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Robot Vision Pattern Recognition of the Eye and Nose Using the Local Binary Pattern Histogram Method

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ABSTRACT

The local binary pattern histogram (LBPH) algorithm is a computer technique that can detect a person's face based on information stored in a database (trained model). In this research, the LBPH approach is applied for face recognition combined with the embedded platform on the actuator system. This application will be incorporated into the robot's control and processing center, which consists of a Raspberry Pi and Arduino board. The robot will be equipped with a program that can identify and recognize a human's face based on information from the person's eyes and nose. Based on the results of facial feature identification testing, the eyes were recognized 131 times (87.33%), and the nose 133 times (88.67%) out of 150 image data samples. From the test results, an accuracy rate of 88%, the partition rate of 95.23%, the recall of 30%, the specificity of 99%, and the F1-Score of 57.5% were obtained.

Keywords: The local binary pattern histogram, face recognition, embedded platform, robot's control, facial feature identification.

1. INTRODUCTION

Humans are social creatures who live in communities or groups. To identify a person, distinguishing qualities or attributes are used as a differentiator or identification [1][2][3]. A face is often used to describe a person. However, additional features such as hair color, eyes, eyebrows, nose, mouth, lips, teeth, hands, height, and even gait are also widely used. Seeing is a common approach to recognizing a person. Seeing is defined as capturing a visual image of an object [4][5], to search for features of the object recorded by vision after the image is acquired. After obtaining these qualities, then identifying the object and its attributes to determine what the object is. These steps are part of the object data processing of computer vision [6][7].

Computer vision is the application of these methods to computers. A camera is a technology used to view visual objects. They come in many shapes and sizes. As a result, the results obtained by these tools vary. This difference is due to the amount of resolution they can provide. The greater the camera resolution, the clearer the capture [8][9]. However, this affects the size of the image after it is captured. One application of camera capture is for the process of facial pattern recognition [10][11]. Face recognition is a computer technique that can detect a person's face based on information stored in a computer database (trained model). In previous research [12][13], Face detection is a stage before face recognition. At this stage, visual objects will be localized to obtain information that will later be needed at the face recognition stage [14][15][16]. The detection process utilizes the eyes, nose, ears, or other parts of the eye, as information that the computer will use to recognize humans.

In this research, the Local Binary Pattern Histogram (LBPH) approach is applied for face recognition [17][18][19] combined with the embedded platform [20][21][22] on the actuator system. The facial features used in this research analysis are the eyes and mouth. This is because this part is the dominant feature in facial features. The approach used is to convert the texture of the image into a binary value. The value shows some of the pixels that form a circle, with the center pixel serving as a reference or threshold [23][24]. In this research, the actuator system is a simple robot vision [23][25], which is used to move the camera to the ideal position to capture the facial object. The robot will be equipped with a program that can identify and recognize a person's face based on information from the person's eyes and nose. This application will be incorporated into the robot's control and processing center, which consists of a Raspberry Pi and Arduino board.

2. DESIGN AND METHOD

This section will explain the design of systems (hardware and software), and the design of the research methods used. This aims to make this research more structured in its delivery. The hardware is a robot arm that functions as a vision robot, which consists of a controller and actuator system. The software is divided into two parts, namely software on image processing and on robot vision.

2.1 SYSTEM DESIGN

The initial stage of this system is to collect datasets for face, nose, and eye identification. The next step is to collect datasets to recognize a person's face. Once all the data is collected, training is done to create a model for face detection and identification (in this study in xml and yml formats). As the camera continuously collects images, they are generally color images of the RGB type. Since the detection technique the author uses only supports grayscale images, the images will be converted to grayscale. After that, the image will be converted into an integral image. The image will then be examined with Haar features and a cascade classifier procedure will be used to find the face, eye, and nose features.

After the detection procedure, the device will provide information about the eyes and nose. This data will be used in the following procedure, face recognition using the local binary pattern histogram technique. This information will be compared with the database or model created in the previous procedure. After recognizing the face, the system will extract the coordinates of the face and its midpoint. The data is then translated and used as a reference for the movement of servo and DC motors on the vision robot. Figure 1, is a picture of the system design.

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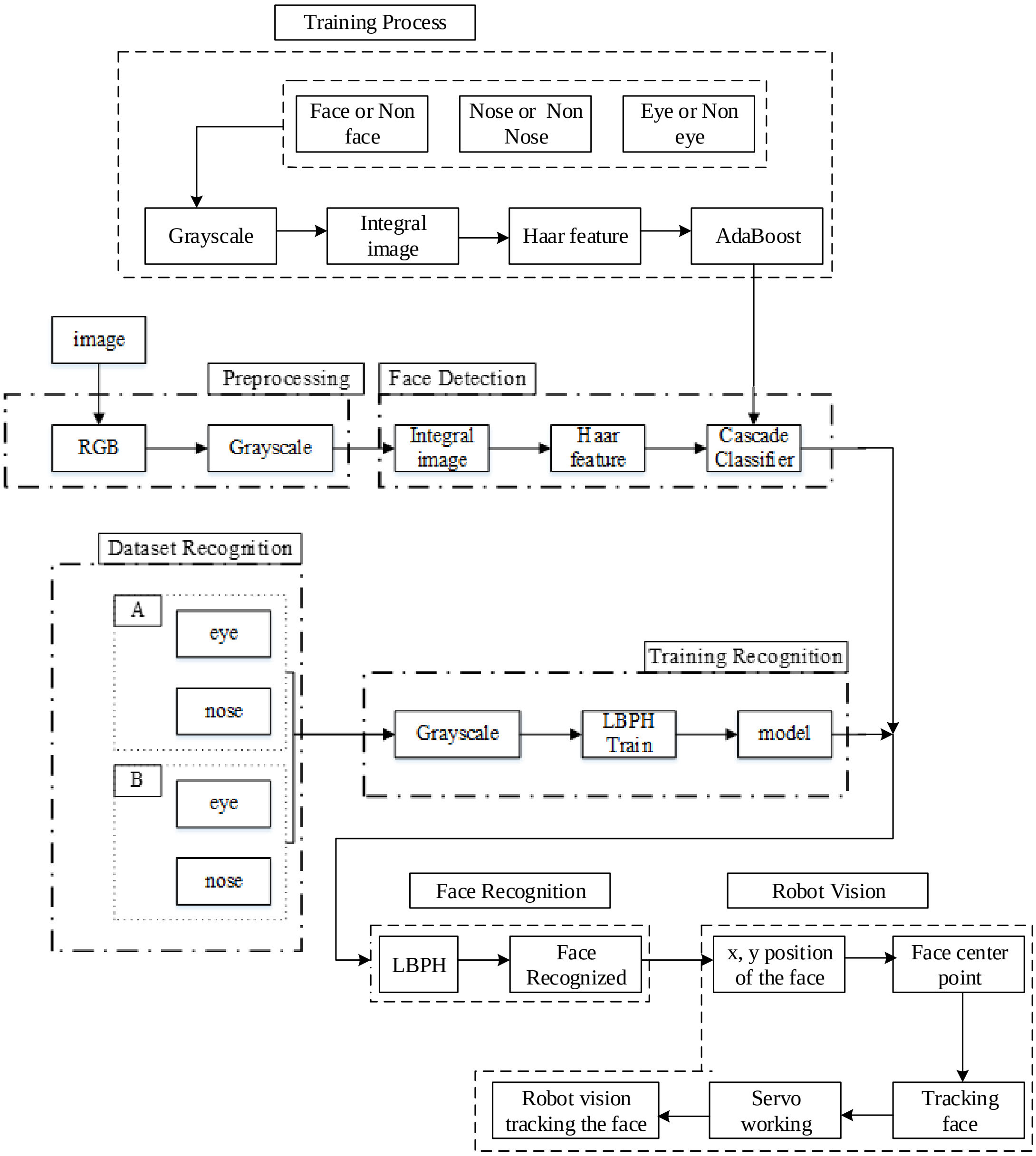

FIGURE 1. Diagram of the system design

2.2 HARDWARE MECHANISM DESIGN

The system utilizes many critical components in its hardware design to ensure effective system operation. The hardware components used are 1 Raspberry Pi, 1 Arduino Uno, 1 Pi Camera, 3 wheels, 2 DC motors, 1 motor driver, 2 servos, and 1 Lipo Battery included. All these components are designed to form a vision robot, which can be seen in Figure 2. In Figure 2 shows how all these components are arranged. The mobility of the vision robot is highly dependent on the facial image captured by the camera. As shown in the previous system block diagram in Figure 1, the image will be the reference and input for the hardware to move.

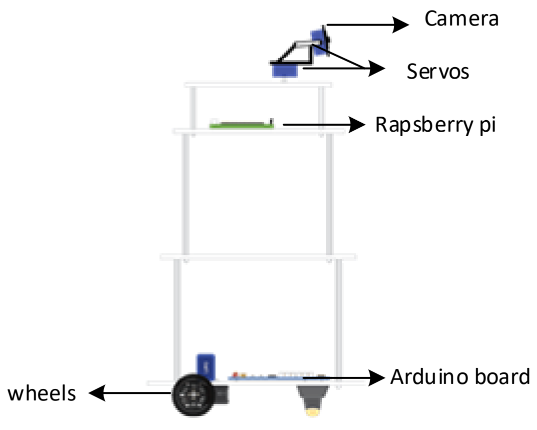

FIGURE 2. Mechanism vision robot design

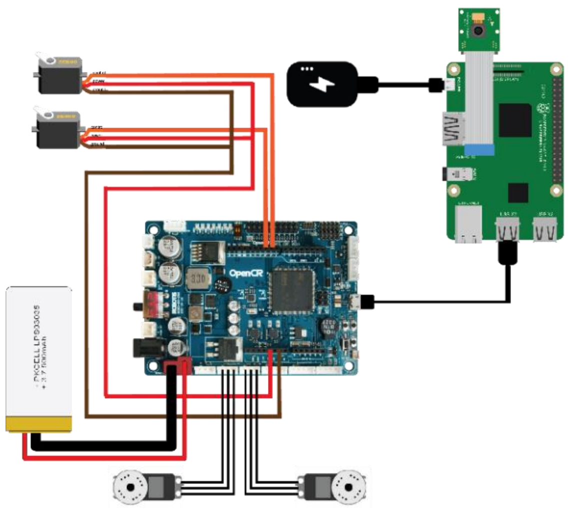

FIGURE 3. Wiring Diagram design

This vision robot will be one meter tall with a radius of 40 cm. The upper frame is used to place the camera and servo motor. On the second level, it is used to place the raspberry pi, while at the bottom level on the frame, it is used to place the microcontroller board, motor driver, dc motor, and wheels. The camera will then be moved horizontally and vertically using two servo motors which are also connected to the ATMega Microcontroller. A lipo battery will be used to power the mobile robot. Figure 3, is a vision robot wiring diagram. Raspberry Pi 3 B+, a mini Computer, will be used for image processing (Face Detection and Recognition). As the control of the movement of the vision robot actuator, an ATMega microcontroller is used. Two DC motors attached to the microcontroller board are used to drive the vision robot, with the direction of moving forward, left, or right.

2.3 ALGORITHM DESIGN

This system's software is written in Python, which is compatible with the Raspberry Pi system's requirements. The Local Binary Patterns Histograms approach is utilized for face identification in the design of face detection utilizing the Viola-Jones algorithm. On this system, software is designed by first creating a flowchart,

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and then the program is created by following the flowchart, as illustrated in Figure 4 below.

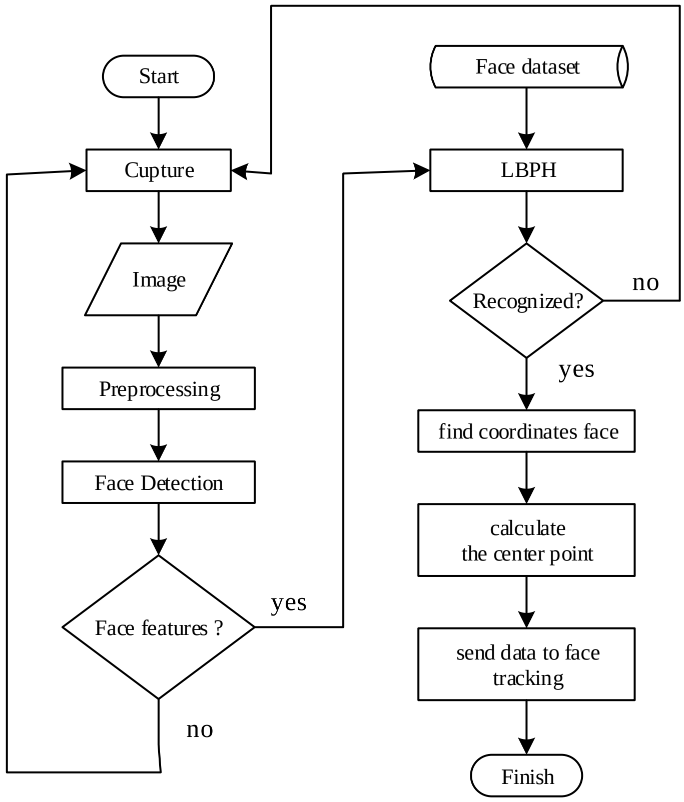

FIGURE 4. Flowchart system

Preprocessing is the first stage of image processing before the face detection method is applied. This is required since this method only handles grayscale pictures, although acquired photos are often RGB. The face detection method in this system corresponds to Viola-Jones' technique. Based on this, this algorithm can be divided into several processes, namely converting a gray image into an integral image, determining the Haar features in the image, determining the threshold or weight of each feature through an Adaboost classifier - this feature or weak classifier will be combined to become a strong classifier -, and dividing the weak classifier into several stages via a cascade classifier process. The picture was transformed to grayscale in the preceding phase.

Following the face detection phase, the picture that is successfully identified in the shape of a face, eyes, and nose will proceed to the face recognition process. The Local Binary Pattern Histogram technique will be used to match the detected picture to the database (model) in face recognition. The pixel values of the preceding gray image will transform to a histogram image after this procedure and computation. Figure 5 shows a depiction of the changes in a picture following the local binary pattern procedure.

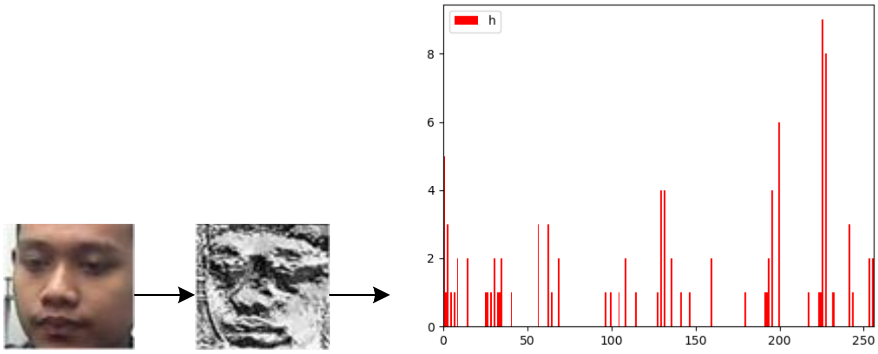

FIGURE 5. The changes in a picture following the local binary pattern procedure

The last step is the system will determine the position of the face based on the x and y coordinates of the face once it has been successfully located, identified, and recognized in an image acquired from one of the camera frames. The system will then compute the center point of the face area. This information will be transmitted to the microprocessor, which will attempt to match the center point of the face region with the center point of the camera frame. This alignment step moves the actuator slowly and is based on the distance calculation received from the prior system data. The actuator's movement has a large influence on the movement of the recognized face.

3. RESULTS AND DISCUSSION

Hardware and software testers used embedded platforms in this research. All the image processing experiments were conducted using a raspberry pi mini computer and the robot vision process using an arduino. Meanwhile, the light intensity is ignored in facial image capture.

The Arduino IDE is used in this test to build and upload programs to the microcontroller. This experiment employs two servo motors, myservo is utilized as an x coordinate plane servo configuration, while myservo2 is used as a y coordinate plane servo configuration. The researchers set the beginning position of the x servo to 90 degrees and the y servo to 80 degrees in the study. In this software, input refers to data collected by serial communication between the microcontroller and the Raspberry Pi. The received bit data will be transformed into string data. The data in the string will be compared. The string data will be compared as follows throughout the comparison procedure: * '5' causes servo x to travel to the left by 5 degrees; * '6' causes the x servo to move to the right by 5 degrees. * '7' causes the y servo to move up by 5 degrees; * '8' causes the y servo to go down by 5 degrees.

Dxl is used as a configuration in the software to move the robot's dc motor. This dc motor will move after 30 servo x 120 degrees is reached. This dc motor's movement correlates to the movement of servo x (if the dc motor fits the conditions for movement and servo x moves to the left, the right wheel moves forward). If the dc motor passes the conditions for moving and servoing. Then, proceed with the DC motor testing. Figure 4.4 depicts the usage of two DC motors in this test. The software code utilized in this investigation is shown in Figure 4.5. The input here is collected through serial communication data between the CPU and the Raspberry Pi, as explained in the preceding section. In addition, dxl is the configuration utilized to activate and run the dc motor. The following is a comparison of the input data (input). * '1' then the dc

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motor 1 (left) will go ahead, causing the robot to rotate to the right. * '2' causes dc motors 1 and 2 to drive ahead, causing the robot to move forward. * '3' causes dc motors 1 and 2 to drive backward, causing the robot to move backward. * '4' then dc motors 1 and 2 do not move, resulting in the robot remaining motionless.

TABLE 1.
The results of this face detection test

No.	face position on the camera	Experiment (sample)	Face Detection	image
1	front	30 times	28 times	
2	left	30 time	25 times	
3	right	30 times	27 times	
4	Face facing up to of the camera	30 times	24 times	
5	Face facing down of the camera	30 times	24 times	
	Total	150 time	128 times	

The next step is to detect faces. The results of this face detection test can be seen in Table 1. The cameras utilized in this section vary, including the Pi Camera, Webcam Camera, and Smartphone Camera. Each camera has a different resolution. However, this has no bearing on data collection for this system since we have set a restriction on the width of the detectable face frame, which is 120 to 140 pixels wide and height. In this test, the Viola-Jones algorithm detects faces with an accuracy of 88%. The next test is to identify the eyes and nose. Faces recognized using the Viola-Jones method will be identified with facial characteristics, notably eyes and nose, using the same technique in this test. The results of face feature identification tests are shown in Table 2. The author uses picture data gathered earlier via the face detection method in this test. The picture data is then used to identify the eyes and nose. According to the image data, the eyes were recognized 131 times (87.33%), and the nose 133 times (88.67%) of the 150 image data samples.

TABLE 2.
Test result of eye and nose identification

No.	face position on the camera	Face identification			
		Eye (sample)	Detection (true)	Nose (sampel)	Detection (true)
1	front		28		28

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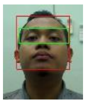
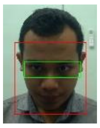
2	left		25		26
3	right		25		27
4	Face facing up to of the camera		28		26
5	Face facing down of the camera		25		26
Total		150	131 times	150	133 times

Face recognition was tested using the Local Binary Pattern Histogram technique, which was implemented in code using an open source library called OpenCV. The author employs two classes of faces in this testing method, namely the faces of researchers and other persons (unknown), each of which has 200 face picture data, as shown in Figure 6. The data is subsequently used in the testing and the training step.

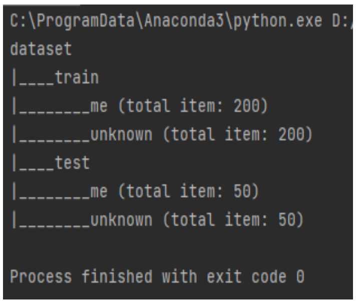


FIGURE 6. Testing and training data

Following training, two face recognition models based on the LBPH algorithm are generated. This facial recognition model includes recognition of the eyes and nose. The accuracy, precision, recall, specificity, and F1-Score values were determined using test data from two classes of 50 face picture data each. This training, in particular, yields the confusion matrix of the model's overall performance. From the test results, the accuracy rate of 88%, the partition rate of 95.23%, the recall of 30%, the specificity of 99%, and the F1-Score of 57.5% were obtained.

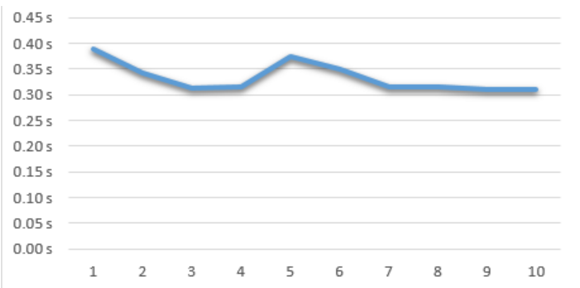


FIGURE 7. Time execution of face recognition

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Figure 7, shows data from the face recognition procedure repeated ten times using eye and nose data from the preceding iteration. This computation begins with the collected eye and nose data and then makes predictions on each eye and nose until the software gives the projected outcomes, either as expected or not. The identification process for the eyes and nose is carried out separately, yielding two values. If both values return the same value and are the return value of the owner's name, the face is identified.

TABLE 3.
Robot movement testing

No.	Face (pixel)			Servo (^{o})		DC Motor	Result	
	x	y	w	x	y		x	y
1	-	-	141	90	100	forward	-	-
2	-	-	194	90	100	backward	-	-
3	308	258	165	90	100	stop	center	center
4	242	248	163	85	100	stop	center	center
5	381	254	166	95	100	stop	left	center
6	324	293	163	90	95	stop	center	down
7	318	187	164	90	105	stop	center	up

Two face recognition models that implement the LBPH method were previously constructed and implemented in the robot vision for the face tracking test. The facial recognition procedure will be carried out using these models. This technique will provide the robot with the location of the face so that the robot may move in accordance with the state of the face. Data from this test are gathered in the form of logs (records) of robot actions that occur during the process of preparation, detection, identification, and robot movement toward the face. The robot behavior derived depending on face position and face width (in pixels) is shown in Table 3. Based on this information, the servo, which consists of the horizontal plane (x) and the vertical plane (y), will function in an attempt to center the face in the center. Similarly, the dc motor operates on the width of the resulting face box (w).

According to Table 3, the dc motor will drive forward if the detected box width is 141 pixels and backward if the detected box width is 191 pixels, but it will halt if the detected box width is 163 to 166 pixels. If the face position (x) is less than 308 pixels, the horizontal servo (x) will move to the right; otherwise, it will move to the left. If the face position (y) is less than 248 pixels, the vertical servo (y) will move up; otherwise, it will move down.

4. CONCLUSION

The faces recognized using the Viola-Jones method will have their facial characteristics, especially the eyes, and nose, identified using the same technique in this test. Based on the results of facial feature identification testing, the eyes were recognized 131 times (87.33%), and the nose 133 times (88.67%) out of 150 image data samples. The face recognition model based on the LBPH algorithm in this study produces Accuracy, precision, recall, specificity, and F1-Score values determined using test data from two classes of 50 face image data each. From the test results, an accuracy rate of 88%, partition rate of 95.23%, recall of 30%, specificity of 99%, and F1-Score of 57.5% were obtained. Then the test results of tracking face on robot vision, the dc motor will move forward if 141 pixels are detected and backward if 191 pixels are detected, but will stop if 163 to 166 pixels are detected. If the face position (x) is less than 308 pixels, the horizontal servo (x) will move to the right; otherwise, the servo will move to the left. If the face position (y) is less than 248 pixels, the vertical servo (y) will move up; otherwise, it will move down.

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