TECHNICAL UNIVERSITY MALAYSIA, MELAKA

APPLICATION OF COLORS SENSOR IN AN AUTOMATED SYSTEM

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ABSTRACT

Sensor provides a means for gathering information on manufacturing operations and processes being performed. In many instances sensors are used to transform a physical stimulus into an electrical signal that may be analyzed by the manufacturing system and used for making decisions about the operations being conducted. The purpose of sensors is to inspect work in progress, to monitor the work-in-progress interface with the manufacturing equipment, and to allow self-monitoring of manufacturing by the manufacturing system's own computer. Color sensors register items by contrast, true color, or translucent index. True color sensors are based on one of the color models, most commonly the RGB model (red, green, blue). A large percentage of the visible spectrum can be created using these three primary colors. Many color sensors are able to detect more than one color for multiple color sorting applications. Depending on the sophistication of the sensor, it can be programmed to recognize only one color, or multiple color types or shades for sorting operations. Through this report, the color identification, the basic color theory and the applications of color sensor will be review. In this report will be focusing on the application of color sensor using conveyor system for sorting RGB color.

ABSTRAK

Sensor merupakan suatu alat untuk mengumpul maklumat untuk operasi pembuatan dan proses yang sedang dijalankan. Kebanyakannya, sensor digunakan untuk menukar stimulus fizikal kepada isyarat elektrik yang mana ia akan dianalisis oleh sistem mekanikal dan akan digunakan untuk membuat keputusan mengenai operasi yang sedang dijalankan. Tujuan sensor digunakan adalah untuk memastikan sesuatu kerja dilakukan dengan betul. Selain itu sensor juga digunakan untuk mengawal kerja-kerja antara muka dengan alatan pembuatan. Sensor juga membenarkan sesuatu operasi di kawal dengan menggunakan Komputer. Sensor warna merupakan sesuatu alat untuk mengesan warna. Ia terdiri daripada kontras, unit warna asas atau index lut cahaya. Unit cahaya adalah terdiri daripada model warna kebiasaannya ialah merah, biru dan hijau. Spektrum boleh dihasilkan dengan peratus yang tinggi dengan menggunakan ketiga-tiga warna asal. Kebanyakan sensor warna boleh mengesan lebih daripada satu warna untuk pelbagai jenis aplikasi warna. Bergantung kepada kebolehan sensor, ia boleh di program untuk mengesan hanya satu warna atau pelbagai jenis warna atau bentuk untuk operasi pengasingan. Melalui laporan ini, identiti warna, teori asas warna dan aplikasi sensor warna akan ditunjukkan. Laporan ini juga akan menumpukan kepada aplikasi mengenalpasti tiga jenis warna asas iaitu merah, biru dan hijau dengan menggunakan sistem conveyor.

CHAPTER 1

INTRODUCTION

1.1 Introduction To The Project

Industries today are approaching to use color sensor to fulfil their needs for a higher production and precise quality. Historically, components used for color sensing were considered expensive and required precision support circuitry, limiting their application mostly to specialized instrumentation. However, new technologies of color sensors with higher levels of integration are becoming available, allowing for more cost-effective solutions. As the cost of color sensing comes down, the number of applications using color sensing is increasing. Color sensors play a significant role in end equipment such as color-monitor calibration, color printers and plotters, paints, textiles, cosmetics manufacture and medical applications such as blood diagnostics, urine analysis, and dental matching. The complexity of a color sensor system is based largely on the number of wavelength bands, or signal channels, it uses to determine color. Systems can range from a relatively simple three-channel colorimeter to a multiband spectrometer.

In this project, an application is going to be developed using TCS230 Color Sensor for detecting RGB color. The TCS230 has an array of photodetectors, each with either a red, green, or blue filter, or no filter (clear). The filters of each color are distributed evenly throughout the array to eliminate location bias among the colors. The applications of this sensor include sorting by color, and color matching.

Certain matters shall be looked upon to complete this project. Information concerning color sensor, their function, application and Basic Stamp programming should be search through many ways such as internet, journals and books. Information on how to program TCS230 Color Sensor must be learning in order to program this application into reality.

The programming should be successful and information of this color sensor can be useful to further understand their application. As a result of this, organization can use this application for student, to use in their research, or studies especially those majoring in Automation and Robotics.

1.2 Problem Statement

Machines can perform highly repetitive tasks better than humans. Worker fatigue on assembly lines can result in reduced performance, and cause challenges in maintaining product quality, an employee who has been performing a repetitive inspection task may eventually fail to recognize a defective product. But automating many of the tasks in the industries may helps to improve the productivity and product quality. In other hand, the use of sensor technology will give the opportunity to the industry to employ more automated processes.

In the past, traditional color sensor output only a 'match/no match' condition to the machine controller. Most color sensed unlike other color sensors that can be programmed to match only one to eight color. For example, some company try to use single sensor type for sorting colors. It is desirable to be able to apply only one single sensor type to identification and separation of all plastic resin types and colors. The primary consideration is to apply the proper sensor, or sensors, to the specific application in order to obtain the best available separation efficiency, with the highest reliability, and at the least cost.

As many industries are looking forward to automate their production, it is difficult for them to select the correct color sensor for their industries or organization as recently has many types of color sensor. Most sensors are color blind although colors play an increasingly important role in today's manufacturing and processing procedures. Many sensors can distinguish between contrasts, light and dark and matte and gloss. But when the detection of a specific color becomes the primary requirement, the sensors find their limitations.

Thus, to relate with industry area, basic design of conveyor system will be construct, then the conveyor system will be fabricate. The main important thing is to define how the color sensor can read the color by using basic stamp program. In describing this project to readers, description of the factors that could affect the performing of this programming and the conveyor system are discussed.

1.3 Objectives, Aims and Scopes of the Project

Objectives

With the use of TCS230 Color Sensor, Basic Stamp programmer and BS2P microcontroller, this project explores the possibility of creating a programming that can sort RGB colors. In this project, the main objective is to create program that can identify red, green and blue colors and fabricate a mechanical system for identify RGB color by using a conveyor. The other objective also includes the understanding of the application of color sensor in an automated system by related literatures review.

1. Learning the basic stamp programming and its application also how it functions.
2. Learning information concerning the TCS230 color sensor module.
3. Create the program that can identify RGB color by using basic stamp.
4. Understand the areas of color sensor application.

1.3.2 Aims

The aims of this project are to ensure that basic stamp has capabilities in programming. Certain matter shall be given priority:

i). Understanding a new knowledge of programming, which can easily be developed as it has be.

ii). Create the program that will show the TCS230 color sensor able to detect RGB colors.

1.3.3 Scope of the Project

The scopes of this project are:

1. Design a system that can identify RGB color from an object
2. Fabricate the system using:
    a. Parallax Board of Education (BOE) Module
    b. TCS230 Color sensor
    c. DC motor
    d. Relay
    e. Microcontroller
    f. Conveyor structure
3. Create a program that can use to identify RGB color.
4. Run the programming system.

1.4 Gantt Chart for PSM 1

CONTENTS	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
PROJECT SELECTION	■															
INFORMATION SOURCING		■	■	■	■	■	■	■								
MAKE LITERATURE REVIEW FROM RESEARCH		■	■	■	■	■	■	■								
DISCUSS ON SIMPLE PROJECT THAT USING COLOR SENSOR			■	■												
DRAFT THE OBJECTIVE AND INTRODUCTION OF COLOR SENSOR				■	■											
SEARCHING MATERIAL AND SELECT INSTRUMENT/TOOL THAT NEED TO BE USED IN THE PROJECT				■	■	■	■	■	SEMESTER BREAK							
STUDY AND LEARNING ABOUT TCS230 COLOR SENSOR MODULE AND PROGRAMMING					■	■	■	■		■	■	■	■	■	■	■
DESIGN A CONVEYOR					■	■	■	■								
START MAKE A DRAF REPORT					■	■	■	■		■	■	■				
PREPARATION FOR FINAL DRAFT REPORT										■	■	■	■			
PREPARATION FOR POWER POINT SLIDE													■	■		
SEMINAR PRESENTATION AND REPORT SUBMISSION															■	■

Table 1.1: Gantt chart for PSM 1

1.5 Gantt Chart for PSM 2

CONTENTS	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
START CREATE PROGRAMMING FOR SORT COLOR									SEMESTER BREAK							
FABRICATE THE CONVEYOR STRUCTURE																
FABRICATE THE CONVEYOR SYSTEM USING SELECTED PARTS																
TEST RUN THE CONVEYOR SYSTEM																
TEST RUN THE CONVEYOR SYSTEM WITH TCS230 COLOR SENSOR																
RUN THE SYSTEM WITH THE SUCCESSFUL COLOR SORT PROGRAM																
COLLECTS THE DATA RESULT AND CONCLUSION.																
PREPARATION FOR FINAL PSM II REPORT																
PREPARATION FOR POWER POINT SLIDE																
SEMINAR PRESENTATION AND REPORT SUBMISSION																

Table 1.2**:** Gantt chart for PSM 2

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

Most sensors are electrical or electronic, although other types exist. A sensor is a type of transducer. Sensors are either direct indicating (e.g. a mercury thermometer or electrical meter) or are paired with an indicator (perhaps indirectly through an analog to digital converter, a computer and a display) so that the value sensed becomes human readable. In addition to other applications, sensors are heavily used in medicine, industry and robotics.

A common requirement in the field of color sensing is that of color identification, or sorting of objects by color. Typically this type of application is simpler than a general-purpose color measurement application. A common task in color sensing is to identify an unknown color as falling into one of these general categories.

2.1 Color Identification

Color names can be used and conjure reasonably consistent perceptions. There have eleven basic color names have been identified such as white, gray, black, red, yellow, green, blue, orange, purple, pink, and brown. Most or all colors can be described in terms of variations and combinations of these colors. Due to the fact that human color vision is accomplished in part by three different types of cone cells in the retina, it follows that three values are necessary and sufficient to define any color.

2.1.1 Color Theory

Berlien (2004) was said that there has three values can be thought of as coordinates of a point in three-dimensional space, giving rise to the concept of color space. Hue, saturation, luminance (HSL) is one such color coordinate system, or color space. A more precise method of describing color is by hue, saturation, and lightness. Hue is the attribute of a color according to its similarity with one of the colors red, yellow, green, or blue, or a combination of adjacent pairs of these colors considered in a closed ring, as shown in this figure 2.1

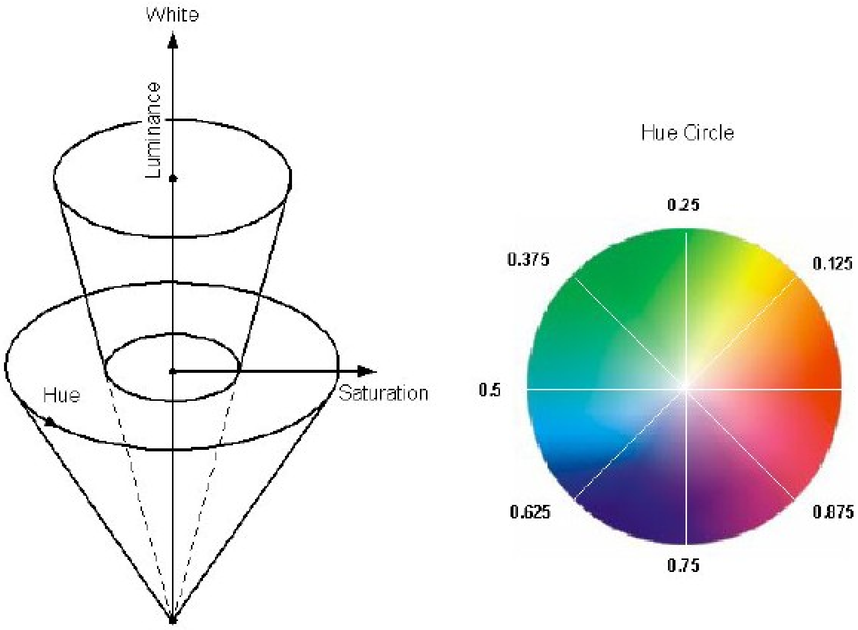

Figure 2.1: HSL diagram with Hue circle (Berlien 2004)

Color theory can also be defined by Soloman (1998). Color science defines color in a space, with coordinates of hue, saturation and intensity (HSI). Hue is related to the reflected wavelength of a color when a white light is shined on it. Intensity (lightness) measures the degree of whiteness or gray scale of a given color. Saturation is a measure of the vividness of a given hue. The term *chromaticity* primarily includes elements of hue and saturation components. Researchers depict color in space using hue as angle of a vector, saturation as the length of it and intensity as a plus or minus height from a center point as shown in figure 2.2.

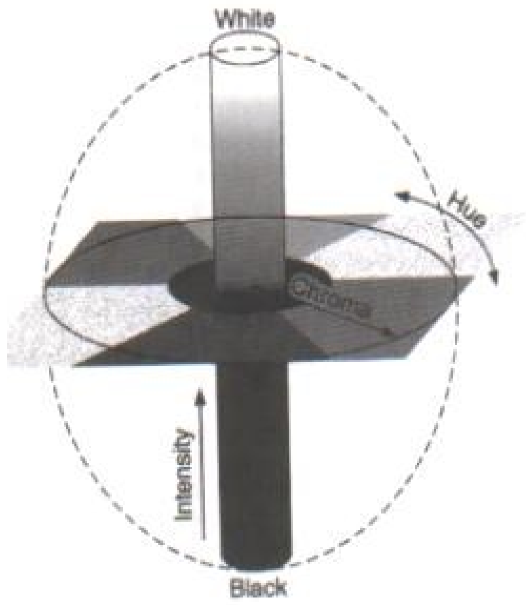

Figure 2.2: Coordinates of hue, saturation and intensity of color in space (Soloman 1998)

From figure 2.3, a color is depicted at a molecular level. Color is created when light interacts with pigment molecules. Color is generated by the way pigment molecules return (bend) incoming light.

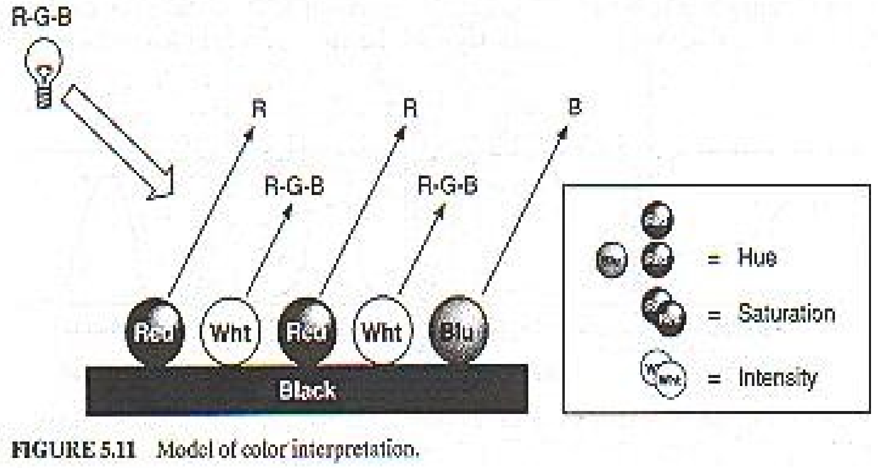

Figure 2.3: Model of color interpretation (Soloman 1998)

2.1.2 Color and Light

A 'color' is an interaction between a very small range of electromagnetic waves and the eyes and brain of a person. What people call red, green, or blue are just ways of categorizing what their brain experiences. An article by Bishop and Lee (2006) brief that, the spectrum of light where the eye can see is called the visible region as can be seen in figure 2.4. Light is a type of energy, which makes up a small portion of the electromagnetic spectrum. Visible light could be expressed as a frequency, but the magnitude is so large people generally express the wavelength of light in units of nanometers (10-9 meters) to describe light. The region of visible light consists of light with a wavelength between approximately 380 nm to 780 nm. The visible colors and their corresponding range of wavelengths can be found in Table 2.1

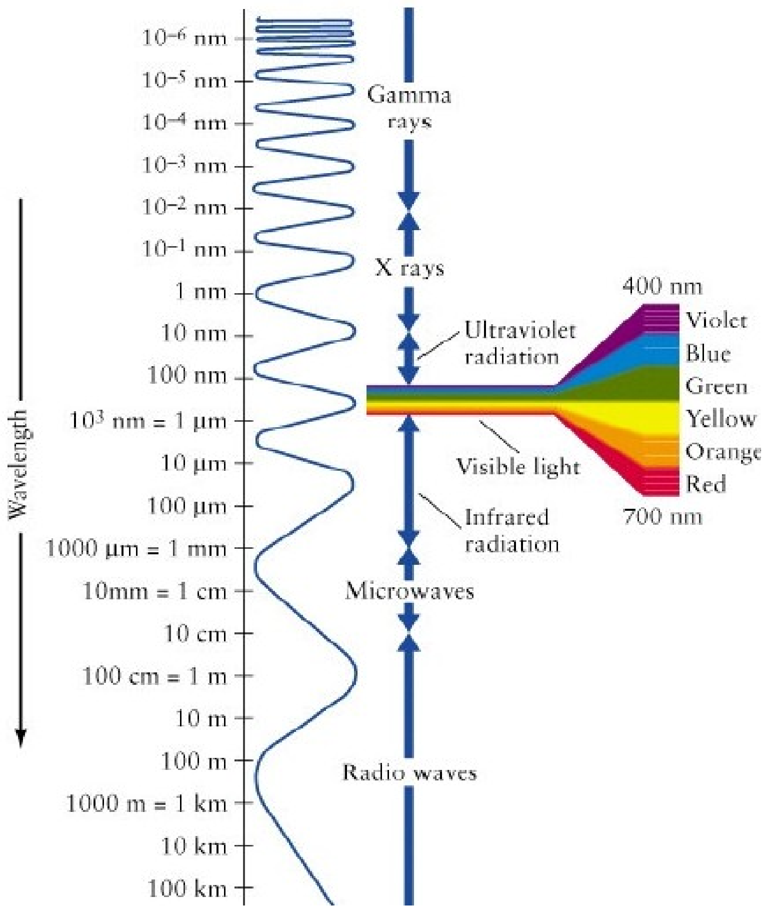

Figure 2.4: Electromagnet radiation (Bishop and Lee 2006)

Table 2.1: Color vs. Wavelength Range (Bishop and Lee 2006)

Color	Wavelength Range (nm)
Violet	380 ~ 410
Indigo	410 ~ 450
Blue	450 ~ 510
Green	510 ~ 560
Yellow	560 ~ 600
Orange	600 ~ 630
Red	630 ~ 780

2.2 Color Sensor

Color sensors register items by contrast, true color, or translucent index. True color sensors are based on one of the color models, most commonly the RGB model. A large percentage of the visible spectrum can be created using these three primary colors. Many color sensors are able to detect more than one color for multiple color sorting applications. Depending on the sophistication of the sensor, it can be programmed to recognize only one color, or multiple color types or shades for sorting operations. Some types of color sensors do not recognize colors, instead focusing on light wavelengths.

Sensor can be configured to locate wavelengths from near infrared (colors in the 750 nm to 2500 nm wavelength range), far infrared (colors in the 6.00 to 15.00 micron wavelength range), and UV (colors in the 50 to 350 and 400 nm wavelength range), in addition to the visible range. Sensors that read the visible range are the most common type of color sensors. They measure color based on an RGB color model. A large percentage of the visible spectrum (380 nm to 750 nm wavelength) can be created using these three colors. Color sensors are generally used for two specific applications:

1. True color recognition

Sensors used for true color recognition are required to "see" different colors or to distinguish between shades of a specific color. They can be used in either a sorting or matching mode. In sorting mode, output is activated when the object to be identified is close to the set color. In matching mode, output is activated when the object to be detected is identical (within tolerance) to the color stored in memory.

2. Color mark detection.

Color mark detection sensors do not detect the color of the mark; rather they "see" differences or changes in the mark in contrast with other marks or backgrounds. They are sometimes referred to as contrast sensors. Color sensors shine light onto the object to be monitored and measure either the direct reflection or the output into color components. Many color sensors have integral light sources to achieve the desired effect. These integral light sources include LEDs, lasers, fiber optic, and halogen lamps.

2.3 Sorting

Sorting is any process of arranging items in some sequence and/or in different sets. It has two common distinct meanings such as ordering and categorizing. Ordering is arranging items of the same kind, class, nature, etc. in some ordered sequence while categorizing is grouping and labeling items with similar properties together by sorts.

2.3.1 Sorting Information or Data

One important kind of sorting is arranging items of information in alphabetical sequence according to some pre-defined ordering relation (sort key by each group of lists), e.g. when one sorts the books in a library by title, subject or author (all alphabetically sorted normally in ascending order). The resulting order may be either ascending or descending, because essentially all sorting is numerical sorting. The main purpose of sorting information is to optimize its usefulness for specific tasks.

2.3.2 Physical Sorting Processes

Various sorting tasks are essential in industrial processes. For example, during the extraction of gold from ore, a device called a shaker table uses gravity, vibration, and flow to separate gold from lighter materials in the ore (sorting by size and weight). Sorting is also a naturally occurring process that results in the concentration of ore. Sorting results from the application of some criterion or differential stressor to a mass to separate it into its components based on some variable quality. Materials that are different, but only slightly such as the isotopes of uranium, are very difficult to separate.

2.3.3 Application of Sorting and Color Sorting

Bickman, Josh et al (1996) state in the article about automated color-sorting uses optical technology that has evolved from early designs intended to remove ceramic contaminants. The system configuration is similar to automated ceramic removal equipment, but color-sorting equipment uses a different light source. Automated systems can generally be instructed to remove any one or a combination of the three glass colors.

According to BG and DW (1992), industrial applications require some sort of automated visual processing and the classification of items placed on a moving conveyor. A typical process comprises of:

(i) Looking at the items on the conveyor via some type of sensor such as a camera

(ii) Localizing any single item

(iii) Classifying the item based on a set of features such as shape

(iv) Performing the necessary action depending on the classifications made.

Bozma and Yal-cin (2002) in their journal explains about a Visual classification setup in an industrial setting typical setup is as shown in Fig. 2.5. In this journal state that how items at random positioned and oriented to be moving on a conveyor. A camera located above the conveyor views the items orthographically. They assume that there is an item separator placed before the camera so that the incoming items are not overlapping which is a realistic assumption in many manufacturing environments. A sensing device signals the presence of perception that is instead of processing the whole image, only areas that are deemed ‘‘interesting’’ and thus calling for attention are analyzed.

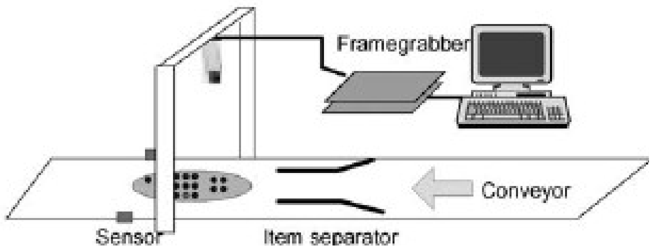

Figure 2.5: Visual classification setup in an industrial setting (Bozma and Yal-cin (2002)

An automated remote controller sorting system has been developed for a TV manufacturing plant as shown in figure 2.6. There are five different types of remote controllers with about ten different colors. Each type of remote controller can be distinguished based only on the outer shape. In this application, all the different types of remote controllers are being manufactured on the same assembly line. The right part at from figure 2.6, the remote controllers are fed automatically one-by-one from the assembly line. A camera acquires their image and visual processing determines their type. Accordingly, the remote controllers are directed to one of the control stations. Those whose types are unidentified are directed to a basket as seen in the front. After being manufactured, they are subjected to functional testing which varies according to their type.

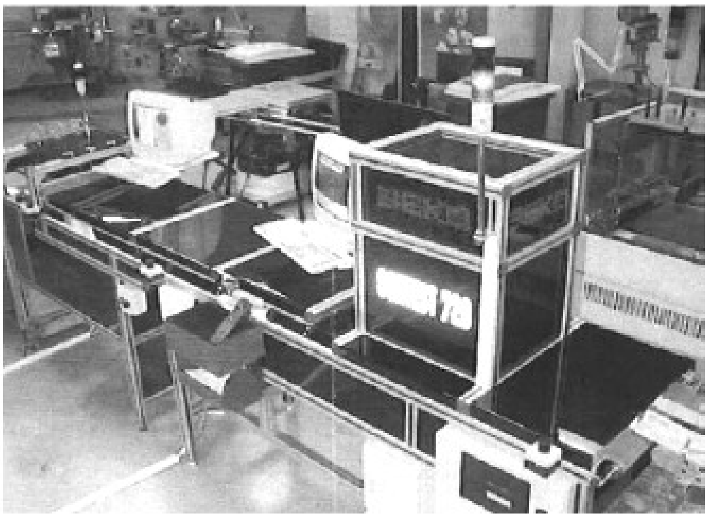

Figure 2.6: Automated sorting system. (Bozma and Yal-cin (2002)

Boukouvalas et al (1997) describes an integrated system developed for the detection of defects on color ceramic tiles and for the color grading of defect-free tiles. The integrated system developed under the ASSIST project (automatic system for surface inspection and sorting of tiles) are used for the detection of defects on color tiles and for the color grading of defect-free tiles.

To meet the ASSIST demands, a multi-camera vision approach has been developed in order to cover many different kinds of defects. The integrated vision system is presented schematically in Figure 2.7. From this figure, the tiles are first inspected for bumps and depressions using a laminated light source at an angle for maximum sensitivity to surface imperfections. This means that each line across the tile receives more or less light of the same intensity. Next, the tile is inspected for other structural faults, such as cracks and holes, using diffuse lighting. Finally, the tiles are inspected for color defects and color grading using the tri-linear color scanner and again diffuse lighting.

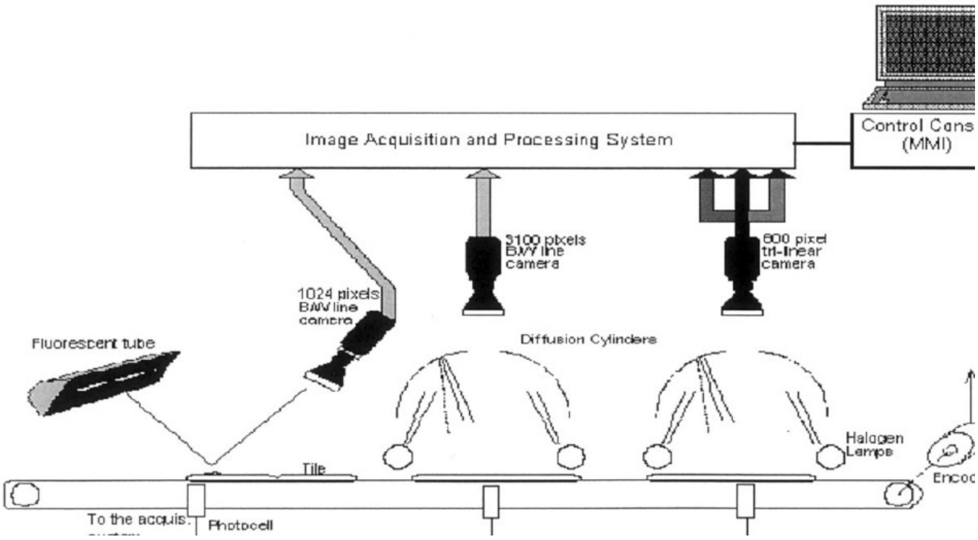

Figure 2.7: The overall structure of the ASSIST system (From Boukouvalas et al, 1997)

There have issues in automatic sorting and present advanced solutions for the sorting of recyclable packaging towards the process automation. Mattone et al (1999) had explained about a technique for detecting and classifying objects. The most of the authors prefer to use 2D Vision techniques to separate the objects from the known belt background and to get some of their geometrical parameters (typically: length, width, or shape parameters). When other parameters than geometrical ones are relevant for sorting, specific sensors are employed. However, a complete different situation characterizes the sorting of recyclable packing, where items of many different kinds (plastic, metals composite, etc), together with some other undesired materials, have to be separated into homogeneous fractions that will undergo the same process.

(i) The shape and position of any item is unknown

(ii) The items on the belt may be in contact or even overlapping.

(iii) Their physical and geometrical characteristics vary in a wide range.

(iv) The items flow can be just characteristics vary in a wide range.

Due to these conditions, that violate all assumptions at points (i-iv), thus making standard automatic techniques inapplicable, this sorting process has not yet been automated actually. After some mechanical and magnetic presorting, the process has to be completed manually by human operators, with serious risks for their health. For this robot application, a semi-automatic solution had been developed at the robotics lab of Fraunhofer IPA. In this setup from figure 2.8, the material to be sorted is poured directly from its container onto a moving conveyor belt which is sealed against the environment. It is then identified and localized by the operator by means of a touch-screen system. A SCARA robot picks the identified items according to a first-in-first-out policy and deposits them in a suitable shunt.

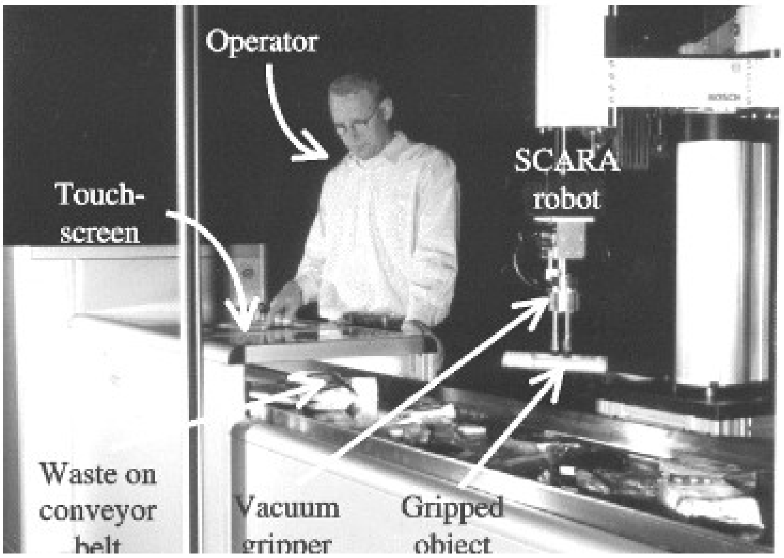

Figure 2.8: The semiautomatic cell for the sorting of wasted packaging developed at Fraunhofer IPA (Mattone et al (1999))

In order to accomplish a fully automated wasted packaging sorting, the following problems have to be faced:

i. Automatic localization of the single items on the belt in presence of contact and overlap.

ii. Classification of a wide class of packaging items for which mechanic/magnetic presorting do not be sufficient.
iii. Optimization of the gripping strategy to keep acceptable system efficiency in spite of the varying load situations.

Jones et al (1989), brief about color sorting system and method. Color sorting system and method is applied to sort fruits and vegetables. The objects to be sorted are scanned with a color video camera and the signals from the camera are digitized and utilized to addresses for colors to be rejected. In this system the data collected by camera will sent to color sorter processor to finalize the good or bad fruits or vegetables. If the objects are rejected, mean the object only have a certain number or sequence of unacceptable colors.

By referring figure 2.9, the sorting apparatus of the present innovation has on preferred use in sorting moving item on a conveyor belt, which the item may be fruits or vegetables. A camera and flash allows for multiple images of the items or products on moving belt to be captured and processed by a color sorter processor. Color sorter processor which is in general controlled by a central processor unit or minicomputer are use to operate a rejecter unit. Timing as to be location of the item on the conveyor belt to provide for proper rejection is accomplished by timing feedback, which for example may be an output from a rotating pulse. Since all of the foregoing must be done on a real time basis and with a conveyor moving at high speed, the color sorter processor must receive the pictorial value from the camera and flash and process them. Typically, video camera will charge coupled device which has a fast response time and it will provide red, green and blue separate outputs. The present invention is also applicable to black and white cameras which will provide gray scale value. These require somewhat less processing time with the same equipment. While items on a moving conveyor belt have been shown, any type of succession of the sorted where a high speed processing of the image information is desired.

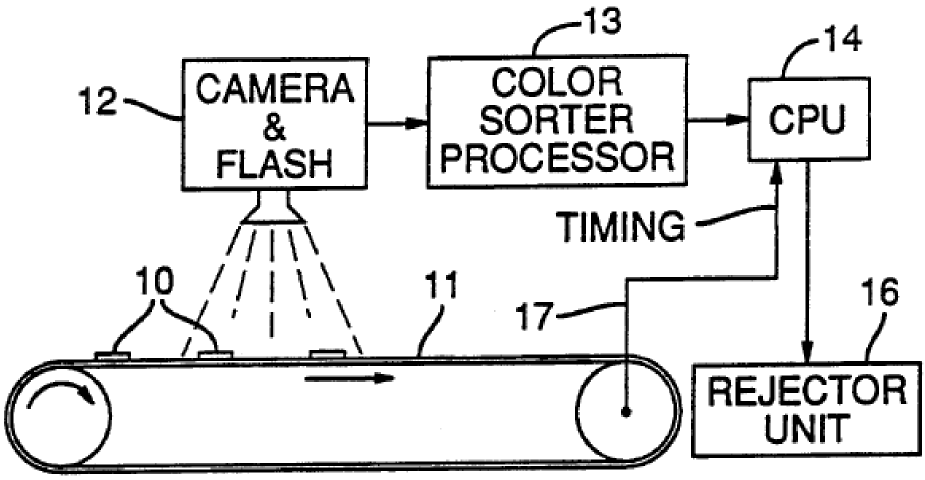

Figure 2.9: Block diagram of items on a conveyor belt being sorted by the apparatus (Jones et al (1989))

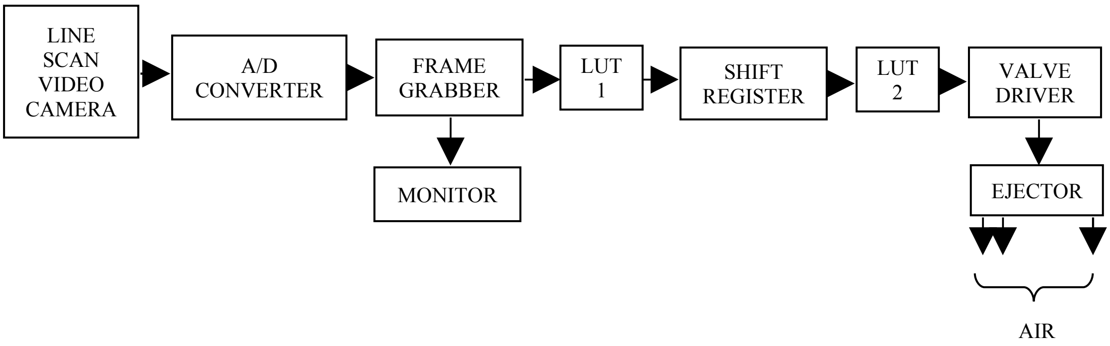

Figure 2.10: Simplified block diagram of color sorting system (Jones et al (1989))

Figure 2.10 show a line scan color video camera which has an array of photosensors. With the belt moving in a direction generally perpendicular to scan line, successive readings of the photosensors are taken to provide data for different scan lines. The data is processed in frames which can consist of any desired number of scan line. The output signals from the video camera are normalized and applied to an analog-to-digital converter. The output of A/D converter is applied to a frame grabber. The output of LUT 1 is applied to the input of shift register and the output of the shift register is applied to the address lines of second look up table (LUT). Shift register and LUT 2 form a spatial filter which causes an object on the conveyor belt to be rejected only if it has a certain number or sequence of unacceptable colors. The output signal from LUT 2 is applied to a valve driver which controls the discharge of air through a plurality of nozzles in an ejector. The air jets from these nozzles divert objects identified as having defects from the normal path of delivery by the belt to a reject area.

2.3.4 Color Sensor Applications.

Historically, components used for color sensing were considered expensive and required precision support circuitry, limiting their application mostly to specialized instrumentation. However, new technologies of color sensors with higher levels of integration are becoming available, allowing for more cost-effective solutions. As the cost of color sensing comes down, the number of applications using color sensing is increasing. Soloman (2004) explain several example applications using color sensor. The following are five examples of unique situations requiring innovative solution.

1. *Sorting automotive parts with different colors.*

   A manufacturer of automotive parts needs to differentiate parts whose only visible difference is a slight variation in color. One part is black, the other a dark grey. Because efficiency demands that the part be sorted at a high rate of speed, the opportunity for mistakes is extremely high. By using advance color sensing technology, the manufacturer can sort these parts at an enhanced rate of speed, saving time and virtually eliminating errors.

2. *Assembly of medical closures with different color components.*

   In this situation, containers of liquid medications consist of an aluminum cap with a plastic cover. A complete closure assembly requires the assurance of proper color combination of two components. Because of this absolute necessity of color accuracy, color sensing technology proves invaluable.

3. *Lumber sorting by color.*

Color cording has become a standard method of differentiation in the lumber industry. Not only different types of lumber but the grade, quality and intended purpose of the lumber is indicated by color. Because the environments in which lumber is sorted can be highly abusive, it is recommended that protective covers be employed to protect the fiber optics used for this process.

4. *Color sensing in the food industry.*

Sensing a white target on a white background is challenging using conventional photoelectric sensors. A manufacturer who needs to insure the presence of the white cap on a jar of mayonnaise improves accuracy with a color sensor that employs the RGB color concept. This technology improves the contrast between two slightly different whites.

5. *Ammunition final inspection and sorting process.*

An ammunition manufacturer codes the style and caliber of bullets with various colors on the tips. The need to insure that the proper type and caliber of product are correctly packaged necessitates the automation of the product line with color sensing technology. Because of the critical nature of this application, it is recommended that two color sensing stations be implemented to add an extra safety margin to the operation.

2.4 Color Sensor

2.4.1 The TCS230 Color Sensor

The TCS230 has an array of photodetectors, each with either a red, green, or blue filter, or no filter (clear). The filters of each color are distributed evenly throughout the array to eliminate location bias among the colors. Internal to the device is an oscillator which produces a square-wave output whose frequency is proportional to the intensity of the chosen color.

Table 2.2: Specification of TCS230 (TAOS Inc (2003))

Light Source	Silicon Photodiodes
Output Options	Pulse Train; Square Wave
Input Voltage	DC input; 6V
Operating Temperature (F)	32 to 158
Notes	Programmable color and full-scale output frequency

According to Basic of Light and Color from TAOS Inc (2003) TCS230 combines three photodiodes, dye-based RGB (red, green, blue) filters, and a current-to-frequency converter circuit on a single chip. Based on the theory of trichromacy, three values, in this case R, G, and B, are necessary and sufficient to describe any color. In a color measurement application, a white light source, such as an incandescent lamp or white LED, is used to illuminate a sample. Reflected light from the sample is directed to the TCS230, either through a lens, or ideally, simply by close proximity to the sample. In the case of a colored source, light from the source is directly incident on the TCS230. The three outputs from the TCS230 are then processed to determine color.

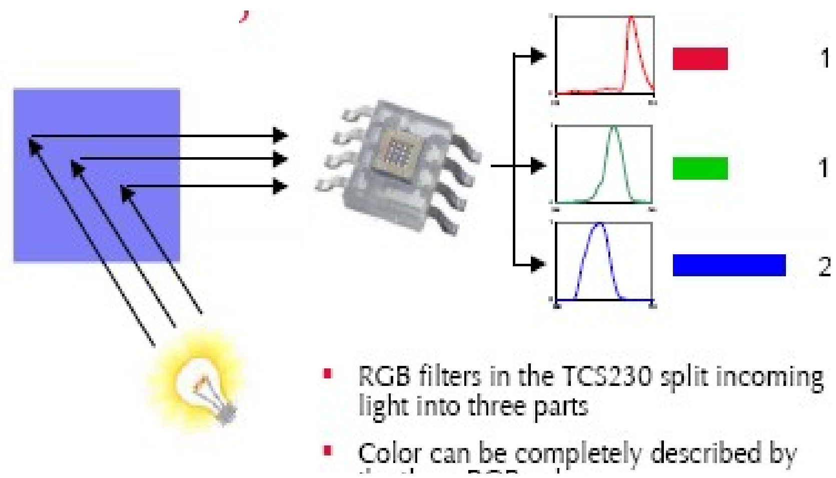

Figure 2.11: Measuring color (Basic of Light and Color (2003))

Williams (2003) brief about TCS230 color Evaluation Module Connected to Basic Stamp as shown as figure 2.12. Pins labeled S0 and S1 which are used to divide the frequency output of the TCS230. Left unconnected, the output frequency is not divided. It's important to point out that in very bright conditions the output frequency of the TCS230 can exceed the capabilities of the BS2's COUNT function.

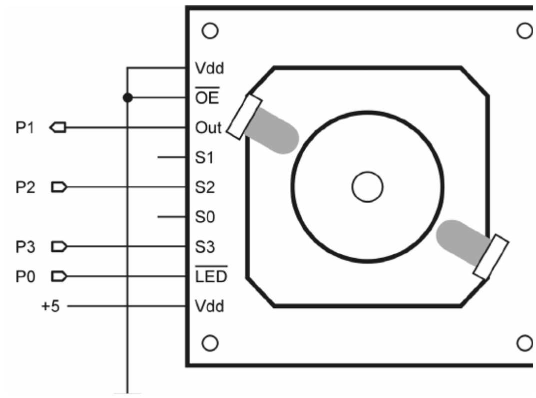

Figure 2.12: TCS230 color Evaluation Module Connected to Basic Stamp (Williams (2003)

2.5 BASIC Stamp

2.5.1 Introduction to the BASIC Stamp

The BASIC Stamp is a microcontroller developed by Parallax, Inc. which is easily programmed using a form of the BASIC programming language. It is called a "Stamp" simply because it is close to the size of an average postage stamp. BASIC Stamps are microcontrollers (tiny computers) that are designed for use in a wide array of applications. Each BASIC Stamp comes with a BASIC Interpreter chip, internal memory (RAM and EEPROM), a 5-volt regulator, a number of general-purpose I/O pins (TTL-level, 0-5 volts), and a set of built-in commands for math and I/O pin operations. BASIC Stamps are capable of running a few thousand instructions per second and are programmed with a simplified, but customized form of the BASIC programming language, called PBASIC.

2.5.2 PBASIC Language

PBASIC (Parallax BASIC) is a hybrid form of the BASIC programming language in which many people are familiar. Currently there are three versions of PBASIC: PBASIC1 for the BASIC Stamp 1, PBASIC2 for the BASIC Stamp 2 and PBASIC2sx for the BASIC Stamp 2sx. Each version is specifically tailored to take advantage of the inherent features of the hardware it runs on. PBASIC is called a hybrid because, while it contains some simplified forms of standard BASIC commands, it also has special commands to efficiently control the I/O pins. It includes many of the instructions featured in other forms of BASIC (GOTO, FOR...NEXT, IF...THEN) as well as some specialized instructions (SERIN, PWM, BUTTON, COUNT and DTMFOUT). Information on Basic Command Reference will include at ***Appendix 1***.

The items need to get started with the BASIC Stamp:

1. The BASIC Stamp Windows Editor programming software
2. The programming cable (a DB-9 serial cable for all BASIC Stamp 2s and a parallel to three-pin cable for BASIC Stamp 1s
3. The BASIC Stamp User's Manual
4. The BASIC Stamp module itself, and optionally
5. The appropriate development board or kit.

2.5.3 Hardware: Board of Education (Rev. B)

The Board of Education is designed to accommodate the BS2-IC, BS2e-IC and BS2sx-IC modules. This board provides a small breadboard for quickly prototyping