moving objects is dependent on the focal length, the distance between the image sensor and the target object, and the image sensor's pixel size.

Also, we determined the applicable object speed using a sensor pixel size of 10 µm and a focal length of 25 mm for the camera lens. As shown in Figure 6.3, we must shorten the exposure time when moving the target object away from the image sensor to capture images of a complex scene.

Following that, we'll discuss the optimum exposure setting for a dynamic scene using a practical example. We intend to capture an image of an object that is cross at 50 seconds at a distance of 8 cm away from the camera. Table 6.2 shows some details of camera system

Table 6.2. Detailed specifications for the camera system that was introduced

Properties	Implementation of the camera system in this work
Pixels number	1024 (H) × 664 (V) (total number of pixels)
Size of pixel	10 µm × 10 µm
Time of exposure	More than 6.4512ms for each image
Data stream (frame rate)	60 fps
The focal length of the lens	25 mm
The maximum speed of an object that is applicable	50 /sec at a distance of 8 cm from the camera

6.5.2. Predefining image (template image)

A normalized correlation algorithm is used for matching the two images. The correlation to work the snap and the template must be of the same dimension or the template must be smaller in size. Few other conditions must be checked for accurate results. The object on the conveyor could be at a different orientation than the template image. This snapshot is rotated to check for disorientation. When an image is rotated its dimensions are changed and its size increases and correlation does not work. To counter this ‘0’ padding is used to resize the snapshot image to meet the required size for correlation.

The two images are correlated and maximum correlation is found if it is greater than a certain threshold (which is checked beforehand) an image is displayed (Image match count, Image matched at ‘x’ degrees).

6.5.3. Image analysis and output

The first step is taking a snapshot from the live feed of the camera above the conveyor belt. When the program starts a prompt asks for uploading the predefined image (template image) of the object. The main program starts after that and live video is displayed on the screen. Processing of the snap is a multistep process that involves removing the noise, converting it into a binary image; blob analysis, etc.…Every frame from the live video is converted into a binary image for fast processing. A two-dimensional median filter is used for noise reduction. For further processing area of white parts of the image are calculated any area less than a specified value are rejected.

The area of all objects is calculated beforehand and snaps that have an area near to the area of the object are used for further processing. In any operation, the output is extremely important. Something is done in exchange for something else. The final output is also generated by machine vision applications. Machine vision applications' outputs are usually classified as Pass/Fail. However, for Pass/Fail outputs, additional attributes may be specified, such as the number of passed/failed items, setting an alarm if the items are failed, and so on. It is dependent on the application's target. Figure 6.4, represented the proposed study.

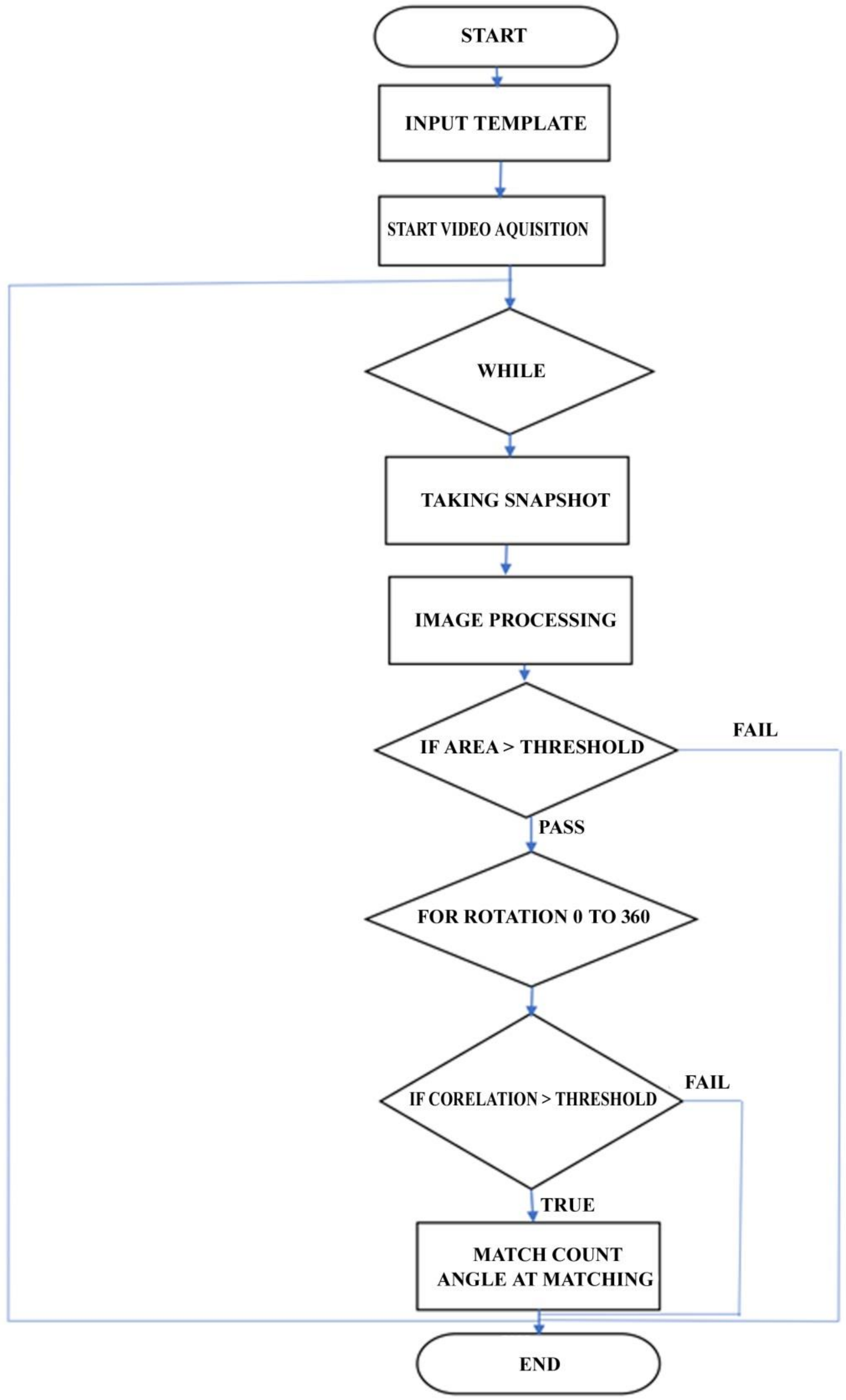

Figure 6.4. Proposed work of object sorting

6.5.4. Image processing technic

This section describes in detail the functionality of the processes involved in the programming of MATLAB.

The function block says image processing involves many processes. It is a multistage process. The first step is converting a grayscale image to a binary image. Converting an image into binary increases working capability and reduces the work time of the process. In MATLAB im2bw() function takes an image as input and outputs a black and white image. The conversion is done based on the threshold value.

In this study, we have used some image processing operations such as the rotation technique to enhance the training data [48]. Rotating has been implemented by applying degrees of 45, 90, 135, 180, 225, 270, 315 degrees, for determining these angles we utilized the (Imrotate) function in MATLAB environment as shown in Figure 6.5.

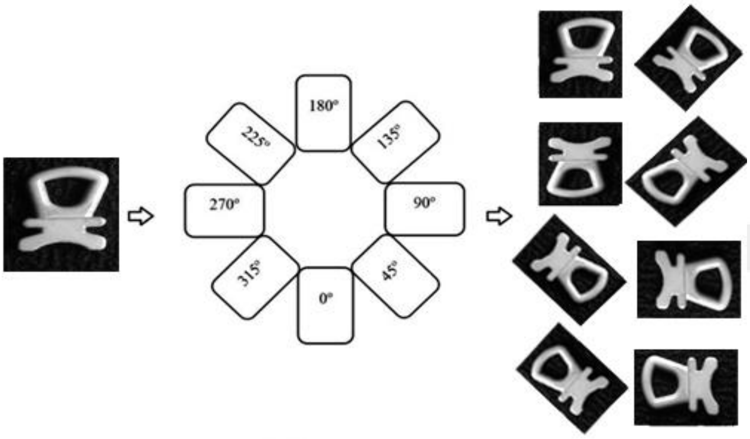

Figure 6.5. Rotation Process in different degrees

Thresholding is the easiest image segmentation technique and the most often used process for converting a grayscale image to a binary image.

We select a threshold value and then classify all gray levels below it as 0 (black, i.e. background) and all gray levels equal to or greater than the threshold value as 1. (White i.e. foreground).The thresholding is defined in the following equation.

$$g(x,y) = \begin{cases} 1 & \text{if } f(x,y) \geq T \\ 0 & \text{otherwise} \end{cases} \quad (6.6)$$

Here, g(x, y) denotes the threshold image pixel located at (x, y), and f(x, y) denotes the greyscale image pixel located at (x, y).

A threshold is set based on the percentage of matching of the two images. Image thresholding is a simple, yet effective, way of partitioning an image into a foreground and background. This image analysis technique is a type of image segmentation that isolates objects

by converting grayscale images into binary images. Image thresholding is most effective in images with high levels of contrast.
In Figure 6.6 is an example of converting an image to a binary image.

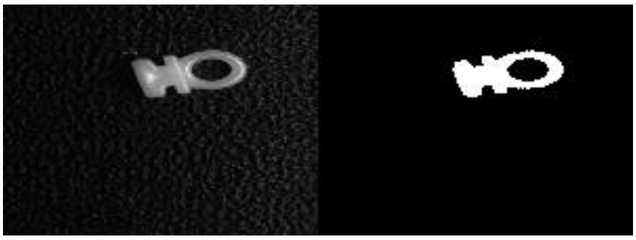

Figure 6.6. Converting greyscale image to binary and the threshold value of 0.5

BW = im2bw(I,level) converts the grayscale image I to binary image BW, by replacing all pixels in the input image with luminance greater than level with the value 1 (white) and replacing all other pixels with the value 0 (black). This range is relative to the signal levels possible for the image's class. Therefore, a level value of 0.5 corresponds to an intensity value halfway between the minimum and maximum value of the class.

The next process involves removing noise s from the image see Figure 6.7. Median filter 2-D is typically used for removing salt and pepper noise in images. The next process involves removing noise from the image. Median filter 2-D is typically used for removing salt and pepper noise in images.

Figure 6.7. Applying the median filter removes the noise

In the next step, small objects are removed from the image that may disrupt the matching process.

BW2 = bwareaopen(BW, P) eliminates all connected components (objects) from the binary image BW that have less than P pixels, resulting in the creation of another binary image, BW2. This is referred to as an area opening. This is the final process in this step of the program. The output after these three processes is shown in Figure 6.8.

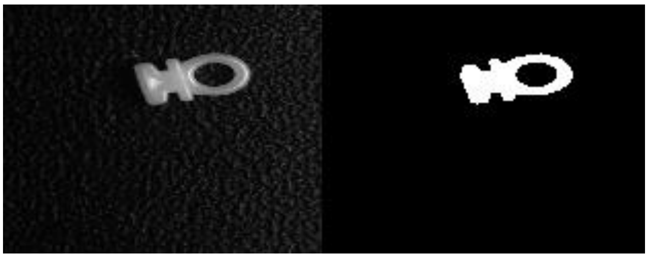

Figure 6.8. Greyscale image (L) processed image (R)

This final image is matched with the template image stored already using correlation. C = normxcorr2 (template, A) returns the normalized cross-correlation matrix between the two matrices template and A. Correlation coefficients are stored in the resulting matrix C. For normalization to be valid, the input image, defined as a numeric image, must be larger than the matrix template.

The Normxcorr2 function follows the following general procedure:

- Calculate cross-correlation in either the spatial or frequency domain, based on the image size.
- Calculate local amounts by the use of precompiled running sums.
- To obtain correlation coefficients, normalize the cross-correlation using local sums.

7. RESULTS AND DISCUSSION

7.1. Experimental Environment

In this section, the experimental environment is set as an industrial inspection system; the mono-color background is used and simple objects recognized. Mono-color background leads to the clear separation between the background and foreground. The clear separation also helps the clear edge detection in preprocessing.

To reduce the time consuming we limited the intersection of line feature to be formed on the edge and its neighbor only. Finally, the normalized cross-correlation algorithm is performed by using the relation between the geometric features.

The objective of this research was to sort different shape and crack of objects from different rotation. The results are shown in Tables 7.1, 7.2, 7.3, 7.4.

7.2. Experimental Matching Result

We performed the experiment with two different plastic objects model and tested with 6 different target live videos two repeats per object. The average for each object is calculated to evaluate the accuracy of one object per line scan that is provided in Table 7.1, 7.2, 7.3.

The classification accuracy of the proposed algorithm is about equal or more than 90%, at a speed of 6 m/s per image, which can meet the requirements of the system. It can be found from Table 7.1, 7.2 that, the correct percentage of match objects is relatively high; this is due to the quality that the feature of match objects may vary greatly, and the classifier tends to classify it to be good object. Figure 7.1, shows the simple plastic objects model used in the present work.

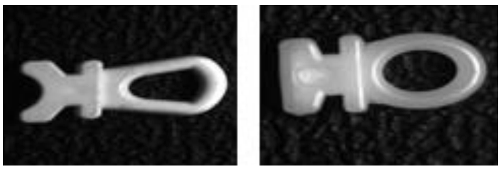

Figure 7.1. Simple plastic objects model 1 and 2

According to Table 7.1 and Figure 7.2.model 1 of an object has used approximately 0 degrees and obtained 93.12 %, but for the second repeat of the object is 92.87 %, while the detection rate of both repeated obtained 92.99 % in an inspection time of 6.7893 m/s per repeat. While when used 90 degrees and obtained 98.16 %, but 97.96 % was replicated for the second, while the detection rate of both repeated obtained 98.06 % per repeat in an inspection time 6.4529 m/s. When used 135 degrees and obtained 95.23%, but for the second repeat of the object, is

94.97%, while the detection rate of both repeated obtained 95.01% in 5.9743 m/s per repeat. Object model 1 has used 180 degrees and obtained 92.99 %, but for the second repeat of the object, is 93.03 %, while the detection rate of both repeated obtained 93.01 % in 5.6468 m/s per repeat. Also, object model 1 has used 225 degrees and obtained 99.13 %, but for the second repeat of the object is 98.94 %, while the detection rate of both repeated obtained 99.03 % in 6.2587 m/s per repeat. Also when used 270 degrees and obtained 96.83 %, but the second repeat of an object is 97.04 %, while detection rate of both repeated obtained 96.93 % in 5.8793 m/s per repeat. Figure 7.3 represents line chart of detection rate of sorting object model 1.

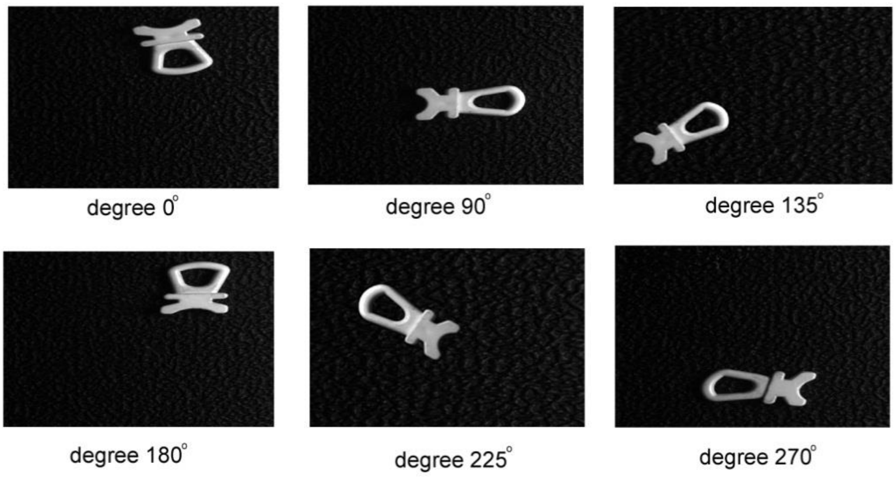

Figure 7.2. Results on target object model 1

Table 7.1. The detection rate of sorting object model 1 during 2 replications by cross-correlation

Object	Rotation degrees	Repeat 1(%)	Repeat 2(%)	Detection rate	Inspection time (m/sec)
Model 1	0	93.12	92.87	92.99	6.7893
Model 1	90	98.16	97.96	98.06	6.4529
Model 1	135	95.23	94.97	95.01	5.9743
Model 1	180	92.99	93.03	93.01	5.6468
Model 1	225	99.13	98.94	99.03	6.2587
Model 1	270	96.83	97.04	96.93	5.8793

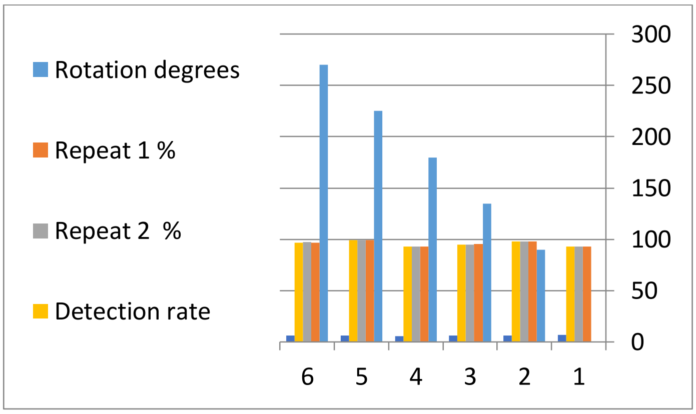

Figure 7.3. Line chart of detection rate of sorting object model 1

According to Table 7.4 and Figure 7.4 object model 2 has used 0 degrees and obtained 94.77 %, but for the second repeat of the object is 95.17 %, while the detection rate of both repeated obtained 94.97 % in 6.4879 m/s per repeat. While used 45 degrees and obtained 98.14 %, but 97.97 % was replicated for the second, while the detection rate of both repeated obtained 98.05 percent per repeat in 5.9984 m/s. Object model 2 has used 90 degrees and obtained 96.88%, but for the second repeat of the object is 97.19%, while the detection rate of both repeated obtained 97.03% in 6.1289 m/s per repeat. When object model 2 has used 270 degrees and obtained 99.56 %, but for the second repeat of the object is 99.14 %, while the detection rate of both repeated obtained 99.35 % in 5.1223 m/s per repeat. Also when used 180 degrees and obtained 94.14 %, but the second repeat of the object is 93.89 %, while the detection rate of both repeated obtained 94.01 % in 5.7823 m/s per repeat. When used 315 degrees and obtained 99.29 %, but the second repeat of the object is 98.95 %, while the detection rate of both repeated obtained 99.12 % in 6.7233 m/s per repeated. Figure 7.5 represents Line chart of detection rate of sorting object model 2.

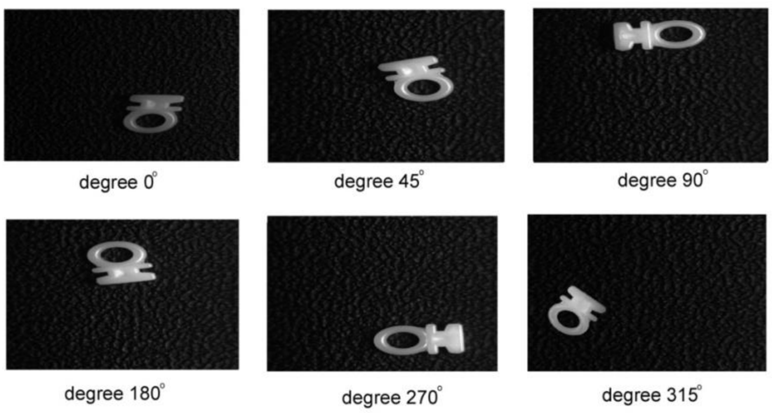

Figure 7.4. Results on target object model 2

Table 7.2. The detection rate of sorting object model 2 during 2 replications by cross-correlation

Object	Rotation degrees	Repeat 1(%)	Repeat 2(%)	Detection rate	Inspection time (m/sec)
Model 2	0	94.77	95.17	94.97	6.4879
Model 2	45	98.14	97.97	98.05	5.9984
Model 2	90	96.88	97.19	97.03	6.1289
Model 2	180	94.14	93.89	94.01	5.7823
Model 2	270	99.56	99.14	99.35	5.1223
Model 2	315	99.29	98.95	99.12	6.7233

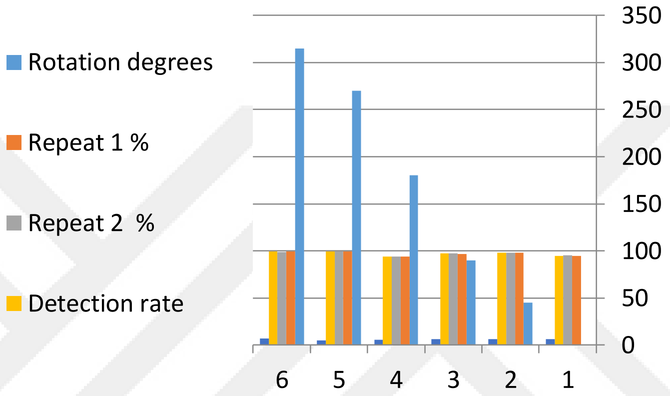

Figure 7.5. Line chart of detection rate of sorting object model 2

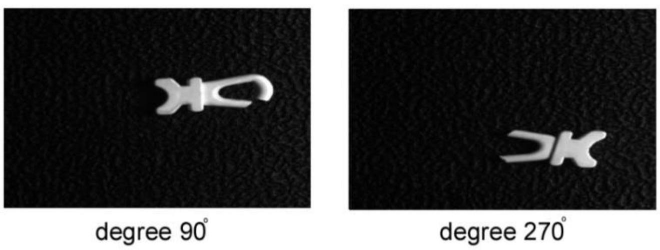

Figure 7.6. Results on target cracked object model 1

According to Table 7.3 and Figure 7.6, the object model 1 has used 90 degrees and obtained 63.15 %, in 5.2945 m/s for once, but for the second time of object has used 270 degrees is 86.96 %, in 5.9843 for once, while the detection rate of both obtained 63.15 % and 86.96 % respectively. Figure 7.7 represents line chart of detection rate of cracked object model 1.

Table 7.3. The detection rate of sorting object cracked model 1 by cross-correlation

Object	Rotation degrees	Detection rate	Inspection time (m/sec)	Match/Not Match
Model 1	90	63.15	5.2945	Not match
Model 1	270	86.96	5.9843	Not match

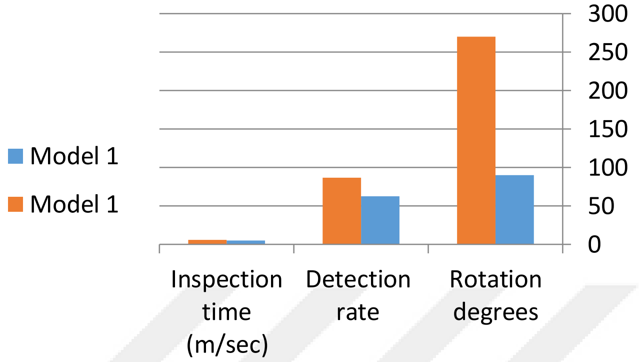

Figure 7.7. Line chart of detection rate of cracked object model 1

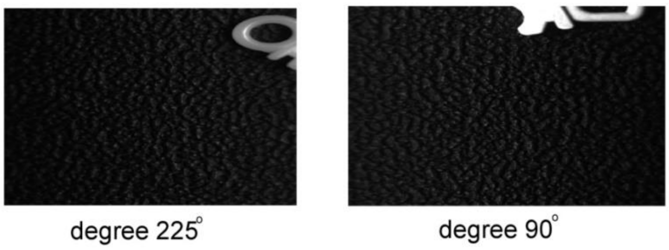

Figure 7.8. The images of different degrees of mismatch object model 1 and 2

According to Table 7.4, and Figure 7.8, the object model 2 has used 225 degrees and obtained 46.33 %, in 5.5464 m/s for once, but for the second time of object model 1 has used 90 degrees is 51.04 %, in 6.4982 m/s for once, while the detection rate of both obtained 46.33 % and 51.04 % respectively. Figure 7.9 represents line chart of detection rate of mismatch object model 1 and 2.

Table 7.4. The detect ion rate of sorting object model 1 and 2 mismatch by cross-correlation

Object	Rotation degrees	Detection rate	Inspection time (m/sec)	Match/Not match
Model 2	225	46.33	5.5464	Not match
Model 1	90	51.04	6.4982	Not match

Figure 7.9. Line chart of detection rate of mismatch object model 1 and 2

7.3. Discussion

System compared the results with two different objects from different shapes and degrees estimated using the proposed method with those estimated using the previously normalized cross-correlation. The method with a high-speed camera and we repeat the object on the conveyor belt two times to compare results to know the detection rate increased or decreased. We captured one image of the object as a template for the target dynamic scene. We set exposure times of more than 60 seconds per object while crossing on a conveyor belt in the comparison experiments. Also, we need to know which object is matched, not match or mismatch, and crack from which degree as shown in Figures 7.2, 7.4, 7.6 and 7.8, When we see both object models 1 and 2 for case pass in degrees 0, 45, 90, 135, 180, 225, 270, and 315 we get approximately the same detection rate. Those results depend on the speed of executing algorithm and camera in a good position and other case cracked and mismatched object the system does not pass and is rejected. A speed coder must be used to obtain the relative speed between the detected target and the line-scan CCD camera image capture system to correct the image error created by the speed mismatch in the line-scan process.

8. CONCLUSIONS

Quality is very important when it comes to sorting objects. Various researchers have devoted their careers to the study of object recognition and made many advances in this area. So many vision-based automated object recognition algorithms have been proposed to effectively and accurately identify object flaws. To ensure the detection outcome is accurate, the image quality must be consistent prior to applying any kind of detection process. As we all know, though, all camera lenses display distortions, most notably radial distortion. To fix the picture and delete the blur, an extensive study has been conducted on 2-D camera image correction. There is, however, little knowledge on camera correction for a 1-D line scan camera, considering the fact that line scan cameras are getting more popular due to their high resolution and data processing performance.

The vision system used in this study for the recognition of objects in terms of their dimensions, such as shape and size, is interactive system built-in MATLAB software with a vision assistant module. The consumer will display the field of view from various perspectives, as well as the component count in-group. Similarly, small, large, and cracked shapes may be identified. The camera can separate objects in this analysis. Also, the program can identify any objects.

In fact, the industry needs component isolation based on the characteristics mentioned above, and we will use an actuation device to distinguish the objects based on the vision system's signal. This requires microcontroller interfacing, which can be seen as future jobs.

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CURRICULUM VITAE

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[redacted]

RESEARCH EXPERIENCES

- ✓ Computer Programming languages available (Python, C++, MATLAB, vb .Net.)
- ✓ Computer programs you can use (CAT/CAM, PROTEUS, CALCULUS, vb.)

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ACADEMIC ACTIVITIES

Paper: Published

DOI : https://doi.org/10.47577/technium.v3i3.3181