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A building security monitoring system based on the internet of things (IoT) with illumination-invariant face recognition for object detection

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Abstract

Theft and intrusion are crimes that often occur in building environments when there is opportunity or negligence by owners and security personnel. Many studies have been carried out to improve environmental security by applying cameras as a surveillance medium. However, the camera is not optimal in detecting objects when the lighting conditions are lacking. Therefore, in this study, a monitoring and object detection system was built by applying the Illumination Invariant model. This model is used to improve the appearance of the image that combines normalization of the lighting by gamma adjustment, conversion to grayscale, and shadow removal. Illumination Invariant is a model used to improve the appearance of objects from changes in environmental lighting intensity so that they can interfere with the image analysis process. The process of detecting and identifying objects is done using human facial features (face detection) captured by the camera. The camera is a Logitec C270 Webcam 720p connected via a USB port on the Raspberry Pi 4. The Raspberry Pi 4 processes human face image data and sends the processing results to a MySQL database using the HTTP protocol. Data transmission is done using the Python Flask web framework. The system was successfully run 100% using black box testing of all functional requirements. Tests on the object detection feature were carried out based on different lighting conditions 3 times using different human face data by comparing the original image and the results of the Illumination Invariant implementation. Based on the test results obtained very good value with object detection accuracy is 87.33%.

1. Introduction

Theft and intrusion are common crimes in room areas and building environments. This crime occurs when there is opportunity and negligence by security officers and owners. This crime often occurs when the holiday season arrives because the building is abandoned by the owner without adequate security. Therefore, strangers would easily enter the building and bring things there. The solution carried out by the Owner is to install conventional surveillance CCTV on each side of the building. CCTV has several functions such as enhancing security systems, monitoring individual activities and protecting the assets we have. However, CCTV also has its drawbacks. One of them is that it can only be used as a medium to record crimes and evidence when there is a crime without knowing when the crime occurred in our area [1], [2]. The CCTV system only acts as passive surveillance. CCTV cameras cannot detect the state of an object and the duration of the object's appearance [3]. Currently, CCTV can be accessed online via a smartphone, but is only used as a surveillance medium [4].

In the 4.0 era, the use of artificial intelligence has been widely used in all our activities, especially to maintain environmental security, especially to maintain environmental security. One application of artificial intelligence in security is detecting and identifying moving objects in the environment using camera sensors. Many studies have been conducted to improve the perimeter security system from unwanted actions. One of them is researching home security systems using IoT technology [5], [6], [7]. This study uses camera and PIR sensors to monitor and detect the movement of objects in a room. The system will issue a warning sound and send an image via the user's smartphone when the sensor detects an object. Other research related to spatial security has been carried out by [8] using the frame difference method to detect the movement of an object in a certain space. The object detection process is carried out by the system by comparing the reference image with the image captured by the camera. Another study uses the SSIM (Structural Similarity) method to detect objects around us. The concept of this method is almost the same as the frame difference, namely calculating the difference in pixels. However, in the SSIM method, pixels are grouped into several groups, then accumulated, so that shadows are not considered objects [9], [10]. The system sends information via SMS messages when objects are detected [11]. Based on some of these studies, the system is still not optimal for detecting objects when the environment is dark. The problem of lighting variations is one of the main problems in image recognition of human faces in the outdoor environment. The facial recognition process can be carried out when all the features of the face can be detected properly by the camera [12]. The lack of lighting levels for an image will be able to reduce the level of accuracy of the system in detecting the object. So lighting is the most important factor in the human face recognition process [13].

Based on the focus of the problems presented, this research builds a surveillance system to detect foreign objects, namely people who are not known in the surrounding environment based on the Internet of Things (IoT). In this study, the human face detection function was applied to detect and identify objects captured by the camera [14]. This research is implemented in an office environment when we enter the office. So that it can help owners and security officers to monitor building security from unknown people. This study applies the Invariant Illumination method, which is used to improve the appearance of objects through light and shadow [15]. so that the system can recognize objects in all lighting conditions in the environment such as dark, normal, or bright lighting. The Illumination Invariant model for facial recognition systems is used to solve problems in the human identification process when there is a change in lighting when the system is operated in actual environment such as a building environment or room area [16]. This study uses the HTTP protocol to send camera data to the server [17], [18]. This system is designed to help owners and security officers keep the building safe from crime around the building, even when the lighting level changes.

2. Research Method

2.1 Related Work

Currently there have been many studies conducted on home security and building security. One of them is the use of IP cameras as a medium for detecting foreign objects in certain rooms or environments [19], [20]. Images captured by IP cameras are processed using a frame difference algorithm to detect human objects in the environment. In this study using the object motion detection feature to detect humans in the building environment [21]. The system will send warning messages and send photos to telegram bots to help detect suspicious object activity to building owners [22]. There are several research gaps in this study, such as the foreign object detection process. The objects detected by the system are immediately categorized as foreign objects or changes in the environment without any identification process for the object. The system immediately notifies the owner without knowing whether the object is recognized by the room owner or not. This study is also less sensitive to ambient lighting. The system is less effective in detecting objects when the lighting in the area is lacking. Another study discusses building security systems using Yolo technology and the Haar Cascade Classifier algorithm to recognize human faces and eyes. This technology is used to help sensors distinguish humans from other objects by detecting human facial poses [23], [24]. This study also uses the Haar Cascade Classifier method to classify detected objects into human objects based on the characteristics of the human face and eyes. There are several research gaps in this study, the security process is carried out by detecting humans around using a camera. This study has no detectable human recognition system, so all individuals caught by the camera are categorized as foreign objects. In this study, there is no security notification function when someone is detected by the camera in this environment.

In another study, a user login system was built at health kiosks using biometric facial recognition technology and the Illumination Invariant facial recognition feature. The Illumination Invariant feature is a technology for dealing with changes in the intensity of illumination around objects. This research was conducted in different lighting conditions such as normal lighting, backlighting, direct lighting, dim lighting and darkness. This research also uses the facial recognition feature to identify users who access the system. The facial recognition process in this system uses intrinsic facial features based on principal component analysis (PCA) for the facial extraction process [25]. There is a research gap in this study, namely the human face is less effective in detecting when the distance between the face and the camera is more than 60cm. This research only focuses on accessing the health information system using the facial recognition function as a substitute for the username and password functions to access the system. There are many studies on object recognition, especially on human face recognition, the lighting factor can affect the level of the system's ability to detect an object [26]. The application of the Illumination Invariant model can assist the system in detecting these objects, especially as in human facial recognition systems [27]. The Illumination Invariant model has weaknesses such as requiring a long process of normalizing the lighting of the image of the object. However, there are advantages that can help the system detect an object at low lighting levels. So that the detected object information can be displayed properly even if there is a change in lighting on the image object.

2.2 System Architecture Design

The System Architecture Design used in this study consists of several components such as a Raspberry Pi, camera, LDR sensor, and internet connection. The layout of the system model is shown in Figure 1. First, the camera takes an image of the object and converts it into an invariant illumination model. Objects in pictures are recognized by the facial recognition function. The process of recognizing human faces is carried out by examining the uniqueness of the shape of human facial features. Then, the detected human face is processed to obtain information about the detected human. The system will record information about each object detected by the system.

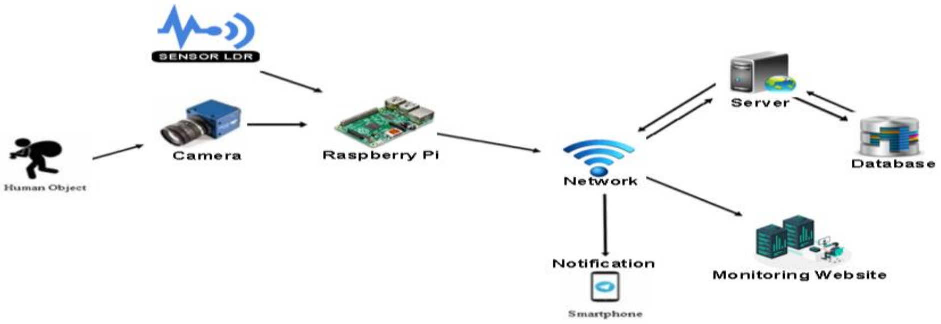


Figure 1. System Architecture Design

2.3 Human Face Detection Method

Facial recognition is a technology based on artificial intelligence (AI) biometrics that can identify a person by analyzing patterns based on the texture and shape of a person's face such as the distance between the eyes, forehead height, eyebrows, nose shape, etc. The identification process can be run after the face recognition process is running. Therefore, face recognition is a very important initial process before the face recognition process takes place [28]. The human face detection system was carried out in this study. It was using the Haar classifier cascade algorithm. This algorithm has the advantage that the calculation process is very fast because it depends on the number of pixels squared and not on all pixels in the image [29]. The flowchart of detecting faces in human images can be seen in Figure 2.

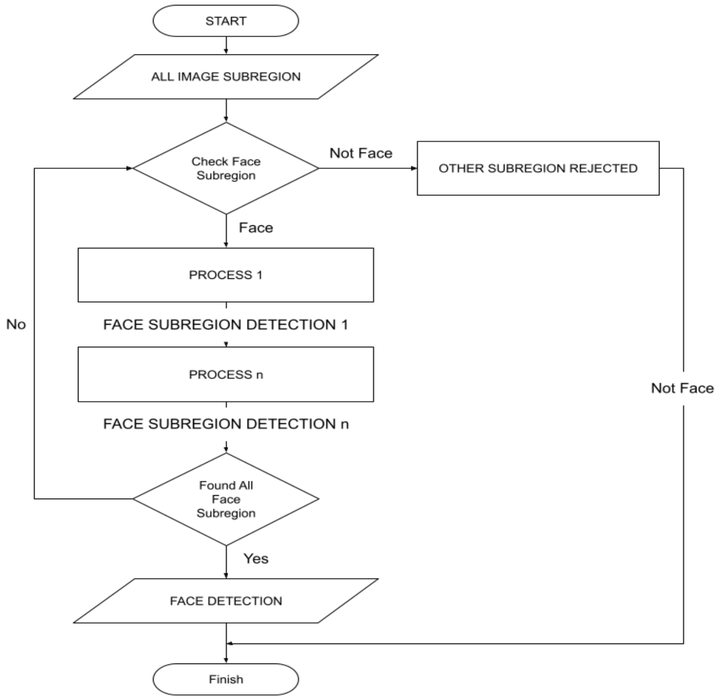


Figure 2. Face Detection Process

2.4 Detection System Flowchart

The following flowchart in Figure 3 is the process of the system that performs the phases of detecting objects captured by the camera. First, the camera captures objects, namely people in the area. Next, the system changes the detected object using the lighting invariant method for the lighting conversion process in the object's surroundings. This process aims to eliminate the influence of lighting on the object's surroundings so that objects can be recognized by the system. After that, the system selects the detected object and captures the face pattern of the human object. This pattern of human faces is matched against a human face database to identify object information. When the human object is detected, the system saves the information in the database. If not detected, the system will send an alert message to the owner or security officer.

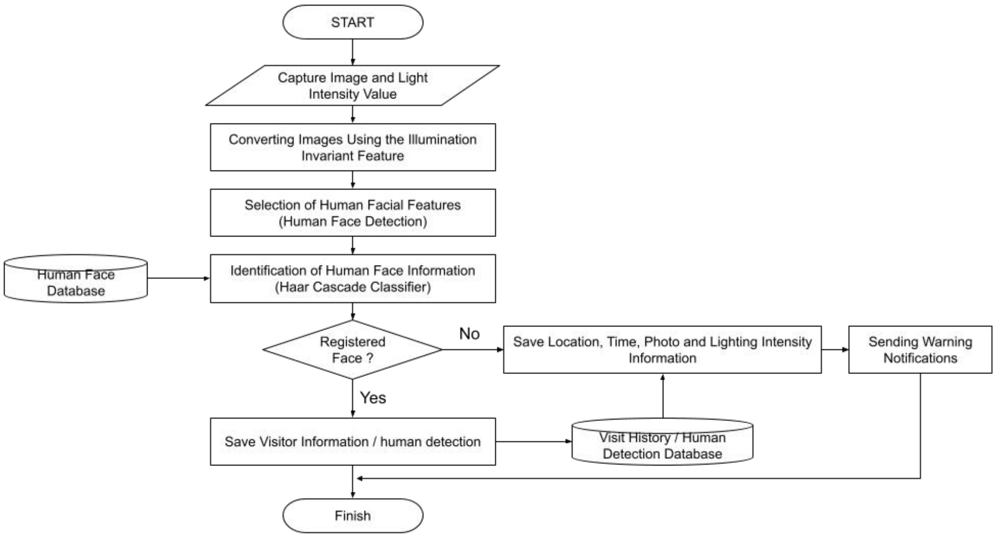


Figure 3. Detection System Flowchart

2.5 Illumination Invariant Model Concept

Different lighting conditions can be a crucial problem in object recognition systems because they can affect the appearance of facial images and increase variations between objects. Illumination Invariant is a method used to enhance the appearance of objects through light reflections and shadows [30]. This study applies the Invariant Illumination method to process images so that the system can recognize objects in the image even though the lighting around the object changes. The Illumination Invariant method is used to solve lighting problems based on 5 types of lighting [31]. The type of lighting category used in this study can be seen in Table 1.

Table 1. types of lighting categories

No	Lighting Category	Lux Value	Description
1	Normal Lighting	100 to 250 lux	an image condition with sufficient lighting in the room
2	Low Lighting	30 to 75 lux	an image under low light conditions, details are still clearly visible from a window with a light source such as sunlight
3	Backlighting	75 to 100 lux	a condition when the light source is behind the object
4	Direct Lighting	> 250 lux	a lighting from many light sources and bright enough
5	Dark	< 30 lux	a low light where the details of the image can still be seen from the room's light source

In this research, the illumination invariant process is carried out by converting human facial data captured by the camera. First, the system will detect the human face captured by the camera. Then the system will carry out the process of normalizing the lighting in the image which aims to increase the brightness of the lighting intensity of the captured image. After that the image will be converted to Grayscale so that the processing of image data will be faster. then this image data will be processed using the illumination Invariant model so that it can improve the appearance of images from lighting and shadows. The results of this human face image processing will be used for the human face identification stage in the system. The design of the image lighting processing process so that it can be recognized by the system can be seen in Figure 4.

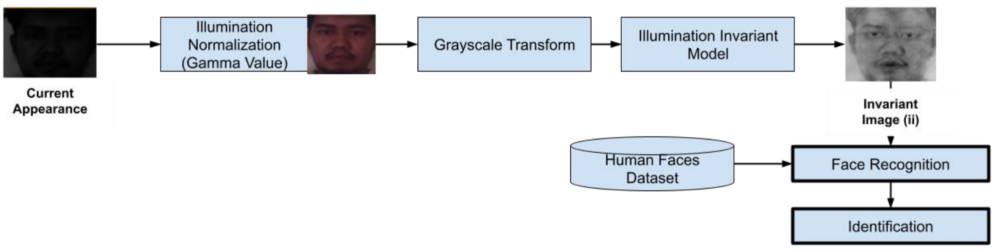


Figure 4. Illumination Invariant Identification Model

3. Results and Discussion

In this study, an object detection monitoring system was built with the name "SimMonitor". SimMonitor is a website-based system built using 3 different programming languages, such as Python, Javascript and PHP. Each programming language has different responsibilities and is connected to one another using the concept of an API (Application Programming Interface). Python programming is used to process human objects captured by the camera. This stage includes the process of detecting human faces, training facial datasets, sending notification messages and identifying human faces detected by a camera using a Raspberry Pi. Javascript programming is used to send, receive and process data from the Raspberry pi. This processed data includes the results of human face identification, dataset training processes, notification information and real-time monitoring from cameras connected to Raspberry Pi. The PHP programming is used to display the results of system data processing stored in the database such as the results of detected objects and the results of data processing from the Raspberry pi. All stages of object data processing such as the process of detecting and identifying human facial images are carried out by the Raspberry Pi. In this study using Python Flask technology which functions to send data processing results from each component connected to the Raspberry Pi. The components used in this study can be seen in Table 2.

Table 2. System Component Details

No	Component	Unit
1	Raspberry Pi 4 Model B (RAM 8 GB)	1 Unit
2	Photoresistor LDR Sensor (Light Dependent Sensor)	1 Unit
3	Camera HD 720p	1 Unit
4	Breadboard	1 Unit
5	Cable Jumper	-
6	Capacitor	1 Unit

In this study, the website that was built has a function as a monitoring media to display the results of data processing carried out by the Raspberry Pi to users who access it, such as building owners and security officers. This website has a feature to register members or people who are allowed to enter the room or building. This registration process is carried out by registering the permitted human faces. In addition, the website is also equipped with features to monitor camera results in real-time and display historical data on human faces detected by the system along with images of object data captured by the camera. but the real-time monitoring process can still run properly without accessing website pages

3.1 System Framework Model

Raspberry pi will process the input from the camera and classify the detected object. If there is a human face caught by the camera, the object will be compared first to the data available in the image dataset. If the object is not registered (the object is not recognized) then the system will notify the security officers [32]. In this study, the object detected was a human by using human facial features (Human Face Detection).

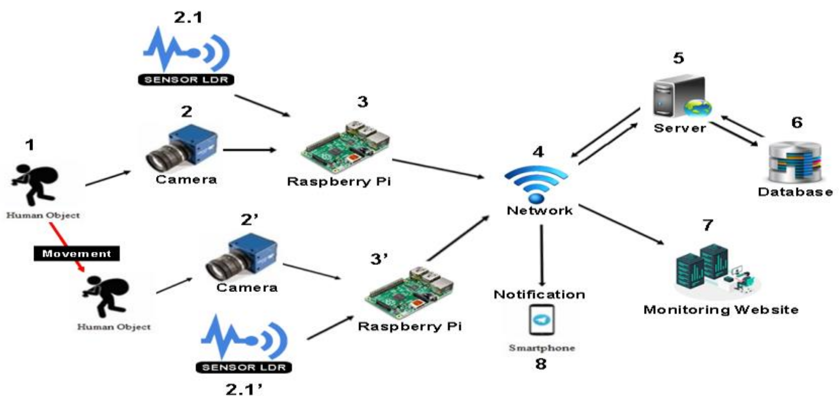


Figure 5. System Framework Model

In object recognition systems, the camera functions as an input medium to detect objects in the form of human faces. This camera is connected to the Raspberry Pi to carry out the process of classifying and identifying detected objects. Meanwhile, LDR sensors are only used to calculate the value of lighting intensity in a room or building environment. This system uses more than one camera (multi-camera) connected to several Raspberry Pi. Each camera has the same function to detect and recognize objects in the form of human faces. The difference between each camera is how to display the location of the captured object. For example, if an object is detected on one of the cameras in the system, then the system will process information from that object. If the object is not recognized, the system will track the object's location. If the object is detected again by another camera, the system will record the time and place the object passed through the camera in that environment. The system will also notify the user about the existence of the object. The system framework for tracking can be seen in Figure 5.

The explanation of each process of the system framework model is as follows. Point 1 (object) is a foreign object that enters the vicinity of the building. In this research, the foreign object is human. Point 2 and Point 2' (camera) are components used to collect data in the form of pictures of people. Both of these components have the same function, the difference for each camera is only the position of the components, e.g., B. The first camera is in room A and the second camera is in room B. Point 2.1' (LDR sensor) is a component that is only used to collect data on the value of lighting intensity in a room or building environment. Point 3 and Point 3' (Raspberry Pi) are very important components in this study. This component is in charge of connecting every existing component and processing all data received from the camera and LDR sensor. The process of detecting and identifying human images is carried out by the Raspberry Pi. So all functions of the system will be processed by this component. Both of these components have the same function. The difference between each of these components is that they collect input in the form of information about when and where the object was last detected. Look at Figure 5; for example, an object is detected on the first camera and the object is not detected by the system. Then this object moves to a second location (second camera), then the system captures information when and where the object is. Point 4 (Internet) is a component for sending data received from the camera to the server. The process of sending data via the HTTP protocol. Point 5 (server) is a service for receiving and processing client requests. This component compares the input data with a database of registered human faces for the object identification process. Item 6 (database) is a component for storing registered facial images and detected object history. Point 7 (Website Dashboard) is a component for displaying and managing human image data. Item 8 (Notifications) is a component for sending and receiving notifications from the system to provide information about the object.

3.2 System Experiment Results

This system is built based on a website that monitors the results of object detection in real-time. The system is designed using the PHP programming language and CodeIgniter 3 framework. The system consists of 3 main menus, namely Dashboard, Content and User Manager. Before accessing the system functions, the user must login to the system. There are three types of user levels in this study, namely Super Admin, Admin and General. Each level has a different number of menus that can be accessed by users. The Super Admin level is fully responsible for systems such as user account management, membership management, detection report management and lighting intensity criteria management. The admin-level is responsible for managing member data such as registering members and conducting data training for human faces. The General level is responsible for monitoring detected objects and taking action on detected objects. After the successful login process, the user can see the system display based on the user's access level. As shown in Figure 6, users can monitor captured object information in real-time. The results of this object information are obtained based on human facial feature data stored in the database.

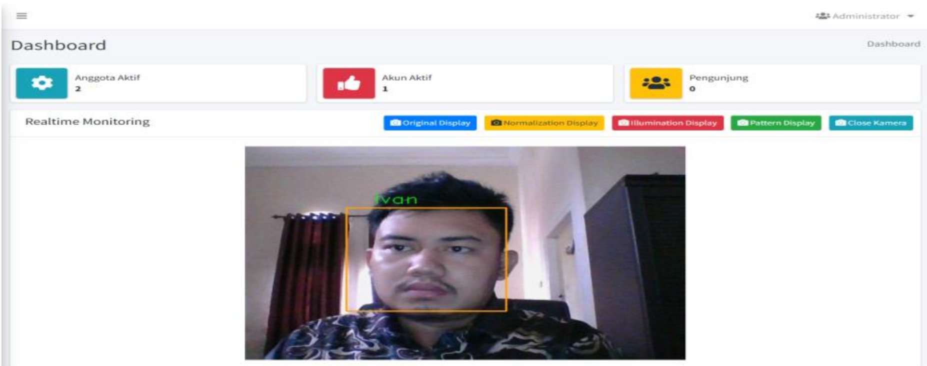
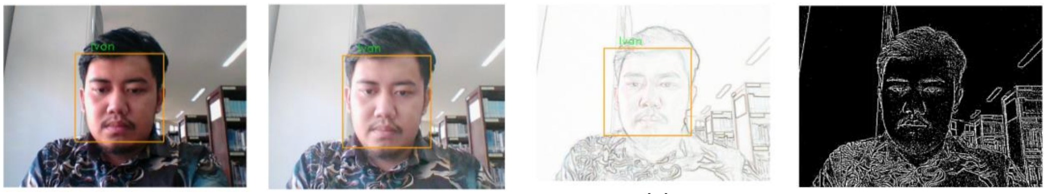


Figure 6. Dashboard Real-time Monitoring

On the dashboard page, the object detection monitoring system (SimMonitor) has 4 real-time monitoring display features. Each real-time monitoring display has a different function. Display 1 (Original Display) is the main display of the real-time monitoring system. This display is used to display the results of object detection under normal conditions from the camera used. Display 2 (Illumination Normalization Display) is a display for normalizing the lighting resulting from the original display. Display 3 (Illumination Model Display) is the result of applying the Illumination Invariant model.

In this view, the system has handled the lighting conditions of the detected objects. Display 4 (Images Pattern Display) is a display used to display the results of object monitoring based on the pattern of the object detected by the camera. This real-time monitoring display is displayed in color, so that the user can see images like the actual conditions of the objects captured by the camera. This view is only a perspective view from the user. However, the entire human face detection and identification process is carried out based on the Illumination Invariant stage which can be seen in Figure 4. In addition, users can change the perspective of the real-time monitoring display according to what the user wants. The results of each real-time monitoring display can be seen in Figure 7.



(a) (b) (c) (d)

Figure 7. Real-time Monitoring Display: (a) Display 1, (b) Display 2, (c) Display 3, and (d) Display 4

To assist in the identification process, this study used 50 samples of human facial data for each member registered with the system. This human face dataset is retrieved manually based on human faces that are allowed to enter the room area or building environment. The dataset registration process is carried out on the website application by the user as the admin level of the system. The process of taking human face samples is carried out using 5 different types of sampling positions, namely 10 face samples for the normal position (straight towards the camera), 10 face samples for a tilted position to the left with a tilt angle of 20°, 10 face samples for an oblique position. to the right with a tilt angle of 20°, 10 face samples for the upward facing position with a 20° angle and 10 face samples for the downward facing position with a 20° angle. Each human face sample will be converted into a Grayscale. The process of converting facial images to grayscale at the face identification stage will be easier and more efficient because it can simplify processing of image pixels by the system. In addition, it's use of less computing resources compared to processing color images. so converting facial images to grayscale is an important step in the face identification process [33]. This human facial data is used to identify objects detected by the system using the Haar Cascade Classifier algorithm. This human face data is stored in a database and grouped based on the owner data of the human face. An example of a human image dataset that is stored in a database can be seen in Figure 8.

Figure 8. Human Face Dataset

All human facial data will be carried out by a training process that is used for the identification stage. The dataset training process is carried out by calculating the pixel value of each human face image data in the database. The pixel of human face images will save into an XML file which is used for the object identification process based on the human face. During the process of identifying human facial features, the system will compare each image in the dataset with the currently detected image. The system will display information from the object if the object has been registered on the system

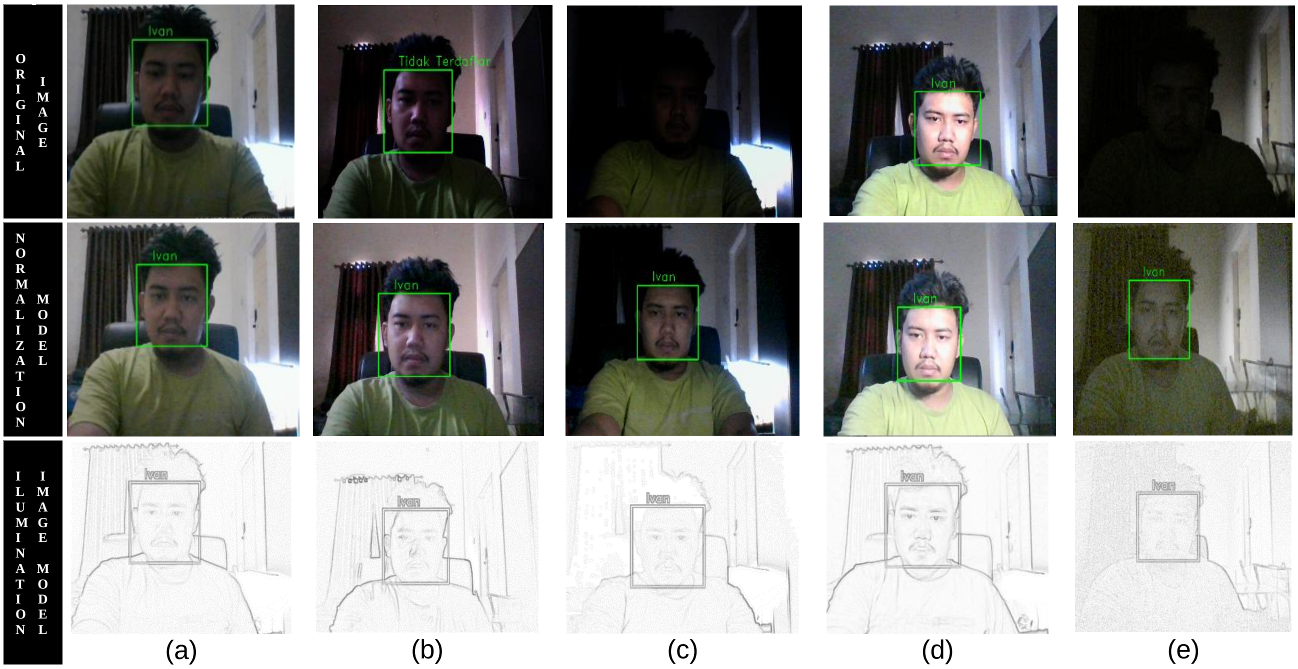
3.3 Invariant Illumination Experiment for Face Recognition

Under certain lighting conditions, the system has difficulty recognizing human facial features in the environment. Look at Figure 9 in point (a). The system has difficulty recognizing human faces. The human face object in the image is less bright, so the system can only recognize 1 human facial feature. The Illumination invariant model is used to assist system performance in detecting human objects in the environment when illumination problems occur. The process of converting the image to an illumination-invariant model is carried out by changing the total RGB value of the existing image pixels so that human face image objects can be recognized. There are several models that can be used to change image pixel values such as the Maddern transform. Look at Figure 9 in point (b), the system has successfully detected all human facial features in the image object.

(a) (b)

Figure 9. Human Face Detection: (a) Original Image and (b) Convert RGB to Illumination Model

In the real-time monitoring system implementation process, this GRB conversion transformation model is difficult to apply if one of the image's GRB pixel values has a value less than 1. The image cannot be displayed if the RGB conversion process has a pixel value lower than 1. Therefore, it is necessary to make changes to the pixel value of the image so that it can be detected in real-time through the monitoring system (SimMonitor). The process of changing the pixel value is done by changing the lighting value in the object image captured by the camera. The image of this object is converted into grayscale for the human face identification stage. This conversion process can be seen in Figure 4. Then the pixel value of the image will be processed in the Invariant Illumination stage. We can see in Figure 10 shows the results of a comparison of object detection based on the lighting type category. The type of lighting category used in this study can be seen in Table 1.



(a) (b) (c) (d) (e)

Figure 10. Face Detection Comparison: (a) Normal Lighting, (b) Low Lighting, (c) Backlighting, (d) Direct Lighting, and (d) Dark (Face looks faint)

3.4 Light Intensity Experiment for Face detection

This test is carried out to test the system in detecting objects even though there are changes in lighting in the object's environment. This test uses 3 human data that have been registered in the system, namely Ivan, Farhan and Azly to evaluate the system's performance in identifying human faces based on different lighting conditions. The testing process is carried out using 5 lighting conditions, namely normal lighting, low lighting, backlighting, direct lighting and dark. The comparison of object detection based on lighting in this study can be seen in Table 3.

Table 3. Comparison of Object Detection Based on Lighting

Lighting Condition	Original Image				Illumination Image Model			
	Ivan	Farhan	Azly	%	Ivan	Farhan	Azly	%
Normal Lighting	3/3	3/3	3/3	100	3/3	3/3	3/3	100
Low Lighting	1/3	1/3	2/3	44.4	3/3	3/3	3/3	100
Backlighting	1/3	0/3	0/3	11.1	3/3	3/3	3/3	100
Direct Lighting	2/3	2/3	1/3	55.5	3/3	3/3	3/3	100
Dark	0/3	0/3	0/3	0	1/3	1/3	1/3	33.3
Total	7/15	6/15	6/15	**42%**	13/15	13/15	13/15	**86.7%**

Based on the results of tests conducted on the human face detection feature based on these 5 conditions. The success rate of the system in detecting all human facial features in actual conditions from the detection results obtained from the camera (Original Images) is 40%. The success rate of this detection is smaller than after carrying out the process of applying the Illumination Invariant model. the system's low success rate in detecting human facial features is due to the difficulty of the system in detecting human facial features, especially in low lighting conditions, backlighting and dark conditions. In low lighting conditions, the percentage of the system in detecting human faces is 44.4%. Whereas in backlight conditions, the percentage of success of the system in detecting human facial features is even lower, namely 11.1%. This is because the image of a human face captured by the camera has a low lighting intensity, so the system cannot find the pattern of the human face.

In implementing the Illumination Invariant model in this study, the system's success rate in detecting human facial features is 86.7%. This is because the system can find patterns in the human face. In applying the Illumination Invariant model, the system can find human facial patterns due to the process of normalizing the lighting of the object being detected. The process of normalizing lighting is carried out to clarify images that have low lighting intensity so that they can be detected by the camera. Based on the comparison results from Table 3, it can be seen that in low-lighting conditions and backlighting the system can to detect all human facial features. In this study Illumination Invariant will have difficulty detecting and identifying human faces if the lighting conditions are too dark and some of the human facial features are not visible on the camera. In addition, applying the Illumination Invariant model for real-time face detection also requires a longer time to convert image data into an Illumination Invariant model.

This study also compared the results of human face detection using different amounts of human face sample data, namely 3 data, 5 data and 10 data. Each human face data is tested 3 times using different lighting conditions. Based on the test results, the percentage values for each test were 86.70%, 88% and 87.30%. So that the average of all tests carried out using different human face sample data is 87.33%. Based on the results of the percentage value of this test, the application of the Illumination Invariant model gives better results when compared to without the application of the Illumination Invariant model in detecting objects based on human facial features. The Comparison of human face detection with different number of human face sample data in this study can be seen in Table 4.

Table 4. Comparison of Object Detection Based on Number of Human Face

Lighting Condition	Original Image			Illumination Image Model		
	3 Data	5 Data	10 Data	3 Data	5 Data	10 Data
Normal Lighting	9/9	15/15	30/30	9/9	15/15	30/30
Low Lighting	4/9	7/15	14/30	9/9	15/15	30/30
Backlighting	1/9	2/15	5/30	9/9	15/15	30/30
Direct Lighting	5/9	9/15	16/30	9/9	15/15	30/30
Dark	0/9	0/15	0/30	3/9	6/15	11/30
Total (%)	19/45	33/75	65/150	39/45	66/75	131/150
	42%	44%	43.30%	86.70%	88%	87.30%
Average (%)		**43.11%**			**87.33%**	

3.5 Experiment for System Notification

This study uses Telegram Bot and Email as a feature for sending notification messages when an object that is not recognized is detected by the camera [34], [35]. The process of sending this warning notification is done using Email and Telegram. This warning message information contains information about when the object was detected and where the user can view information from the detected object. The display of email notifications can be seen in Figure 12. Meanwhile, the display of telegram notifications can be seen in Figure 13.

Figure 12. Email Notification Display

On the telegram display, notification messages are sent to the object detection monitoring system group (SimMonitor). This message is sent via telegram when an object is detected. To get notification messages via this telegram, users must join the SimMonitor group first (https://t.me/SimMonitor).

Figure 13. Telegram Notification Display

Based on the test results of the system notification feature which was carried out through the object detection monitoring website (SimMonitor). The use of the telegram bot feature in the process of sending object detection information is considered good enough to be applied to a real-time monitoring system. This is because the process of sending notification data via a telegram bot can be done quickly when an unknown human is detected by the system. In contrast to using the email-based notification feature. The process of sending warning messages cannot be done quickly without the presence of an unrecognized human face detected by the system. This is because sending notifications via email has a delay time when sending warning messages. In this study, we tested the notification message-sending feature. Notifications are sent via telegrams and emails when an unknown human is detected by the system. The process of sending this notification will be repeated every 30 seconds when an unknown human is detected at the same location. In addition to sending notification messages, the system also stores visit history data in the database.

In this study also tested the process of recapitulating visit history data or object data detected by the camera. The process of recapitulating the results of the visit history data is grouped into 2 categories, namely categories of recognized human objects (registered on the system) and categories of human objects that are not recognized by the system. For groups of human objects that are recognized by the system, the system will store visit history data or the results of object detection in the database without sending notifications via telegrams and e-mails. The process of storing visit history data can be done every 10 minutes when the same object is detected at the same location. For groups of unrecognized human objects, the system will immediately save the visit history data into the database and send notification messages. The process of storing data and sending notifications is carried out every 30 seconds when an object is detected by the system at the same camera location. Based on the test results, the process of sending notification messages and recapitulating visiting data from the object detection system (SimMonitor) can function properly.

3.6 Experiment for Black Box Testing

Black box testing is carried out to test the functional requirements of the object detection monitoring system (SimMonitor). before testing the system functionality, the user must try to access all the features available on the system.

This test aims to determine the functionality of the system can work properly to assist in detecting objects through the website. This test was carried out using 7 test cases to describe the main features of the system. based on the results of black box test, it can be seen that all the functional requirements of the system function as expected, so the system can be used properly. The results of black box testing can be seen in Table 5.

Table 5. Black Box Testing Result

No	Test Case	Test Scenario	Result
1	Login Page	The actor does not fill in the Username and Password. The system displays a failed login message	Valid
		The actor fills in the wrong Username and Password. The system displays a failed login message	Valid
		The actor fills in the correct username and password. The system opens the dashboard page	Valid
2	Dashboard page	The actor chooses the real-time display monitor display 1 (Original Images) The system displays the results of monitor display 1 (Original Images)	Valid
		The actor chooses the real-time display monitor display 2 (Illumination Normalization) The system displays the results of monitor display 2 (Illumination Normalization)	Valid
		The actor chooses the real-time display monitor display 3 (Illumination Images) The system displays the results of monitor display 3 (Illumination Images)	Valid
		The actor chooses the real-time display monitor display 4 (Pattern Images) The system displays the results of monitor display 4 (Pattern Images)	Valid
3	Member Page	Actors can see a list of members. The system displays a list of members from the database	Valid
		Actors can add new member data. The system adds new member data to the database	Valid
		Actors can change member information. System changes member information from database	Valid
		The actor registers the member face dataset. The system adds 50 member face dataset to the database	Valid
		Actors can carry out the dataset training process. The system performs the training process for member datasets from the database	Valid
4	Visit History / Human Detection Page	Actors can see list of visitor information. The system displays list of visitor / human detection Information from the database	Valid
		Actors can view detailed visit information. The system displays visit information with photos of detected objects	Valid
5	Light Intensity Page	Actors can view light intensity data. The system displays a list of light intensity in the database	Valid
		The actor can edit the light intensity value. The system changes the light intensity value from the database	Valid
6	Manage Users page	Actors can add new users. The system adds user data to the database	Valid
		Actors can edit member data except for Super Admin data. The system can change user data except for Super Admin user data into the database	Valid

4. Conclusion

Based on the results of the research conducted, the Monitor System for detecting foreign objects was successfully implemented. This system can assist owners and security officers in monitoring and identifying objects in the area around rooms and buildings. The system can detect objects (humans) captured by the camera based on the human face recognition feature even though there are changes in lighting in the object areaIn this study the application of the Illumination Invariant model was carried out to help the system detect and identify human facial features properly even though there are differences in the intensity of lighting in the object area. From the results of testing the human face detection feature which was carried out with 3 tests on 5 lighting conditions using 3, 5 and 10 different human face test data. The application of the Illumination Invariant model gives better results when compared to without applying the Illumination Invariant model in detecting objects based on human facial features. The percentage results obtained with the Illumination Invariant model is 87.33%. Based on the test results on the system's notification feature, the system can provide notifications to owners and security officers if an object that is not recognized is detected by the camera based on human facial features (Human Face Detection). The process of sending notifications is carried out using email and telegram bots every 30 seconds when an object that is not recognized is detected by the camera. The system also records each object's history and is stored in the database. In future work, the notification feature needs to be improved by adding a calling-alert feature, so that security notifications will be received more quickly by owners and security officers. then the LDR sensor needs to be improvised by adding a feature that changes lighting parameters automatically based on lighting values in the area around the room and the building environment, so that the system can adjust the value of significant lighting changes in the object environment automatically. Finally, it is necessary to do more research regarding security in the process of sending data from the Raspberry Pi to the server. This relates to the use of networks in Internet of Things (IoT) technology, so it is necessary to add network security in the process of sending data via the internet network.

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