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Object Detection And Monitor System For Building Security Based On Internet Of Things (IoT) Using Illumination Invariant Face Recognition

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Abstract: Theft, burglary and intrusion are criminal acts that often occur in the environment when there are opportunity or negligence made by the owner and security officers. Many studies have been carried out to improve environmental security by applying cameras as a surveillance medium. However, the camera is still not optimal at detecting objects if the environment is in poor lighting conditions (dark). Therefore, in this study, a monitoring and object detection system was built by applying the Illumination Invariant model. Illumination Invariant model that is used to improve the appearance of object images from light and shadow reflections. In this study, the detection process and objects are carried out using human facial features captured by the camera. The camera used is a Logitec C270 Webcam HD 720p via the USB port on the Raspberry Pi. Raspberry Pi processes human face image data and sends the results of data processing to a MySQL database using the HTTP Protocol. The process of sending data is done with the concept of API (Application Programming Interface) using Python Flask. In this study, all tests were carried out on the system using black box testing techniques with the results of the functional requirements being successfully executed 100%. In this study, testing the object detection feature based on different lighting conditions. The test was carried out 15 times by comparing the original image and the results of the implementation of the Illumination Invariant model. Based on the test results by applying the illumination of the Invariant model, the quality of object detection accuracy is 86.7%.

Keywords: Crime, CCTV, Illumination Invariant, Face Detection, HTTP

1. Introduction

Theft, burglary and infiltration are crimes that often occur in the surrounding environment. This crime occurs when there is an opportunity or negligence committed by the security officer and the owner. This crime often occurs when the holiday period arrives, because the building is abandoned by the owner without adequate security. Therefore, it will be easy for foreigners to enter the building and take the existing items there.

The effort made by the owner are installing conventional CCTV on each side of the building. CCTV has several function such as increasing the security system, monitoring a person's activities and protect the assets we have. However, there are weaknesses of CCTV. One of them is can only be used as a medium for recording the crime and as evidence if there is a crime without knowing when the crime occurred in our environment [1-2]. The CCTV system only functions as passive surveillance. CCTV cameras cannot identify the state of an object and the duration of the object's appearance [3]. Currently, CCTV can be accessed online via a smartphone but it's only used as a surveillance medium.

In the 4.0 era, the use of artificial intelligence has been widely applied to all of our activities, especially to maintain the security of the surrounding environment, especially to keep the surrounding environment safe. One of the applications of artificial intelligence in security sector is to detect and identify moving objects in the surrounding environment using camera sensors. Many studies have been conducted to improve the environmental security system from unwanted actions. One of them is research on home security systems using IoT technology [4-6]. This study uses camera sensors and PIR sensors to monitor and detect the movement of objects in a room. The system will sounding alarm alert and send an image via the user's smartphone if the sensor detects an object. Other research related to room security was carried out by [7] using the Frame Difference method to detect the movement of an object in a certain room. The process of detecting an object is carried out by the system by comparing the reference frame with the frame captured by the camera. If there is a difference in the pixel value with the image captured by the camera, it indicates an object has been detected. Based on this, it is necessary to develop a room security system to help detect unknown objects easily. In

another study using the SSIM (Structural Similarity) method to detect objects around our room. The concept of this method is almost the same as Frame Difference, which is to calculate the difference in pixels. However, in the SSIM method, pixels are grouped into groups, then they will be accumulated so that shadows are not considered objects [8]. The system will send information via SMS message if there is an object detected. Based on some of these studies, the system is still not optimal for detecting objects when the environment is dark.

Related to the focus of the problems presented, in this study a monitoring system will be built to detect foreign objects, namely people who are not recognized in the surrounding environment based on the Internet of Things (IoT). In this study, we will apply the human face recognition feature (Human Face Detection) to detect and identify objects captured by the camera. This research will be implemented in an office environment when we enter the office room. So that it can help owner and security officer to monitor the security of the building from unknown people. This study applies the Illumination Invariant method which is used to improve the appearance of objects from light and shadow reflections. So the system can detect objects from all lighting conditions in the environment such as dark, normal or bright lighting. This study uses the HTTP protocol to send camera data to the server. This system is expected to help owner and security officer in maintaining building security from crimes that occur in the environment even though there is a change in the intensity of the lighting there.

2. Research Methods

A. Related Work

Many studies related to Home Security and building security have been carried out so far. One of them is utilizing IP cameras as a medium to detect the foreign objects in certain room or in surrounding environment [9]. The image captured by the IP camera will be processed using the Frame Difference algorithm to decide whether there is a change in the environmental conditions. This research is applied to indoor and outdoor locations. The first location is placed in the outside environment to detect illegal parking in the neighborhood. The second location is placed in the room to detect the movement of unrecognized objects in the room. In this study, there are several research gaps such as the process of detecting foreign objects. On the inside of the room (indoor), objects captured by the system will be immediately categorized as foreign objects or categorized as environmental changes without any identification process of the object. The system immediately provides notifications to the owner without knowing the object is recognized or not by the owner of the room. This study also has a lack of sensitivity to environmental lighting. The system is less effective in detecting objects if the lighting in the environment is lacking.

In another study discusses about the building security system using Yolo technology and Haar Cascade Classifier algorithm to detect human faces and eyes. This technology is used to assist sensors in distinguishing between humans and other objects by detecting human facial posture [10]. This study also uses the Haar Cascade Classifier Method to classify captured objects into human objects based on facial features and human eyes. In this study, there are several research gaps, the security process is carried out by detecting humans using cameras in the environment. This study does not have an identification feature for humans that are detected, so all people detected by the camera will be categorized as foreign objects. In this study, there is no security notification feature if there are humans detected by the camera in the environment.

In another study, a User Login Method system was built at Healthcare Kiosk using facial recognition biometric technology and the Illumination Invariant feature on face recognition. Illumination Invariant feature is a technology to handle changes in lighting intensity in the object's environment. This research was implemented in different lighting conditions such as normal lighting, backlighting, direct-lighting, low-lighting, and dark. This study also uses facial recognition features to identify users who access the system. The face recognition process in this system uses the eigenface base feature on the principal component analysis (PCA) for the facial extraction process [11]. In this study, there is a research gap where the human face will be less effective to detect if the distance between the face and the camera is more than 60cm. This study only focuses on accessing the health information system using the face detection feature as a substitute for the username and password feature to access the system

B. System Design Model

The research method model used in this study consists of several components which can be seen in Figure 1. First, the camera will capture an image of the object and convert it first into the Illumination Invariant model. Objects in the image will be detected using the Face Detection feature. The human face detection process is done by checking the unique shape of the human facial features. The detected human face is then processed to find out information about the detected human. The system will record information on each object detected by the system.

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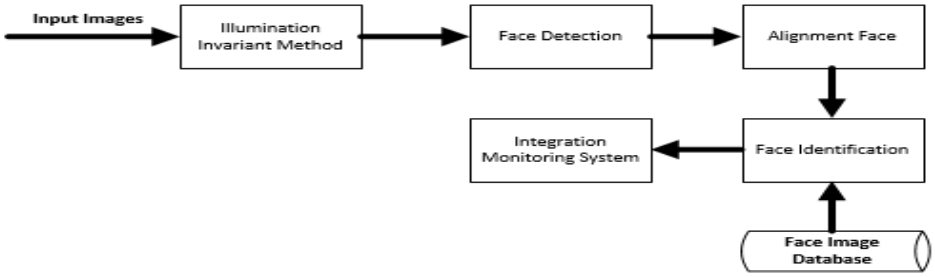

Figure 1. System Design Model.

The architecture of the monitoring system development for room and building security consists of several main components such as Raspberry Pi, cameras, LDR sensors and internet connections. The design of the system architecture can be seen in the following figure.

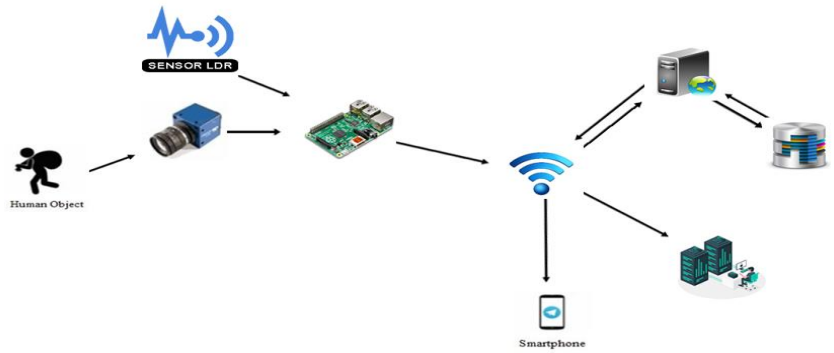

Figure 2. The architecture System Design.

C. Human Face Recognition Method

Face Recognition is a technology based on Biometric Artificial Intelligence (AI) that can identify a person by analyzing patterns based on the texture and shape of a person's face. Identification process can be carried out after the face detection process is running. Therefore, face detection is one of the very important initial processes before the face recognition process takes place [12]. The face detection process is obtained based on the geometric shape of the human face such as the distance between the eyes, forehead height, eyebrows, nose shape and etc. In this study, the human face recognition system (Human Face Detection) was carried out using the Haar Cascade Classifier algorithm. This algorithm has the advantage that the computational process is very fast because it depends on the number of pixels in the square and not all the pixels of the image [13]. The flowchart below is the Face Detection process on a human image.

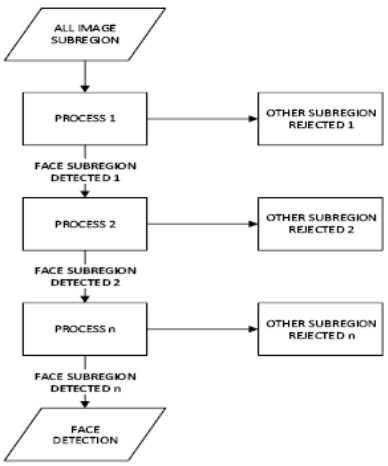

Figure 3. Face Detection Process.

D. Illumination Invariant Method

Different lighting conditions can create vital problems in object recognition systems because they can affect the appearance of facial images and increase variation between objects. The image below is an example of variations in lighting poses and facial expressions that can make it difficult for the system to recognize faces.

Figure 4. Lighting Pose Variations.

Illumination Invariant is a method used to improve the appearance of objects from light and shadow reflections. The formulation of the Illumination Invariant Model as below.

$$I_{x,y} = \frac{\{r_{x,y}+1\}}{\{k_{x,y}r_{x,y}+1\}} I^{*}_{x,y} \quad (1)$$

Where $I_{x,y}$ is the pixel intensity of the Illumination Invariant, $I^{*}_{x,y}$ is the raw image in pixels (x,y) and $K_{x,y}$ is the normalized label in the range 0 – 1 in the input image $I^{*}_{x,y}$ in pixels (x,y).

3. Result and Discussion

In this study, the camera position is placed on the path leading to a certain room. This system can monitor every object activity that enters the room area. The camera installation is placed in a series of room entry monitoring boxes. Before the object enters the room area, the object must release all the attributes that exist in the object's face area such as hat, mask and glasses. This aims to help the system to be more effective in identifying objects that enter the room area. The design of the monitoring box installation can be seen in Figure 5.

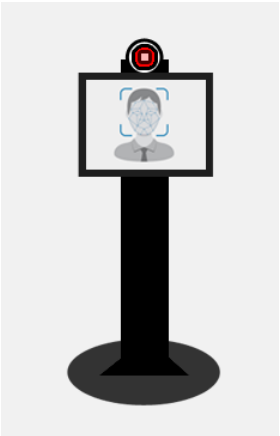

Figure 5. Monitoring Post Box Design.

A. 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

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not registered (the object is not recognized) then the system will notify the security officers [14]. In this study, the object detected was a human by using human facial features (Human Face Detection).

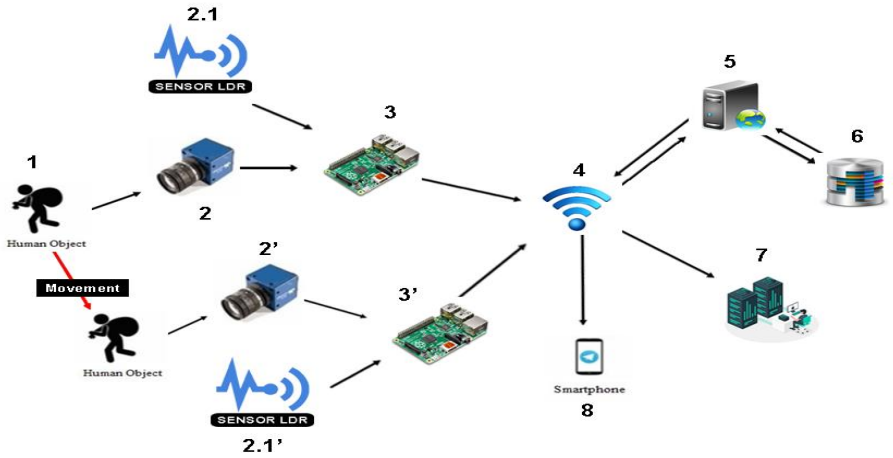

Figure 6. System Framework Model.

In the object detection process, the camera is used as an input medium to detect objects in the form of human faces. This camera is connected to the Raspberry Pi to perform the classification and identification process of captured objects. While the LDR sensor is used to detect the intensity of the lighting on the object's environment. In this system, more than one camera (multi-camera) is used which is 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 to indicate the location of the captured object. So for example an object is detected on one of the cameras in the system, then the object will be processed and identified information from the object. If the object is not recognized or does not exist in the data in the database, the system will track the object. If the object is detected again in a different camera, the system will record the time and place when the object passed the camera in that environment. The system will also notify the user of information about the existence of the object. The system framework for tracking can be seen in Figure 6.

The explanation of each process from the system framework model is as follows. Point 1 (Object) is a foreign object that enters the environment around the building. The foreign object referred is a human. Point 2 and Point 2' (Camera) are components used to capture data in the form of images from humans. These two components have the same function, the difference between each camera is only the location of the components, such as the first camera is in room A and the second camera is in room B. Point 2.1' (LDR Sensor) is a component used to capture lighting intensity data in the object's environment. Point 3 and Point 3' (Raspbarry Pi) are components for processing input obtained from cameras. Raspbarry Pi will process human images and determine human facial patterns for identification. These two components have the same function. The difference between each of these components is to capture input in the form of information on when and where the object was last detected. Look at Figure 6, for example an object is detected on the first camera and the object is not recognized by the system. Then this object moves to a second location (second camera), then the system will capture information when and where the object is located. Point 4 (Internet) is a component for sending data obtained from the camera to the server. The process of sending data using the HTTP protocol. Point 5 (Server) is a service for receiving and processing requests desired by the client. This component will compare the input data with the registered human face database for object identification process. Point 6 (Database) is a component for storing registered face images and detected object history. Point 7 (Website Dashboard) is a component for displaying and managing human image data. Point 8 (Notifications) is a component for sending and receiving notifications from the system to provide information whether the object is recognized or not.

B. Detection System Flowchart

The flowchart below is the process of the system performing the detection stages of objects captured by the camera.

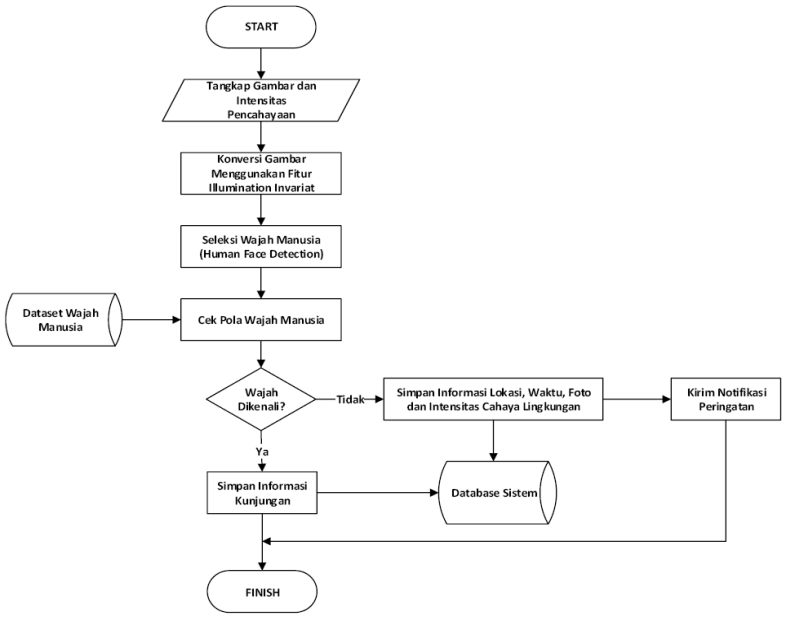

Figure 7. Detection System Flowchart.

First of all, the camera will capture objects, namely humans, in the environment. Next, the system will convert the captured object using the Illumination Invariant method for the conversion process to lighting in the object's environment. This process aims to eliminate the influence of lighting on the object's environment, so that objects can be detected by the system. After that the system will select the detected object and take the facial pattern of the human object. This human face pattern will be matched to the human face database for the identification process of object information. If the human object is recognized, the system will store the information in the database. If it is not recognized, the system will send a warning notification to the owner or security officer

C. Invariant Illumination Experiment for Face Recognition

This study applies the Illumination Invariant method to process images so that the system can detect objects in the image even though the lighting changes in the object's environment. Illumination Invariant method is used to solve lighting problems based on these 5 types of lighting. This study uses about 50 samples of human face data for each human object. This human face data is used for the process of identifying objects or humans detected by the system. Every human object has a lot of facial data which aims to assist the system in increasing the accuracy of the identification of detected human object information. Every human information is stored in the system database. The design of the image lighting handling process so that it can be detected by the system can be seen in the image below.

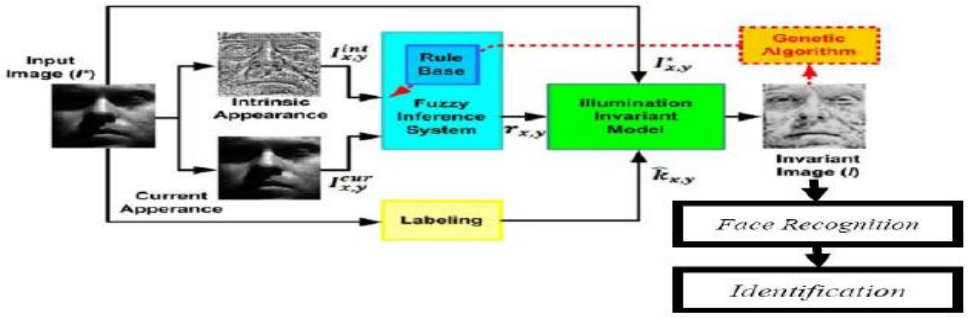

Figure 8. Illumination Invariant Identification Model.

The object detection system testing process is carried out using 25 human data. 15 human data have been registered in the system and 10 other human data have not been registered in the system. In the process of testing these 25 human data through the camera, we will calculate the percentage of the system's success in identifying the 25 human data.

D. Light Intensity Experiment for Face detection

In this study, the human face recognition system (Human Face Detection) was carried out using the Haar Cascade Classifier algorithm. This algorithm has the advantage of very fast computation, because it depends on the number of pixels in a square, not every pixel of an image [13]. This study uses an LDR (Light Dependent Sensor) sensor to calculate the intensity of lighting in the environment. This light sensor is used to identify 5 types of lighting from an object in a certain environment such as normal lighting, low lighting, backlighting, direct lighting and dark.

The grouping of 5 types of lighting of an object captured in this particular environment is as follows [11]. Normal lighting is an image condition with sufficient lighting in the room. This condition is measured in lux meter in the range of 100 to 250 lux. Low lighting is an image condition with less lighting, the details are still clearly visible from the window with a light source such as sunlight. This condition is measured in lux meter in the range of 30 to 75 lux. Backlighting is a condition when the light source is behind the object. This condition is measured in lux meter in the range of 75 to 100 lux. Direct lighting is lighting from many light sources and is bright enough. This condition is measured with a lux meter in the range >250 lux. Dark is a low lighting where the details of the image can still be seen from the light source of the room. This condition is measured with a lux meter in the range <30 lux.

Light sensitivity testing is carried out using 5 conditions where each condition uses 5 human data that have been registered in the system. This study tested each of these objects can be detected with these 5 specified lighting conditions.

E. Experiment for System Notification

To give a warning message about the condition of the building to the security, this study uses the Telegram application which is applied to the Raspberry Pi. Telegram is a free and open source social media application that provides chat and bot services [15]. This research uses Telegram bot and email to automate the sending of captured images to owners and security personnel as notifications. The test in this study uses 20 human data where 10 human data have been registered in the system while 10 other human data have not been registered in the system. Every object will pass through the camera area and the system will detect every object that passes through the camera. At this stage we will see the response of the system to the object. If the object is recognized, the system will display information about the object. Meanwhile, if the object is not recognized or not registered with the system, the system will send a warning notification to the owner and security personnel. The next stage of this unregistered object will enter the second camera area. At this stage we check whether the system can provide information on the location of the object from the first point to the second point.

F. System Experiment Results

This research is built on a web-based basis using 3 different programming languages, namely Python, Javascript and PHP. Each programming language has different responsibilities and relates to each other using API (Application Programming Interface) concept. Python programming is used to process human image data captured by the camera. The stages of this process include Human Face Detection, Dataset Training and Human Face Identification captured by the camera via Raspberry Pi. Javascript programming is used to send, receive and process data from Raspberry Pi to the user on the Website. PHP programming is used for the stages of making the layout and functions of the website such as displaying monitoring results and processing data from the database.

In this study using Python Flask technology which serves to send the results of data processing from each component connected to the Raspberry Pi. The components used in this study can be seen in Table 1.

Table 1. System Component Details

No	Component	Unit
1	Raspberry Pi 4 RAM 4GB	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	Kapasitor	1 Unit

Before accessing the system features, the user must login to the system first. In this study, there are 3 types of user levels, namely Super Admin, Admin and General. Each level has a difference in the number of menus that can be accessed by the user. Super Admin level has full responsibility for systems such as user account management, member management, detection report management and lighting intensity criteria management. The Admin level has the responsibility to manage member data, such as registering datasets and training human face datasets. General level has responsibility for monitoring detected objects and taking action on detected objects. After the login process is successful, the user can see the system display based on the user's access level. As can be seen in Figure 9, the user can monitor the detected object information in real time. The results of this object information are obtained based on human facial feature data stored in the database.

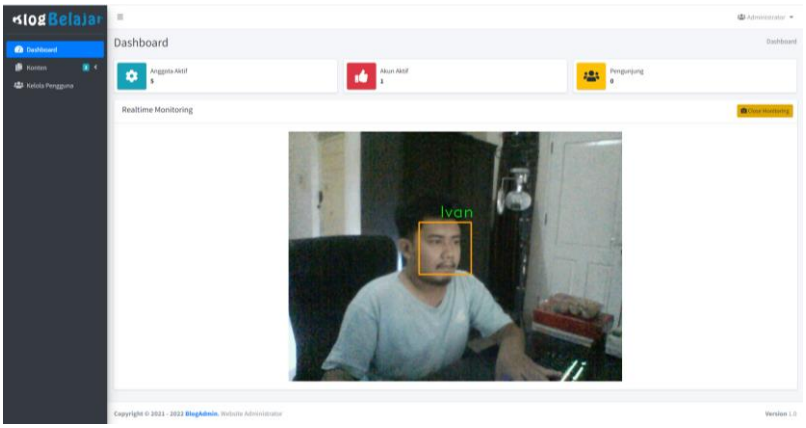

Figure 9. Dashboard Real time Monitoring.

Member registration process can be done by accessing the member menu. As can be seen in Figure 10, there are several features in member menu display such as displaying member data, adding member data, updating member data, adding face datasets and training datasets. In the member view there is a status column that serves to display object information on the system. If the status is “AKTIF”, the system can display information on the object, while if the status is “DRAFT”, the system cannot recognize and display information about the detected object. 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 image are saved into a XML file which is used for the object identification process based on the human face.

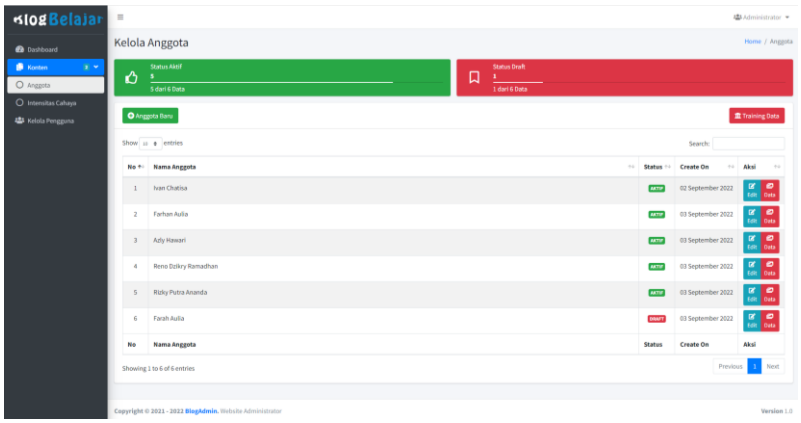

Figure 10. Member List and Training Data.

The human face data registration process is carried out based on the selected member data. The human face data registration process can be done by activating the camera on the system and wait until the system detects human facial features. The detected human face data is saved into server folder based on the data format from “FormatFile” column. This data format is created automatically when adding new member data.

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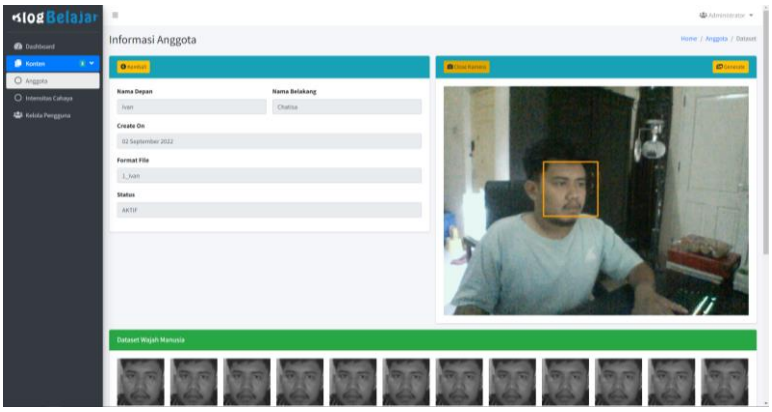

Figure 11. Dataset Registration Page.

In this study, 50 samples of human face image data were used for each registered object which aims to assist the system in making identification more effective. The example images from our dataset sample in the database we have created are shown in Figure 12.

Figure 12. Human Face Dataset.

As can be seen in Figure 12, the system only retrieves and stores human facial features in the dataset folder on the server. This face image is grouped based on the name and id of the registered object. 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. An example of an image that has been registered on our system is shown in Figure 13.

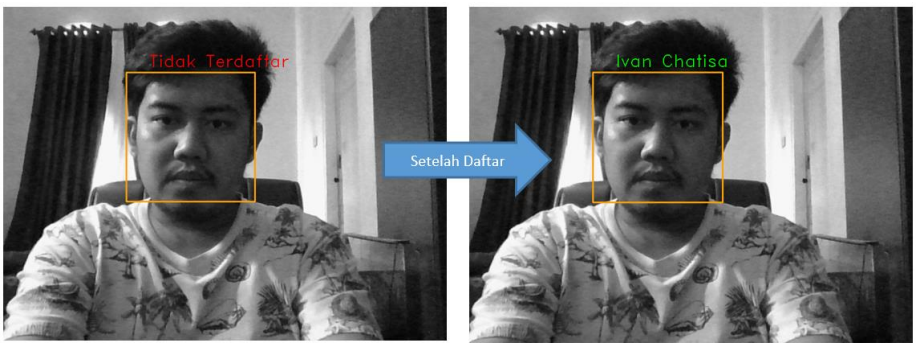

Figure 13. Human Face Identification.

In certain lighting conditions, the system has difficulty in detecting human facial features in the environment. Look at Figure 14. The system has difficulty in detecting the human face. The human face object in the image has less lighting so the system can only detect 1 human facial feature.

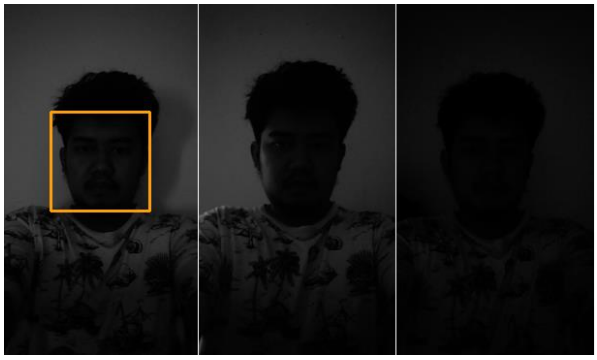

Figure 14. Human Face Based on Light Condition.

Illumination Invariant model that is used to assist system performance in detecting human objects in the environment when there is a lighting problem there. Look at Figure 15, we can see that the system has successfully detected all human facial features on the object images. The process of converting the image into the Illumination invariant model is done by changing the entire RGB value of the existing image pixels so that the image object of the human face can be detected.

Figure 15. Implementation of Illumination Invariant Model.

4.Conclusions

Based on the results of research conducted, the system can assist owners and security officers in monitoring and identifying objects that are in the environment around the building or room. Based on the results of previous studies, it can be concluded that this system can assist owners and security officers in detecting objects (humans) captured by cameras based on human facial recognition features even though there is a change in the intensity of lighting in the object's environment using the Illumination Invariant method. In this study, the human face recognition system (Human Face Detection) was carried out using the Haar Cascade Classifier algorithm. This algorithm has the advantages of being computationally very fast, because it depends on the number of pixels in a square, not every pixel of an image. This study uses about 50 samples of human face data for each human object. This human face data is used for the process of identifying objects or humans detected by the system. The more samples of human face data are taken, the system will be more accurate in identifying the detected human information.

Acknowledgement

Finally, I would like to thank all those who played a role in supporting the success of this research. This paper is far from perfect, but it is hoped that it will be useful for readers, for that the author needs criticism and suggestions from readers so that this paper is better in the future.

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