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A Webcam and LabVIEW-based System for Efficient Object Recognition based on Colour and Shape Features

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ABSTRACT

This paper proposes a system for efficient object recognition based on colour and shape features using a webcam and LabVIEW. The study aims to develop a model scale conveyor belt system for Lego brick sorting based on colour and shape. The proposed system uses the webcam and LabVIEW's graphical programming environment to capture and analyse images, extract colour and shape features, and perform object recognition. An Arduino microcontroller, integrated with LabVIEW software, is used to move the servo and motor of the conveyor belt sorting system based on the analysed image capture from the webcam. The proposed system has the potential to be applied in real-world applications such as the food industry, particularly in fruit and vegetable sorting which will help reduce the amount of time and labour needed for manual sorting and food waste by ensuring that only good quality produce is sold. Another potential real-world application for the proposed system is quality control and defect detection in the manufacturing industry. The system proposed in this paper can sort objects using object recognition based on the object's colour and shape features, with the overall system average reliability percentage is 90%. Overall, the system is applicable in real-world applications if the limitations mentioned are overcome and improved by integrating with the Internet of Things (IOT) for a long-range monitoring system.

1. Introduction

Computer vision is a sub-field of computer science that focuses on extracting valuable data from digital sources like images or video. It involves analysing and understanding information from a single image or video to replicate human visual perception and identify objects [1]. Larry Roberts was the first to introduce the computer vision topic in his PhD thesis in 1963, where he proposed a method to extract 3D object detail from 2D line drawings [2]. Advancing in camera and computer technology

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has made it possible to capture high-quality images and process vast amounts of data in less than a second, leading to computer vision's rapid growth in various fields, including military, healthcare, agriculture, and manufacturing [3]. Object recognition, one sub-field of computer vision, involves tracking objects' position and direction based on object characteristics such as colour and shape [4]. An example of object recognition applications that can be seen nowadays is facial recognition in surveillance systems [5]. However, processing digital images remain complex for computers because they perceive each 200x200 RGB image as containing 120,000 bytes of values [6,7].

By using a computer vision, this paper proposes a system for efficient object recognition based on colour and shape features using a webcam and LabVIEW. The study aims to develop a model scale conveyor belt system for LEGO brick sorting based on colour and shape. The proposed system uses the webcam and LabVIEW's graphical programming environment to capture and analyse images, extract colour and shape features, and perform object recognition. An Arduino microcontroller, integrated with LabVIEW software, is used to move the servo and motor of the conveyor belt sorting system based on the analysed image capture from the webcam. The analysed object recognition images are then displayed on a self-made LabVIEW GUI system, which includes features to control the speed of the conveyor belt, an LED indicator for rejection and colour matching. The system's focus on colour and shape features is motivated by their importance in defining the identity and functionality of objects, as well as their relative ease of extraction compared to more complex features such as texture and appearance, which are more suitable for objects with labelling.

2. Literature Review

2.1 Types of Image Processing Technique

Object recognition process generally starts with image acquisition, which by using a sensor device such as a camera to capture the real word image or video and store it in digital format. The captured image or video can be either in grayscale or RGB colour, but mainly in the 21st-century era, the camera captures an image in RGB colour form compared with 19s century camera. Other than that, the captured image can be stored in a variety of formats depending on the camera settings, such as JPEG (Joint Photographic Experts Group), PNG (Portable Network Graphics), TIFF (Tagged Image File Format), and RAW (unprocessed data from the camera's image sensor). However, each format had distinct characteristics, such as file size, pixel depth, and compression, which affected the quality of the image. Thus, image processing was needed to enhance or improve the raw imaged capture from a variety of camera settings and file formats [8]. Currently, there are various techniques of image processing have been studied and applied in computer vision fields for different purposes of application. Table 1 shows the summary of contracting techniques of image processing and its functioning [8-12].

Table 1
Summary of image processing technique

Image Processing Techniques	Function
Image enhancement	A process of improving the image quality by sharpening and eliminating the noise.
Image restoration	A process of restoring the degraded image by removing blur or noise.
Image segmentation	A process in which an image is divided into multiple smaller regions based on its characteristic.
Image compression	A technique which eliminates the duplicate data to minimise the image size.
Feature extraction	A technique used to extract valuable data from an image such as edges or corners.
Morphological processing	A technique that used erosion or dilation to extract the shape and location of the image.

One of the previous research examples which used image processing techniques for object detection and recognition was Dhiman's [13] studies in 2018. The studies used three methods of image processing which are image enhancement, feature extraction, and image segmentation, as shown in Figure 1. The proposed algorithm was tested using both the Berkeley Segmentation Dataset and Benchmark (BSDS) and remotely sensed images and performed considerably well compared to an existing feature detection algorithm. However, there are still challenges in detecting image features for object recognition due to noise, variations in lighting, object orientation, and occlusions. In addition, traditional object recognition methods heavily rely on predefined templates or models, making it challenging to detect complex or novel objects, and it may struggle with objects that have multiple or ambiguous interpretations. These limitations suggest the need for more advanced and innovative approaches to overcome object recognition challenges.

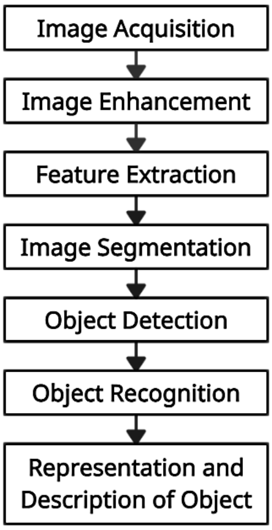


Fig. 1. Method for object recognition

2.2 Webcam and LabVIEW Technology

A webcam is a digital camera used for capturing images or video, typically connected to a computer or compatible device. It is commonly used for personal communication, live streaming, and online meetings [14]. Webcams are affordable and versatile, with auto-focusing, zooming, and high-definition video capabilities. Microsoft LifeCam Cinema and HP Wide Vision HD Camera were used for object recognition purposes in this study. LabVIEW on the other hand is a graphically based programming environment that provides a user-friendly interface for data acquisition and analysis [15]. It uses built-in functional blocks for various features and allows users to create customized Graphical User Interfaces (GUIs) in various formats. LabVIEW is compatible with popular data acquisition devices such as Arduino and Raspberry Pi and supports real-time video capturing analysis. This paper used an add-on feature called Hobbyist to communicate LabVIEW with Arduino UNO for controlling the servo and motor in the conveyor sorting system.

2.3 Overview Application of Webcam and LabVIEW Technology

Integrating a webcam with LabVIEW has a significant interest in computer vision fields, such as real-time image processing, reliable and accurate object recognition, and a user-friendly interface. With the capabilities of a webcam to capture real-time video and the LabVIEW function block to process and analyse the captured video, the computer vision application is set off. Table 2 shows the comparison of previous studies that used the integration of a webcam and LabVIEW for computer vision applications for a variety of fields.

Table 2
Previous studies comparison

Author	Applications	Advantages	Disadvantages	Result
Wati and Abadianto [16]	Smart home security systems	Able to detect a face when the person is wearing glasses or a Muslim cap	Face detection algorithm can detect a face limit of 240cm only	The accuracy of the face recognition is 80%
Saranya *et al.,* [17]	Face mask detector	LabVIEW provided a stable and reliable connection	High execution time causing long processing time	The accuracy of the system is over 90%
Alano *et al.,* [18]	Intelligent security systems	The person's height does not affect the system's accuracy	The delay in the system was caused by the types of webcams used	The average accuracy of the system exceeds 85%
Riandini *et al.,* [19]	Object dimension measurement	Able to measure the length and area of an object	High noise and image mismatch caused by webcam positioning	Converted pixel data had a resolution measurement of 0.1220mm of physical units
Sahu *et al.,* [20]	Sorting machine	Compatible with low budget webcam	Not capable of detecting the colour of the high-speed object	The system maximum possibility of an unsorted object is 4%

Based on the table comparison of previous studies above, it concluded that the integration of webcam and LabVIEW for computer vision applications offer decent advantages of object recognition with high accuracy, which is above 80%. In addition, the integration of the webcam and LabVIEW has a stable and reliable connection which gives a high latency and is compatible with low-budget webcams for image processing. However, there are still some disadvantages of this integration due to types of computers and webcam capability which cause limitations in processing large data, high execution time, and delay causing webcam. Furthermore, there is a limit to this integration of webcam and LabVIEW to detect long-range distance and high-speed objects. In summary, using a webcam and LabVIEW in object recognition has advantages and disadvantages based on the specific application. Nevertheless, the proposed system is suitable for this method due to the low distance object detection and low speed of the conveyor system.

3. Methodology

3.1 LabVIEW Algorithms for Object Recognition

This paper proposed using two different webcams connected to LabVIEW software for image processing and object recognition. Figure 2 shows the simulation of accepted and rejected shapes and colours of Lego bricks used for object recognition in this paper. The Lego brick used for this paper consists of three different types of shapes and colours, which are yellow, green, blue, 2x2, 2x4, and 1x6 brick. The proposed system will reject any colour of 2x2 brick on Lego, and other than that, it will be accepted. The webcam used in this paper is Microsoft LifeCam Cinema which is used for shape detection, and HP Wide Vision HD Camera for colour detection. Both of the webcams had the exact video resolution of 1280x720 pixels with a frame rate of 30 frames per second (FPS). However, in this paper, the Microsoft LifeCam Cinema provided a clear, bright image compared to HP Wide Vision HD Camera, which is a bit dark due to the default setting.

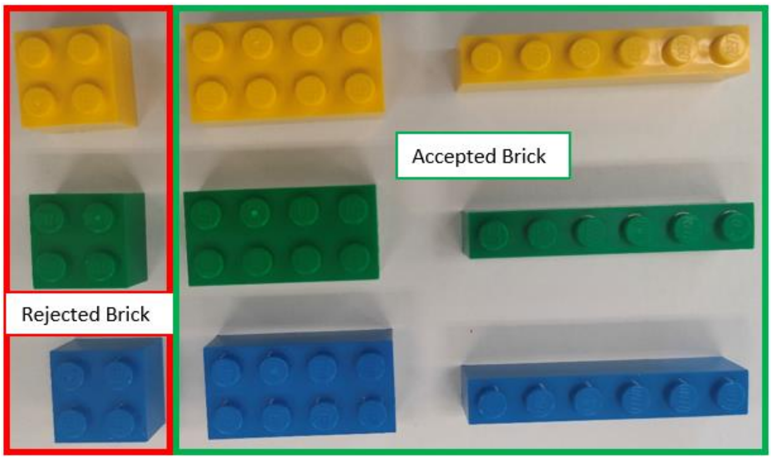


Fig. 2. Simulating accepted/rejected shapes and colours of Lego brick

3.1.1 Shape detection

Shape detection is a difficult process due to it involves various image processing processes to extract the object features, such as edge and brightness. However, with the LabVIEW Vision Assistant function, shape detection for this paper is achievable due to the function having various image processing capabilities, such as edge detector, brightness setting, colour plane extraction, and more. This paper proposed two different shape detection methods involving machine vision learning, the first method is colour pattern matching, and the second method is pattern matching (grayscale). The first method for colour pattern matching script in LabVIEW is shown in Figure 3, where the script starts with the captured image, followed by colour pattern matching and ends with the set coordinate system. In colour pattern matching, an example of rejected object template is needed for machine learning to analyse and extract its features to match the original image. Colour pattern matching is a combination approach of colour and spatial information to find colour patterns in an image quickly.

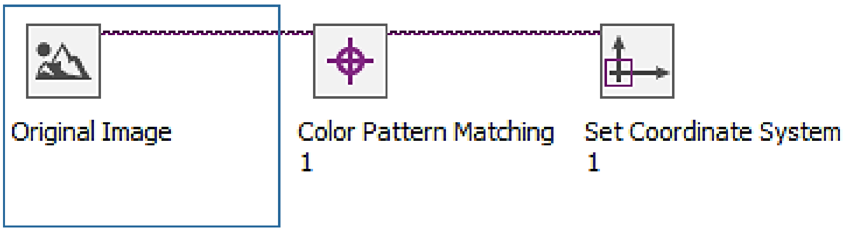


Fig. 3. LabVIEW colour pattern matching script

The second method script, which used pattern matching, is shown in Figure 4. It begins with captured image and continues with image processing to change the coloured image into a grayscale image by using colour plane extraction Hue, Saturation, and Intensity (HSI)-Intensity Plane method. Then an object example image template was needed for the machine learning to extract object features such as geometric, edge and Efficient non-uniform sampling.

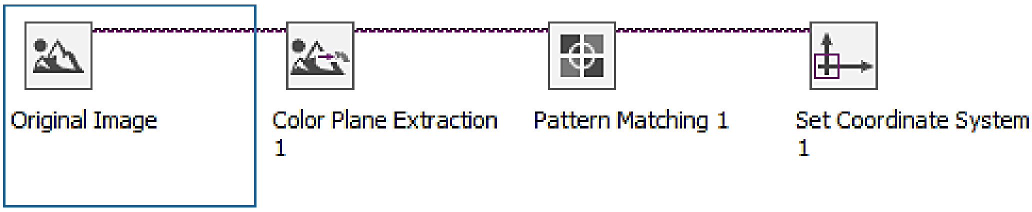
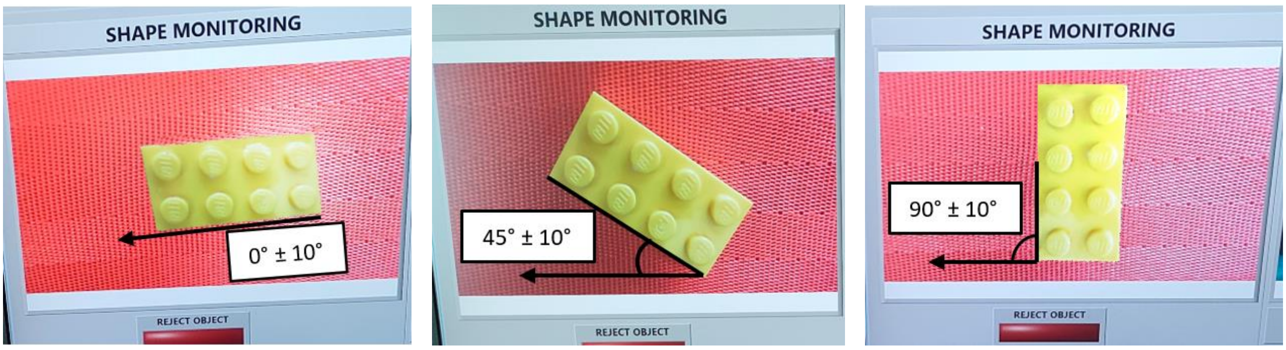


Fig. 4. LabVIEW pattern matching script

Figure 5 shows the placement of Lego bricks at different angles for object detection accuracy tests on the two proposed methods. Twenty test samples for different angle Lego brick are conducted with a plus or minus of 10-degree angle accuracy of placement.



(a) (b) (c)

Fig. 5. Different angle placement of Lego brick, (a) 0° angle placement, (b) 45° angle placement, (c) 90° angle placement

Table 3 shows the comparison of colour pattern matching and pattern matching method in term of object detection accuracy of different angle and execution time in 20 samples test of the same object shape. The 20 samples' test results showed that the colour pattern matching had higher object recognition accuracy in different angles than the pattern matching method, even though it takes longer to process. Thus, the colour pattern matching method was used in this paper for shape detection for object recognition.

Table 3
Two methods result comparison

Method	Object Match in 0° angle	Object Match in 45° angle	Object Match in 90° angle	Average Accuracy	Average execution time (ms)
Colour Pattern Matching	20	18	19	95%	6.37
Pattern Matching	19	8	11	63%	1.89

However, it is important to note that the Colour Pattern Matching method had a higher average execution time, with 6.37 milliseconds compared to 1.89 milliseconds for the Pattern Matching method. This difference in execution time may be an important consideration for real-time applications or systems that require quick processing.

3.1.2 Colour detection

For the colour extraction in LabVIEW features, an IMAQ ColorLearn VI was used to determine the colour of each Lego brick. Figure 6 shows the general block diagram of using IMAQ ColorLean VI to determine the colour spectrum value for each colour of Lego bricks. The colour spectrum array of the IMAQ ColorLearn VI function block varies with the colour sensitivity setting, which in low-level sensitivity, only 16 colour spectrum arrays column were shown, 30 columns for mid-level sensitivity and 58 columns for high-level sensitivity. The value for each colour spectrum array column ranges from 0 to 1, which 0 indicating the colour is not present and otherwise for 1. In this paper, a low-level sensitivity was used, and the colour spectrum array column indicates the value of 1 if the colour of Lego bricks matches. As a result, the yellow colour Lego brick match with column 5, column 7 for green colour and finally, column 9 for blue colour. The colour spectrum for this paper is distinct from Szabó *et al.,* [21], where the study result shows that the yellow colour falls under 4 columns, column 2 for green and column 3 for blue colour. Many factors may affect the change in the colour spectrum result, mainly due to the types of webcams used and the brightness of the captured image.

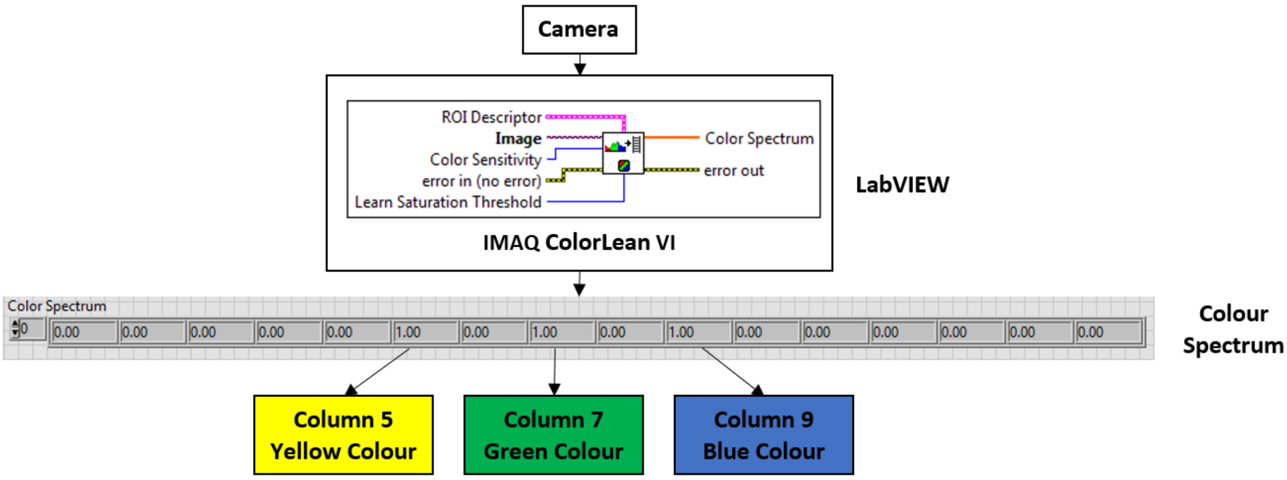


Fig. 6. General block diagram of colour detection setting

3.2 LabVIEW Programming and User Interface

Figure 7 and Figure 8 show the LabVIEW front panel and block diagram of this project, which was written in a graphical programming language. In addition, drivers and toolkits, such as the NI Vision Acquisition Software and the Hobbyist LINX toolkit, were installed in this LabVIEW community version to integrate it with a webcam and an Arduino microcontroller.

Figure 8(a) shows the LabVIEW programming used for image acquisition to detect colour from webcam 2 using the IMAQ Colour Learn VI method mentioned in 3.1.2. An in-range Boolean operator was then used to determine whether the colour values were within a specific range. If the value was within range, the function returned 'true', and 'false' otherwise. The acquired image from webcam 2 and the analysed object colour detection were then displayed at the LabVIEW GUI's 'Colour Monitoring' section as shown in Figure 7(b). After determining the object's colour, a digital read function from the Hobbyist LINX toolkit was used to communicate with an IR sensor connected to the Arduino UNO to determine whether the object on the conveyor belt had reached the sorting station. If both operations were true, the programming shown in Figure 8(d) was executed.

Moving on to Figure 8(b), the programming used as the setup program determined the pin and angle of the servo motor and DC motor that moved the conveyor belt. Figure 8(c) programming was used to acquire an image from webcam 1 and perform shape detection using Vision Assistant with the method mentioned in 3.1.1. The image acquired was displayed at the LabVIEW GUI's 'Shape Monitoring' section as shown in Figure 7(a). Three Vision Assistants were used in this project to determine three different colours of the same reject-shaped object. Finally, if the detected object colour and shape were true with the IR sensor detecting it reaching the sorting station, the servo programming shown in Figure 8(d) was then used to sort out the object from the conveyor system.

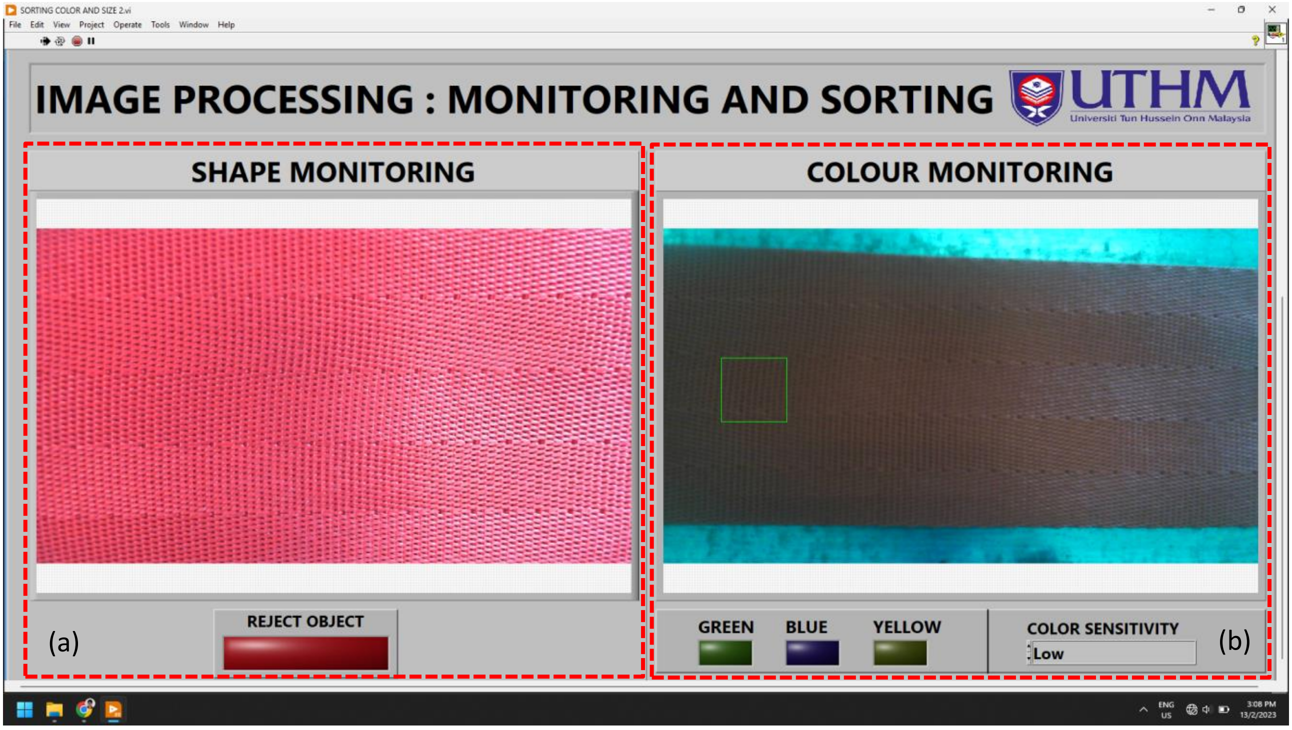


Fig. 7. LabVIEW Graphical User Interface (GUI) of the project

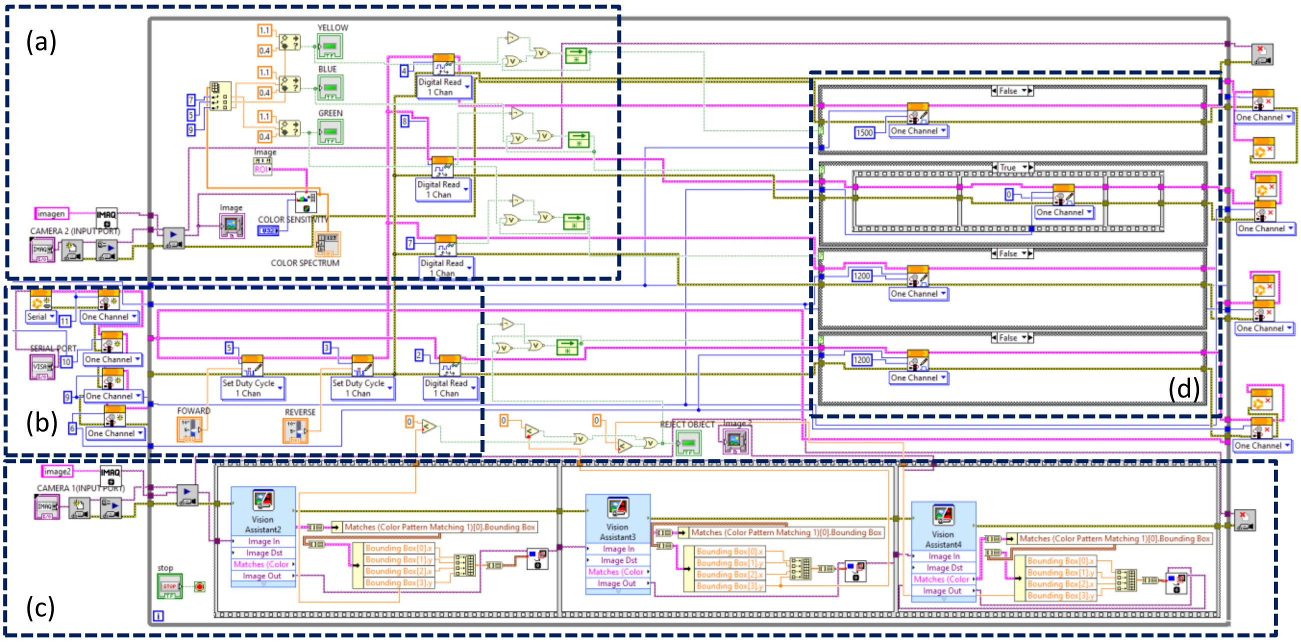


Fig. 8. LabVIEW graphical programming of the project

4. System Implementation and Results

Figure 9 shows the proposed model scale conveyor belt system for Lego brick sorting based on shape and colour with a self-made LabVIEW-based GUI, which will act as a user monitoring system.

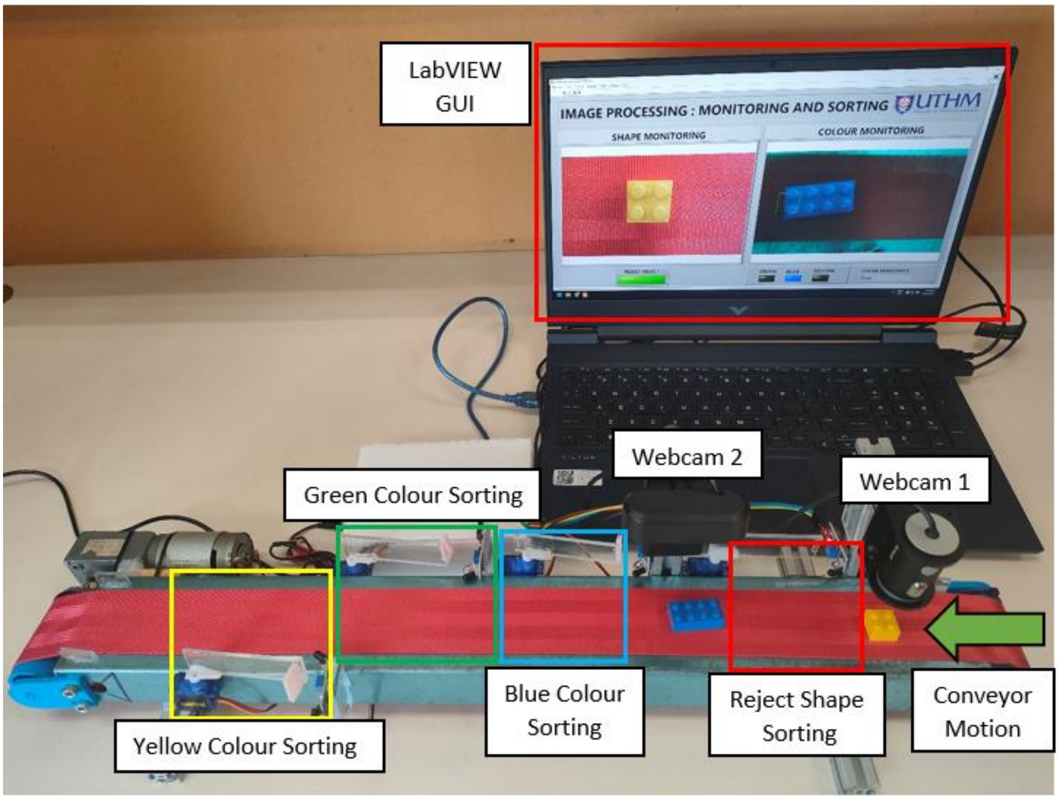


Fig. 9. Model scale conveyor belt system for Lego brick sorting

The system consists of two types of webcams, which is Webcam 1 was used for shape detection, and Webcam 2 was used for colour detection. The proposed system can divide into two different parts of the process which the first part is designed for shape detection at Webcam 1 consisting of a servo motor with an infrared (IR) sensor to detect and sort the rejected Lego bricks. The second part of the process started with Webcam 2 until the end of the conveyor belt system used for colour detection, with three separate stations consisting of servo and IR sensors for yellow, blue and green Lego brick sorting. Both the webcam and Arduino UNO were connected to the LabVIEW system through the laptop's USB port. An Arduino UNO was used to control the servo and DC motor, which had been programmed in LabVIEW software based on the features data extracted from the object recognition method. The belt of the conveyor system was moved using a DC motor attached to the roller, and the speed of the DC motor can be controlled through LabVIEW GUI. Then, all of the input and output of the system can be monitored on LabVIEW-based GUI, which displays the image of Webcam 1 and 2 with LED indicators to show the detected features of Lego bricks. The flowchart for this proposed system is shown in Figure 10.

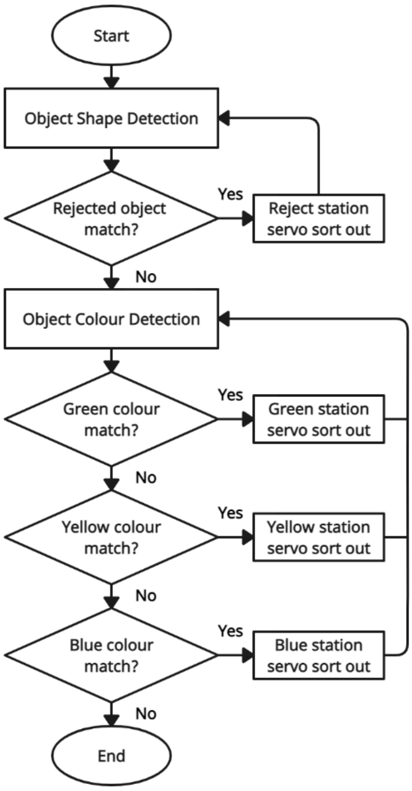


Fig. 10. System operating flowchart

The system begins with moving the conveyor belt system by adjusting the speed toggle at LabVIEW GUI. Then a Lego brick was placed on the right side of the conveyor system, as shown in Figure 11. The conveyor belt will drive the Lego brick to the first process of the system, which is shape detection at the Webcam 1 station. Next, the Webcam 1 station analyses the captured image of Lego brick using the colour pattern matching method, and the result will be displayed at LabVIEW GUI with the reject LED indicator light up if the rejecting object detected is matched with the template image and otherwise for pass object as shown in Figure 12(a) and Figure 12(b). At the same time, the servo motor will block the patch and push out the brick from the conveyor belt system after the IR sensor detects the rejected object.

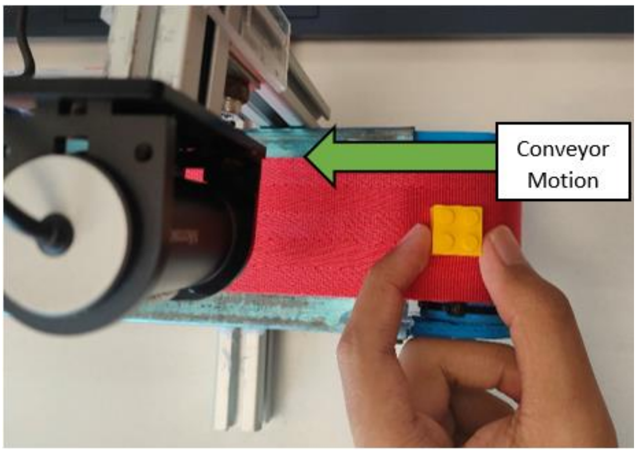
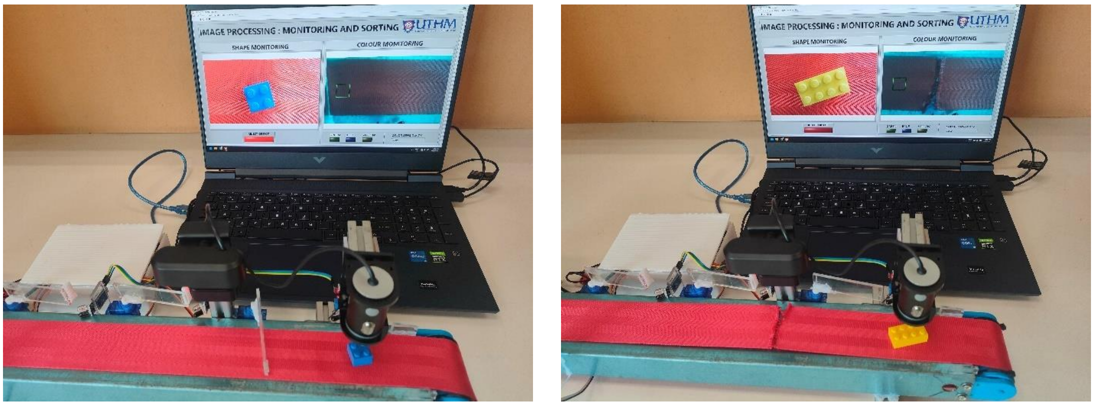


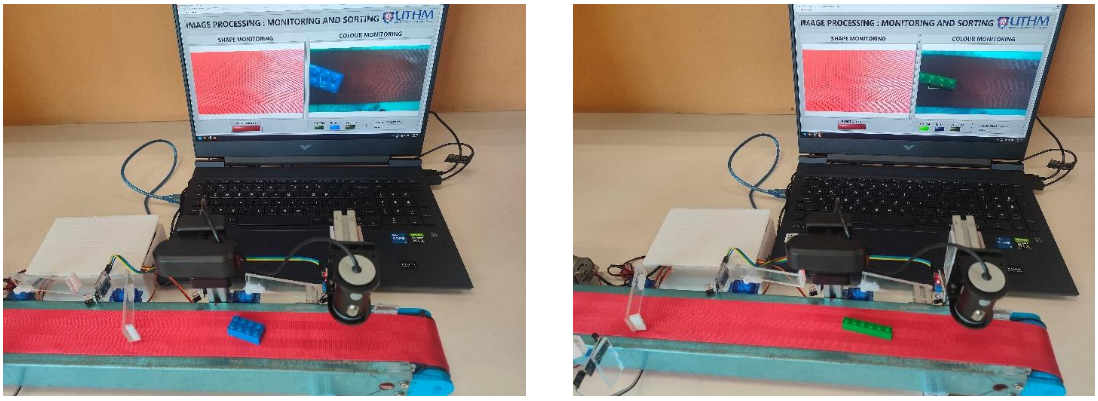
Fig. 11. Object placement on a conveyor belt system



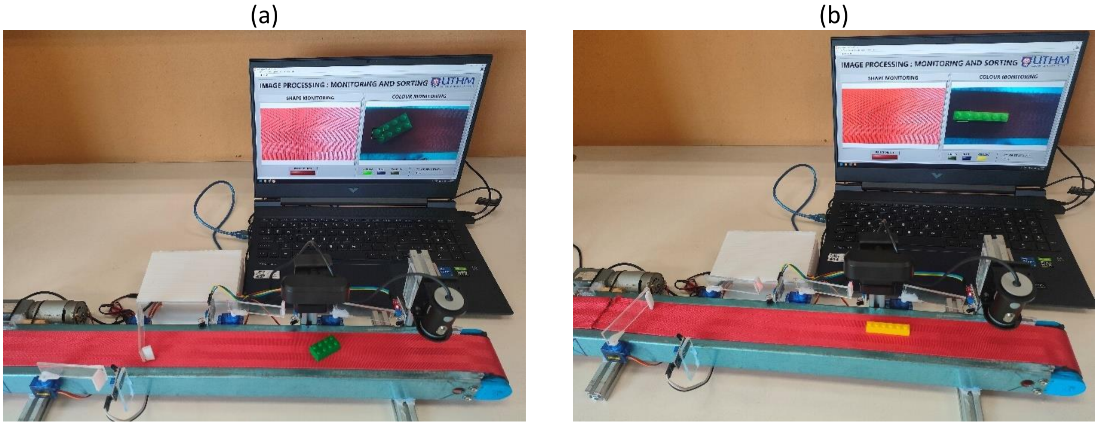
(a) (b)

Fig. 12. Lego brick shape detection; (a) Rejected brick, (b) Accepted brick

The system did otherwise for the accepted object by allowing it to move to the next station, which is Webcam 2 station for colour detection. The IMAQ ColorLearn method was used to detect the colour that matches with the colour spectrum value, as mentioned in section 3.1.2. If the image captured value matches either three setting values, 5 for yellow, 7 for green and 9 for blue. The LabVIEW GUI LED indicator for each colour will light up, and each servo colour station will block and sort out the object from the conveyor belt system. Figure 13(a) to Figure 13(d) show the system detects the different colours of accepted Lego bricks which are 2x4 and 1x6 Lego bricks.



(a) (b)



(c) (d)

Fig. 13. Lego brick colour detection, (a) 2x4 Blue brick, (b) 1x6 Green brick, (c) 2x4 Green brick, (d) 1x6 Yellow brick

A series of tests were conducted to evaluate the reliability of the Lego brick identification and sorting system. The findings are shown in Table 4, which indicates that the system exhibits high reliability for colour detection, with a reliability rate exceeding 98% for yellow, blue, and green colour detection. However, shape detection has lower reliability which is 85% for rejected shapes compared to colour detection. On the other hand, the sorting process has an inconsistent reliability success rate ranging from 78% for rejected shape sorting, 85% for green, 88 % for yellow and 93% for blue colour sorting. Further analysis will be discussed in the following section to underlying factors contributing to the variability in the reliability of the sorting process.

Table 4
Reliability result for the proposed system

Category	Number of attempts	Successful attempt	Fail attempt	Reliability (%)
Rejected Shape Detection	40	34	6	85
Rejected Shape Sorting	40	31	9	78
Yellow Colour Detection	40	39	1	98
Yellow Colour Sorting	40	35	5	88
Blue Colour Detection	40	40	0	100
Blue Colour Sorting	40	37	3	93
Green Colour Detection	40	40	0	100
Green Colour Sorting	40	34	6	85

5. Discussion and Conclusion

The conveyor system for object recognition based on colour and shape features had high reliability percentages for detection. However, the mechanical issues in the sorting station, such as the IR sensor's inability to detect small objects, limited the system's capabilities. These limitations could be addressed through the integration of a pneumatic system for sorting or by testing with larger objects, as well as using a black or white conveyor belt to improve image processing.

In conclusion, this proposed system is suitable for larger systems applications such as real-time production line monitoring or for line balancing studies. One of the system potentials for real-world applications are such as sorting high-quality produce in the food industry or identifying and rejecting defective parts in manufacturing. With an overall system reliability of 84%, integration with the Internet of Things (IOT) could improve the system for long-range monitoring [22]. The study demonstrated the potential for using a low-cost webcam and LabVIEW software for object recognition and sorting based on colour and shape features.

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