Implementation YOLOv5 Method for Detecting Safety Equipment Completeness Images on Site Tower (Case Study: PT. Nexwave Surabaya)

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Abstract— **The safety equipment completeness detection system is vital for workplace accident prevention. One effective method for this system is YOLOv5, known for its speed and accuracy due to its optimized deep neural network architecture. In this research, we developed a system titled "Implementation of YOLOv5 for Detecting Safety Equipment Completeness on Site Towers (Case Study: PT. Nexwave Surabaya)." We trained this system with a custom dataset from PT. Nexwave Surabaya, comprising 380 images of 5 detection classes: helmets, gloves, safety shoes, vests, and harnesses. The system is built on a Raspberry Pi 4B and connected to a USB camera for real-time safety equipment detection. Testing involved all safety equipment in use, with vests and harnesses alternated for ground and elevated workers. Object detection results showed confidence values ranging from 0.52 to 0.95. The highest confidence value, 0.90, was achieved at a light intensity of 27,360 lux and a distance of 4 meters. To ensure successful results, an average confidence value of >= 0.70 is required for uploading to Google Drive, with detected results stored as backup on the SD card. This system significantly enhances workplace safety by effectively detecting safety equipment completeness using YOLOv5 and Raspberry Pi technology.**

Keywords*— *Camera, Google Drive, Object Detection, Raspberry Pi, Safety Equipment.

I. INTRODUCTION

The organization and its employees place a high focus on safety and health. Through initiatives to prevent workplace accidents and illnesses related to the workplace, occupational health and safety seeks to ensure and safeguard the safety and health of workers. Safety equipment is a term used to describe products created expressly to help safeguard employees from health or safety issues at work [1] [2]. The Minister of Manpower and Transmigration of the Republic of Indonesia Regulation Number PER.08/MEN/VII/2010 specifies that employees must wear personal protective equipment before entering the workplace [3]. According to the International Labor Organization (ILO), Indonesia has a fairly high rate of work accidents. The number of work accidents in Indonesia has been increasing, in 2017 there were 123,041 work accidents, while in 2018 there were 173,105 work accidents [4].

According to the findings of interviews with BTS tower employees conducted by Maharani Suryani (2019), being struck by objects falling from the tower's top, such as bolts and screwdrivers, is the most common cause of work accidents for employees while they are on the tower site. In addition, environmental issues in the form of animal disturbances like ants and bees frequently happen while workers ascend the tower. As a result of not wearing gloves because they become too warm while performing their duties, some workers suffer damage to their palms [5]. The deliberate inability to feel comfortable due to heat, discomfort when moving around while working, and the perception that the work is not dangerous are a few of the factors that contribute to workers' lack of implementation of the use of safety equipment. Other variables, such as a lack of sufficient management oversight of the usage of personal protective equipment, were also significant contributors to this incident [6].

One of the biggest Indonesian telecommunications subcontractors, PT. NexWave, performs tasks like installing and servicing telecommunications network equipment. At PT. NexWave Surabaya, the tower site is where the majority of field work is completed [7]. OSHA (Occupational Safety and Health Administration) states that there are a number of risks involved with working at a communication tower site, including falling from a height, electrical hazards, inclement weather, equipment failure, tower structural collapse, and falling objects. [8] [9]. In order to ensure their own safety, employees on the ground and at heights at the tower site are required to wear a variety of safety gear, including gloves, helmets, shoes, vests, full-body harnesses, goggles, and masks [10].

One of the workflows at PT. Nexwave involves, upon arrival at the site, the team being required to sign in by attaching a photo as evidence of their presence at the site location. They are also mandated to wear Safety Equipment, which includes personal protective gear. The evidence photos of the use of this

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protective equipment will be submitted to the Quality Control team and will undergo a manual recheck. If any deficiencies are identified, the QC team must contact the field team for a reshoot, consuming additional time to complete tasks, both in the office and the field. The received photo results will be used as one of the attachments to be combined with other supporting documents and sent to the vendor as a handover document for the job's results from the subcontractor (PT. Nexwave Surabaya) to the vendor.

In research by Agustin Nurfirmansyah & Rohman Dijaya (2022) how to detect Personal Protective Equipment (PPE) used in building construction using the YOLOv4 method, which is able to detect the use of PPE that is within the range of CCTV and displays the value of the accuracy of PPE detection on a laptop by adjusting the PPE with the dataset that has been made. Except for non-conformance information recorded on a laptop, there was no warning system developed for construction workers in this study [11]. Based on these issues, a technique to check the completeness of safety equipment before employees enter the tower site was developed for this paper. This study uses a Raspberry Pi 4 connected to a webcam and the You Only Look Once (YOLOv5) approach to determine whether safety equipment such as personal protective equipment (PPE) or PPE worn by workers is complete. The Raspberry Pi will send instructions to the LCD to display the "Lengkap" detection results and capture images of the results for later storage to the SD Card, which is used as a data backup and uploaded to the Google Drive API so that it can be directly accessed by the QC team without the need to manually recheck the completeness of PPE from photos sent. The buzzer and LED will be turned on if the safety equipment is deemed to be lacking.

II. METHOD

A. System Block Diagram

Systematically, the workings of the tools that the system runs are made in the form of a block diagram shown in Figure1.

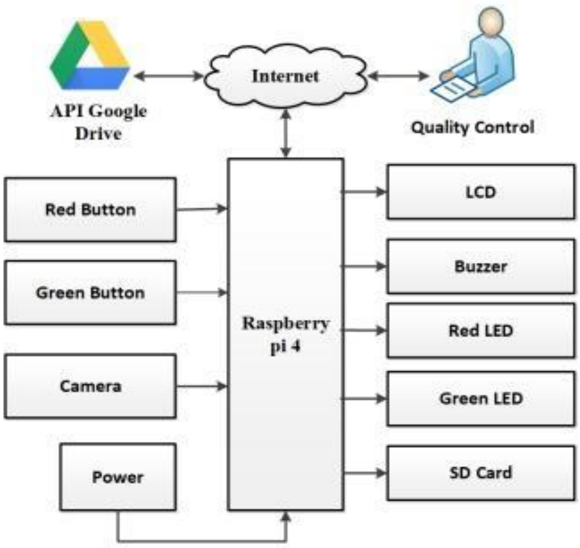


Figure 1. System Block Diagram

In Figure 1 the block diagram of the system will explain the work process of the system carried out during the study, the description of Figure 1 is as follows:

1. Power is used as the electricity source to boot up the Raspberry Pi.
2. The camera functions as an input to detect the completeness of safety equipment.
3. The green button serves as an input to activate the camera, while the red button is used to capture images of safety equipment.
4. The Raspberry Pi 4 is employed as the central control unit of the system and acts as the computational unit for processing the classification method.
5. The LCD is utilized to display the process and results of the system's detection.
6. The buzzer is used as an alarm indicator in case there is a discrepancy in the detection results.
7. The red LED indicates that the camera booting process is complete, while the green LED serves as an indicator to capture images and run the detection results.
8. The captured images from the USB camera detection will be stored on the SD Card as a backup and uploaded to a Google Drive folder using an ID that is utilized to identify and access specific items via the Google Drive API or URL for accessibility by the Quality Control team.

B. Mechanical Design

The mechanical design that will be created can be seen in the following explanation.

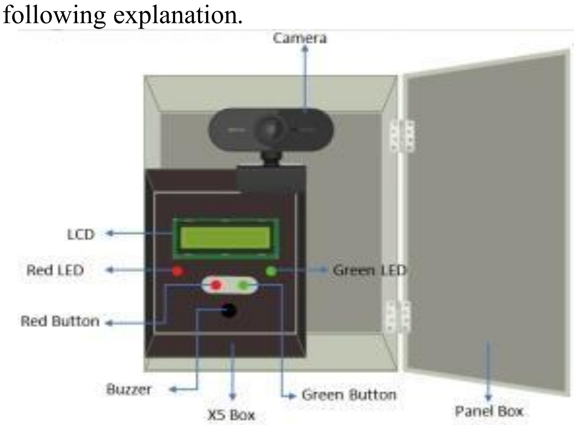


Figure 2. Mechanical Design

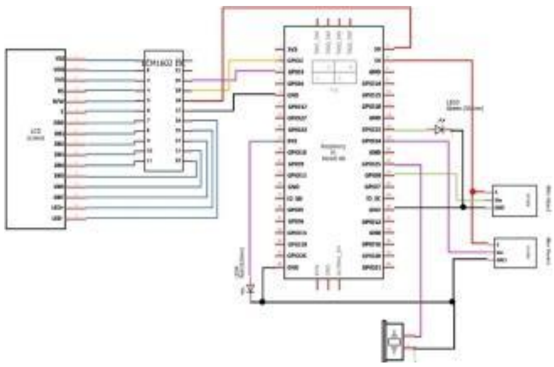


Figure 3. Schematic System

In Figure 3 depicts the schematic diagram of the entire components utilized in the system, comprising Raspberry Pi, I2C, LCD, red and green LEDs, buzzer, as well as red and green buttons. The main controller utilized in this system is the Raspberry Pi 4B, employed for image processing, handling inputs such as buttons and a camera, and managing outputs like LEDs, buzzers, and an LCD display.

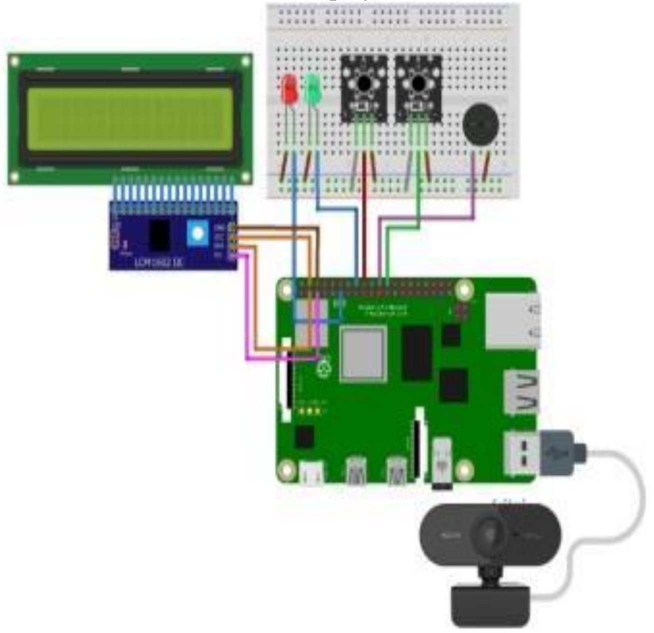


Figure 4. Overall Schematic Component

The main controller used in this system is the Raspberry Pi 4B, which is utilized for image processing and running input from buttons – a green button to power on the camera, a red button to capture images, and a camera to detect the usage of safety equipment. Additionally, the system employs various output components, such as a buzzer for alarm, a red LED as an indicator for the camera booting process completion, a green LED for status during image detection and when the buzzer is activated, and an LCD used to display the image detection process and results. The SD card used for storage output is a local SD card serving as the storage location for the Raspbian OS. For the configuration of the Raspberry Pi pins used, please refer to Table 1.

TABLE I
PINS CONFIGURATION FOR RASPBERRY PI 4B

Raspberry Pi Pins	Description
GPIO 8	Connected to green button module's OUT pin
GPIO 24	Connected to red button module's OUT pin
GPIO 23	Connected to the anode leg of the green LED
GPIO 17	Connected to the anode leg of the red LED
GPIO 25	Connected to the anode leg of the buzzer
GND	Connected to the GND pin on the I2C LCD
VCC	Connected to the VCC pin on the I2C LCD
GPIO 2 (SDA)	Connected to the SDA pin on the I2C LCD
GPIO 3 (SCL)	Connected to the SCL pin on the I2C LCD

C. Flowchart

In Figure 5, the usage of YOLOv5 methodology begins with the collection of a dataset from PT. Nexwave Surabaya. This dataset is then uploaded to the Roboflow platform for the dataset labeling process, in accordance with the objects to be detected, which include helmets, gloves, safety shoes, vests, and harnesses. Once the labeling process is completed, the dataset is divided into training, testing, and validation data. After the dataset is successfully divided, export the dataset by copying the provided YOLOv5 snippet code on Roboflow. Open the custom YOLOv5 notebook provided by Google and perform the installation according to the code sequence in the notebook. Paste the previously copied code snippet and proceed with the dataset download process until completion. The dataset will then undergo the training process, with adjustments made for pixel size and desired epochs. After the training process is finished, export the model to the best.pt file or export the training results folder in .zip format.

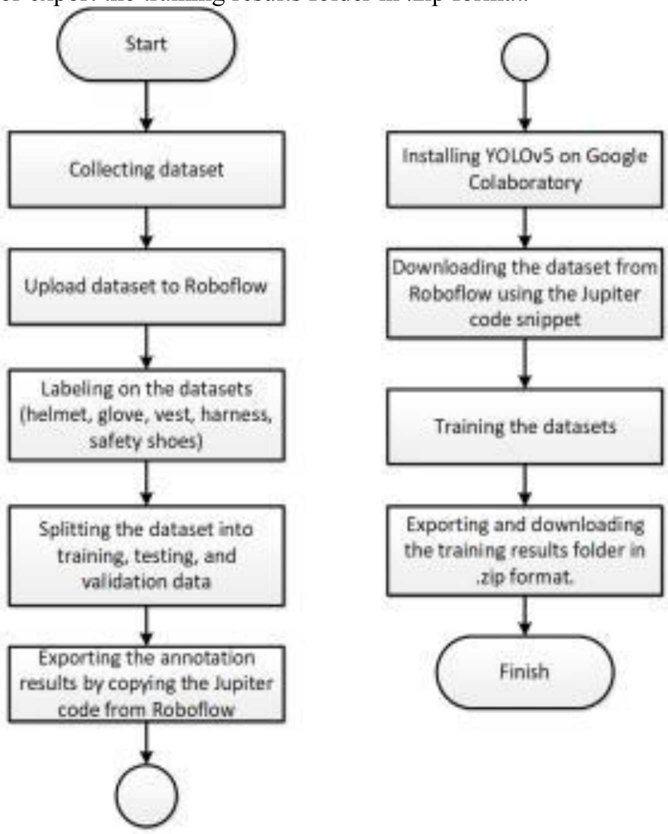


Figure 5. Yolov5 Detection Flowchart

In Figure 6, the system begins with the worker pressing the green button to switch on the camera. After the camera is turned on, the worker waits until the boot process is complete and the red LED is on. After the boot process is complete, the LCD will show the subsequent steps, which include pressing the red button to begin the image capture process and placing the worker's entire body in front of the camera for approximately 10-15 seconds. The camera will then take an image marked with a green LED on, and the Raspberry Pi will then detect any safety gear, such as vests, helmets, gloves, full body harnesses, and safety shoes, that the worker is wearing. To determine how much resemblance each safety equipment object has, the detection results will be compared to the dataset model that has already been trained. The results of this comparison will then be evaluated to determine the level of object detection accuracy. If the average accuracy level of the detected object is >=70%, the model is considered complete, and the LCD will display the words "Lengkap" and uploaded it on Google Drive. Which will be shown on the discovered image. If the evaluation results are less than 70%, the Buzzer will sound and the green LED will light up as a sign that the SE is not complete, so the detection process will be repeated by pressing the green button again to reset the system.

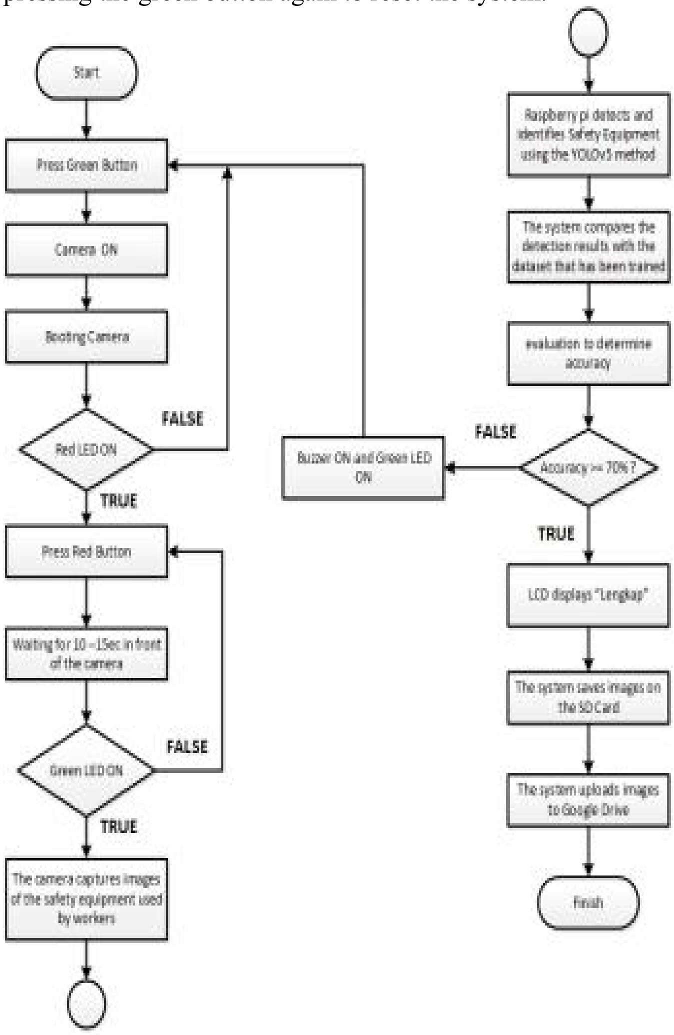


Figure 6. System Flowchart

D. Collecting Dataset

The collection of this dataset is conducted through two methods, namely utilizing the open-source library Roboflow [12] and a custom dataset. As for the custom dataset, it comprises a total of 380 images, encompassing 5 object classes that are detected: glove, harness, helmet, safety shoes, and vest.

Figure 7. Custom Dataset Collection

The collected dataset is stored in "JPEG" or ".jpg" file formats. Subsequently, this dataset will be uploaded to the Roboflow platform for annotation processes, including labeling and partitioning the dataset into three groups: training data, testing data, and validation data.

Figure 8. Anotation Process

The dataset partitioning is carried out using specific ratios, wherein 66% of the dataset is utilized as training data with 250 images, 21% as validation data comprising 78 images, and 14% as testing data, containing 52 images [13].

Figure 9. Splitting Dataset Result

E. YOLOv5 Dataset Training

The training process utilizing the custom YOLOv5 dataset from Roboflow will be conducted on the Google Colaboratory platform. Google has provided a dedicated Colab notebook that enables custom dataset training through Roboflow [14]. The initial step in the YOLOv5 training process on Google Colaboratory involves installing the necessary prerequisites for YOLOv5. Subsequently, the path to the dataset directory to be used within the operating system environment is specified, enabling its accessibility to various programs or scripts running within the system. In this experiment, the path is set to "/content/datasets". Following this, the preprocessed dataset is downloaded from Roboflow using the YOLOv5 code snippet copied earlier from the Roboflow Jupiter notebook.

```
!pip install roboflow

from roboflow import Roboflow
rf = Roboflow(api_key="MFoLyqDysVDBVLkVK61Z")
project = rf.workspace("skripsi-eioid").project("skripsi-safety-equipment-ppe")
dataset = project.version(4).download("yolov5")
```

Figure 10. Snippet Code From Robloflow

During training phase, the image size will be adjusted to 416 x 416 pixels, and each data batch will comprise 16 images. The training will proceed for a total of 50 epochs or iterations. The results of the conducted training will be stored in the directory "runs/train/exp". The "exp" directory will be exported as a .zip format and subsequently uploaded to the Raspberry Pi device as the dataset to be utilized in running the system.

```
!python train.py --img 416 --batch 16 --epochs 50 --data {dataset.location}/data.yaml --weights yolov5s.pt --cache
```

Figure 11. Yolov5 Training Code Configuration

```
Validating runs/train/exp/weights/best.pt...
Fusing layers...
Model summary: 157 layers, 7023610 parameters, 0 gradients, 15.8 GFLOPs
               Class     Images  Instances          P          R      mAP50   mAP50-95:
                 all         78        241      0.886      0.894      0.896      0.494
               glove         78         42      0.942      0.779      0.864      0.455
             harness         78         34       0.83      0.824      0.813      0.411
              helmet         78         54      0.894      0.981      0.907      0.495
        safety shoes         78         85      0.851      0.965      0.937      0.485
                vest         78         26      0.913      0.923      0.957      0.622
Results saved to runs/train/exp
```

Figure 12. Yolov5 Training Result

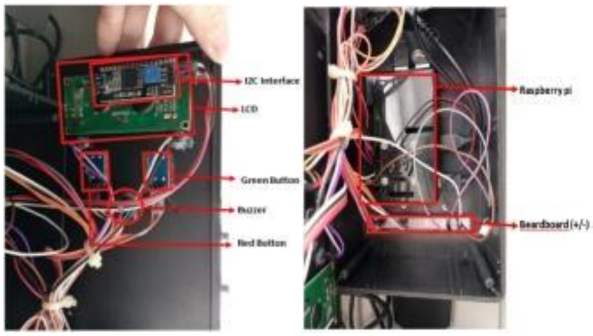
Figure 13. Exp Folder

III. RESULTS AND DISCUSSION

A. Hardware Implementation

In the Hardware Implementation Results section, the hardware display that will be utilized as a safety equipment detection system on the tower site will be elaborated.

Figure 14. Hardware Implementation



B. Buzzer and LEDs Testing

Testing of the buzzer and LED outputs is conducted to ascertain whether the components can function effectively according to the specified conditions. This testing is performed under several conditions as follows:

TABLE II
BUZZER TESTING

No.	Condition	Testing Result
2.	If the results of detection of safety equipment have an average accuracy of <0.7	ON
3.	If the safety equipment detection results have an average accuracy >= 0.7	OFF
5.	If the detection results are not uploaded	ON
6.	If the detection results are uploaded	OFF

TABLE III
LEDS TESTING

No.	Condition	Testing Result	
		Red LED	Green LED
1.	When booting the camera after pressing the green button	ON	
2.	When the red button is pressed to capture the image		ON
3.	During the image detection process		ON
4.	When buzzer is ON		ON

C. Safety Equipment Detection Testing

The testing of safety equipment detection is conducted on each object to be detected, namely helmets, gloves, vests, safety shoes, and harnesses. In this testing, bounding boxes will be displayed with labels and confidence scores of the detected objects. This testing is performed multiple times to ensure that the system is capable of detecting and recognizing objects accurately.

TABLE IV
RESULT OF SAFETY EQUIPMENT DETECTION

No.	Image Detection	Description
1		Helmet detected
2		Glove detected
3		Vest Detected
4		Harness detected
5		Safety Shoes detected

D. Image Detection Test Using Distance and Light Intensity Parameters

This testing is conducted to determine the influence of distance and sunlight intensity on the effectiveness of safety equipment detection. The testing is carried out under two different conditions. The first testing involves the detection of safety equipment such as helmets, vests, gloves, and safety shoes. The second testing involves the detection of safety equipment such as helmets, gloves, safety shoes, and harnesses. These conditions are implemented due to the existence of two types of tasks on the tower: ground-level workers and height-level workers, where workers on the ground do not require harness usage, while workers at heights require the use of harnesses.

Luxmeters in this testing are used as instruments to measure the light intensity value during the detection process, and the detection distances are set at 2m, 3m, 4m, 5m, and 6m from the device. Only True Positive values of the detected objects will be recorded in this testing.

1) Image Detection Test Wearing Vest

This testing is conducted to determine the confidence value of true positives for detected objects. The testing is carried out using safety equipment such as helmets, vests, gloves, and safety shoes. For the detection of gloves and safety shoes, there are two sides, namely right and left, so the accuracy values of the objects listed in Table 5 represent the average value of both sides.

Figure 15. Result Of Safety Equipment Detection Wearing Vest

TABLE V
RESULT OF OVERALL SAFETY EQUIPMENT DETECTION WEARING VEST

Light Intensity (Lux) x10	Distance (m)	Helmet	Vest	Glove	Shoes
2040	2	0,76	0,72	0,72	0,55
2633	3	0,65	0,75	0,86	0,82
2736	4	0,84	0,90	0,87	0,82
2416	5	0.79	0,82	0,79	0,83
2608	6	0,84	0,71	0,75	0,80

From the test results that have been carried out in Table 5, the following graph is obtained:

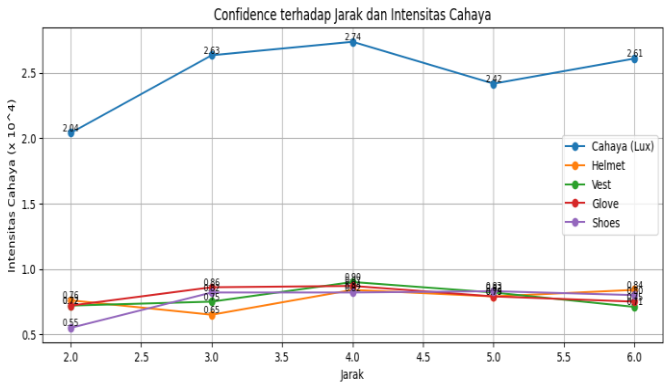


Figure 16. Graph Of Safety Equipment Detection With Vest Against Distance And Light Intensity

From Figure 16 it is observed that the detection results for safety equipment while wearing a vest, overall, achieved the best detection results at a distance of 4 meters from the device, with the highest received light intensity value being 27.36xlux. At this distance, the helmet, gloves, and vest objects also received the highest confidence values, whereas safety shoes achieved the best accuracy at a distance of 5 meters, with a received light intensity value of 2416 lux.

2) Image Detection Test Wearing Harness

This testing is conducted to determine the true positive confidence value of the detected objects. The testing is carried out using safety equipment such as a helmet, harness, gloves, and safety shoes. In the detection of gloves and safety shoes, there are two sides, namely the right and left sides, so the accuracy values of the objects listed in Table 6 represent the average value of both sides.

Figure 17. Result Of The 1st Safety Equipment Detection Wearing Harness

Figure 17 is an example of the system detection results obtained during the initial test using a harness at a distance of 3 meters from the device. The complete detection results will be displayed in Table 6:

TABLE VI
RESULT OF 1ST SAFETY EQUIPMENT DETECTION WITHOUT VEST

Light Intensity (Lux) x10	Distance (m)	Helm	Harness	Glove	Shoes
1147	2	-	0,82	0,85	0,61
1324	3	0,45	0,56	0,84	0,77
1104	4	0,76	0,29	-	0,67
1098	5	0,72	-	-	0,83
1100	6	0,80	-	-	0,84

Figure 18. Result Of The 2nd Safety Equipment Detection Wearing Harness

Figure 18 is an example of the system detection results obtained during the second test using a harness at a distance of 3 meters from the device. The complete detection results will be displayed in Table 7:

TABLE VII
RESULT OF 2ND SAFETY EQUIPMENT DETECTION WITHOUT VEST

Light Intensity (Lux)	Distance (m)	Helm	Harness	Glove	Shoes
9594	2	-	0,79	0,64	0,85
10680	3	0,40	0,71	0,83	0,84
9751	4	0,73	-	0,78	0,85
9697	5	0,67	-	0,81	0,75
9385	6	0,60	-	0,70	0,81

In this condition, two tests were conducted at different locations with the same distance. This was done because the first test yielded unsatisfactory detection results, prompting a second test to ensure the appropriateness of the testing. From the results of the tests that have been carried out in Table 6 and Table 7, the average data is obtained as follows:

TABLE VIII
AVERAGE RESULT OF SAFETY EQUIPMENT DETECTION WITHOUT VEST

Light Intensity (Lux)	Distance (m)	Helm	Harness	Glove	Shoes
10532	2	-	0.805	0,74	0.73
11960	3	0.425	0.635	83.5	80.5
10395	4	0.745	0.145	0.39	0.76
10338	5	0.695	-	0.405	0.79
10192	6	0.70	-	0.35	0.825

From the test results that have been carried out in Table 8, the following graph is obtained:

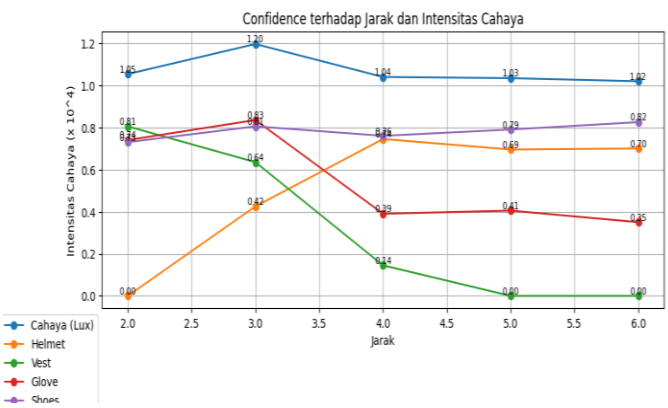


Figure 19. Graph Of 1st Safety Equipment Detection Without Harness

In Figure 18, It is known that the detection results of safety equipment with a harness can detect safety equipment optimally at a distance of 3 meters with a received light intensity value of 11,960 lux where at this distance all safety equipment objects used can be read correctly. The harness object can be read up to a distance of 4 meters with a confidence value of 0.145 when receiving a light intensity of 10,395 lux. At a distance of more than 4 meters the harness object cannot be recognized by the system, while at a distance of 2 meters the system cannot identify the helmet object due to the proximity of the object, resulting in the detection image being truncated.

E. Testing of Uploading Image Detection to Google Drive

The images utilized in this test comprise the outcomes from the preceding detections outlined in Table 5, Table 6, and Table 7. This assessment is conducted to capture photographs of the detection results that have been duly evaluated by the system. These photographs will be uploaded to the designated Google Drive, accessible for utilization by the Quality Control team. Access to the Google Drive can be achieved through two methods: logging into your Google Drive account or utilizing the link [15].

Figure 20. Total And Average Values On LCD

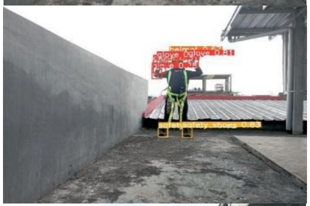
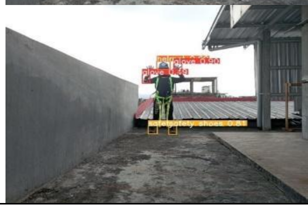
Figure 21. LCD Display If Average>= 0.70

Figure 22. LCD Display If Average <0.70

Figure 20 is the LCD display after the camera has successfully captured the image, raspberry pi will identify the total accuracy value and the average value of the object accuracy obtained and display it on the LCD. Figure 21 is the LCD display if the average value of the detection results is >= 0.70, where in this condition the image captured by the camera will be automatically uploaded to Google Drive. Figure 22 is the LCD display if the average value of the detection results is <0.70, in this condition the LCD will display a statement that the image was not uploaded while the buzzer and green LED will be ON.

TABLE IX
RESULT OF UPLOADING IMAGE TO GOOGLE DRIVE

Avg Accuracy	Images Result on Google Drive	Description	
		Up loaded	Not Up Loaded
0,672		-	V
0,808		V	-
0,853		V	-
0,805		V	-
0,704		V	-

Avg Accuracy	Images Result on Google Drive	Description	
		Up loaded	Not Up Loaded
0,688		-	V
0,703		V	-
0,594		-	V
0,79		V	-
0,826		V	-
0,752		V	-
0,74		V	-
0,758		V	-
0,594		-	V
0,634		-	V

In Table 9 it is known that some of the average accuracy values in the overall detection results differ from the true positive confidence values previously listed in Table 5, Table 6, and Table 7. This discrepancy is due to the presence of false positive conditions, where objects that should not be present are mistakenly identified by the system as detection objects, as well as false negative conditions, where objects that should be present are not detected by the system. These two conditions affect the overall average confidence values. In the case of false positives, the detected objects tend to have low confidence values, which subsequently impact the total number of objects, resulting in a decrease in the overall average value. The overall average value is calculated by summing the confidence values of each detected object and then dividing by the total number of objects.

When uploading images to Google Drive in Table 8, there were several detection results that failed to upload due to various conditions. Is the explanation:

Figure 23. 1st Attempt At Uploading Images

In Figure 23 is the detection result in the 1st experiment with a detection distance of 2 meters using a vest, where the detection position was too close so that the whole body could not be input perfectly which caused the safety shoes image to be cut off so that the confidence value obtained was small.

Figure 24. 8th Attempt At Uploading Images

In Figure 24 is the detection outcome in the 8th experiment conducted at a detection distance of 4 meters using a harness. In this detection result, a false negative scenario occurred, as the system failed to recognize the glove object. A similar situation was observed in the results of the 15th experiment, which took place at a detection distance of 6 meters, where the system could not recognize the harness object.

Figure 25 14th Attempt At Uploading Images

Figure 25 is the result of the 14th experiment with a detection range of 5 meters using a harness. The detection results experienced false negatives on the harness object and false positives on the glove object, where objects other than gloves were repeatedly detected as gloves (multiple detections). This condition also occurred in the 6th experiment at a 2-meter detection range, where the system couldn't detect the helmet object and repeatedly detected the safety shoes object.

In this test, any detection result with an average accuracy value of >=0.70 will be automatically uploaded to Google Drive, as shown in Figure 26.

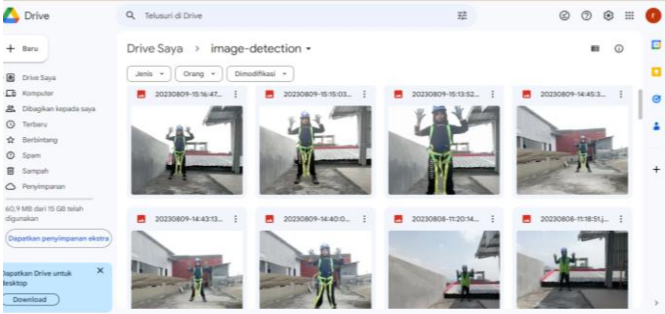


Figure 26. Images That Successfully Uploaded On Google Drive

IV. CONCLUSION

From the research that has been done it can be concluded that the system has been performing well as anticipated. The camera effectively detects images, and the system is capable of uploading the detected images to Google Drive. However, there are still instances of false positives and false negatives in certain detection outcomes, which can impact the overall accuracy score. Several factors contribute to this in the current testing phase, such as excessively distant detection range, small-sized objects, inadequate lighting conditions, and misidentification due to similarities in shape or color with surrounding objects at the detection site. There are several suggestions for further research to enhance this study. These include incorporating additional RAM into the Raspberry Pi to improve the system's execution speed, employing a more light-sensitive camera lens to capture images more effectively, augmenting the quantity and variety of the dataset to minimize occurrences of false negatives, false positives, and overspecification in safety equipment detection result, the use of a web application to display detection results and serve as the location for uploading detected image results, and the addition of remote control to replace buttons as an input method for camera control and image capture, making system operation more convenient.

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