FACIAL RECOGNITION PERFORMANCE BASED ON THE LIGHTING SET-UP MODELS APPLIED TO HOME SECURITY DOOR ACCESS USING PRINCIPAL COMPONENT ANALYSIS AND RASPBERRY PI CONTROLLER

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ABSTRACT

Security protects individuals, data, and properties together with its corresponding measures in line to the emerging application of technology like the face recognition. This study aims to test the effects of lighting models on the recognition performance along with different angles and distance applied for door access by providing signals to Raspberry PI Controller. The study built 240 training datasets and applied the best algorithms – Haar-Cascade for face detection, Principal Component Analysis for extraction, Support Vector Machine for classification and Euclidean Distance for recognition. The study tested the model with five subjects which then marked a score of 100% for fluorescent light, 74.65 % for candle light, and 88 % for flashlight with an average percentage accuracy of 89.5. The results implied an adverse recognition result influenced by the lighting conditions, the face angle positions and distance issues.

KEYWORDS – Security, facial recognition, facial detection, lighting model, IOT

INTRODUCTION

Security is everyone's concern with the aim to protect people from harm, violence, thieves, attackers, criminals, potential damages, not just to properties, and information but also to human lives [1][2], [3]. This concern has been addressed due to the advancement of technology in which several tools and techniques that are made to be readily available and carefully studied to ease people worries [4]. Some of the tools and techniques that are being used for security include: the CCTV camera to capture object accompanied event or scenario [5], sensors for detecting an object, password in accessing account, RFID technology, voice recognition, finger printing scanner, iris detection and gestures – processes used for detecting the identify of a person [6], [7], [8]. In addition, still the traditional type of security, people still use things like the padlocks, deadbolts, knob locks and levers [9]. However, due to the increasing rate of crimes recorded by the PNP's Directorate for Investigation and Detective Management (DIDM), there was a total of 100,668 index crimes noted from January to November 2017. In particular, the thefts noted were 32,356 in year 2017. Robbery incidents also recorded 15,083 in 2017 – registering a 23.6% decline. Rape incidents on the other hand, logged 7,584 in the same year. Homicide is the only index crime which increased by 14.6% in 2017. Noticeably, the 2,082 killings recorded in 2016 leveled up to 2,386 in 2017. Consequently, murder incidents with 8,239 in number tallied between January and November 2017. The cited incidents are the main reasons why security solution evolved by combining physical devices and software solutions to further strengthen the security according to the specific purpose it serves. Likewise, ensuring that intruders and criminals might have trouble to make entry or to steal information access. Facial recognition is widely common among the emerging technology that is used for security that is why there are several studies were conducted on this specific area. The existing studies used various approaches and methods to achieve high accuracy results. Nevertheless, through the fourth-generation industry, facial recognition became usable and effective in performing with digital and human features, provided the unique attributes of each individual. The said features are then being used when it comes to security that relates to physical characteristics of a person and nowadays, it is receiving much attention due to its vast application in surveillance and crime prevention [10].

LITERATURE REVIEW

Several studies were carefully reviewed to identify opportunities for improvement and new ideas to conduct an experiment in the aim of strengthening the recognition performance rates. One of the studies revealed that with low resolution, out-of-focus, and blurring of images, the performance rate of the recognition may be greatly affected [11]. Another approach done is the use of Haar-Cascade for face detection, Log Gabor for feature extraction, and the Principal Component Analysis together with the Euclidean-Based Distance – the study accumulated 88% for the natural lighting due to light turned to be full on the face, and the top; the left light factors on the other hand, resulted to a 72% accuracy while bottom and right light angles marked a rate of 79% which recorded an over-all result of 74% - 79%. Moreover, according to several studies, the lighting condition and posed alignment of the face significantly affect the recognition results [12]. A single straight-posed face and tilted face without any user interaction through the implementation of inclination of less than 90 degrees recorded 92% accuracy and 85% for images containing a tilted face using the 100 sample images. With this, the study recommended to reduce false detection rate in dealing with images through a more complex background [13]. Furthermore, a study using PCA and SVM under 13 different lighting condition with applied methods in 34 subjects marked an average recognition rate of 37.3 to 44% while the other methods using the 10, 20 and 40 samples marked an average accuracy of 89.2%, 83% and 86% [14]. A separate study on frontal view with 27 individuals marked a score of 100% [15]. Consequently, a study which used Raspberry Pi model three (3) specifically for door access from an input frontal view face signal noted an accuracy rate of 70%. Among the aforementioned studies, this study attempted to conduct new experiment using different lighting conditions such as the fluorescent light, candle light and flashlight. In line with that said conditions, the use of flashlight and candle lights were not yet tested in all the available and existing studies. The used of flashlight was consider as this is used to check and recognize a person especially at night while the used of candle light is being considered as the last resort of people in the absence of battery and electricity – a completely acceptable circumstance since the technology is still designed to capture an object even the electricity is down. Also, the variation angles from 0% to 45% degrees in an upward and downward angle, and left and right position of the face were utilized – to provide dataset variations for the machine to learn and thus, increase the detection accuracy. Moreover, the face recognition provides an input signal to Raspberry PI controller to unlock the door only for those authorized and registered face images in the training datasets.

Research Objectives

- To build the datasets in different angles and pose variation.
- To apply the Haar-Cascade Classifier API for face detection, Support Vector Machine for classification, Principal Component Analysis for extraction and Euclidean and Eigen-API for face recognition.
- To test the recognition accuracy of the prototype model and implement the said model for the door locking system.

Theoretical Framework

Principal Components Analysis Algorithm (PCA) is widely used for it optimizes the features' space. A lot of PCA Algorithm application were also being used in different studies [16] – PCA Algorithm for Facial Recognition with information theory approach on coding and decoding of the face images turned in a rate of 99.50% recognition. Another is based on [17] the application of PCA for Fingerprints Recognition in providing access control – with an accuracy rate greater than 80%. PCA Algorithm was also applied to the Speech and emotion Recognition in several studies [18]. PCA, applied together with the MFCC gave the accuracy rate of 69.95 % when 15 Eigen values are selected; 57.61% for 20 values, and 49.38% for 25 Eigen values.

Support Vector Machine (SVM) is consisted of kernel functions with vast applications in different fields. According to [19], SVM can be used in predicting stock price direction which resulted towards an 80% accuracy. Also, there were researches about SVM that was mainly utilized on image processing. In fact, based on the study of [20], the researchers tried to use many machine learning frameworks to recognize the stop sign images but SVM outperformed all the others for it resulted to a 90% accuracy rate. SVM is also being used in Medical fields like the study of [21] where the techniques included a decision support system with Artificial Intelligence (AI) to help doctors identify the diagnosis of chest diseases – SVM noted a better result of 97.23% compared to ASVM which only resulted to a rate of 92.63%.

Haar-Cascade Classifier is also being widely used nowadays. This method is being applied in cellphones, cameras, and other security measurements. Object detection is the main features of this classifier but as year passed, Haar can also be used in terms of facial detection like in the study done by [22] where the facial features of the user were utilized and analyzed – resulted to a 98.83% accuracy rate while in the study of [23], the Haar classifier was applied through

the use of hand gesture recognition with the application of AdaBoost Learning algorithm which turned in a 90% accuracy rate. Since Haar was mainly developed for object detection, there were also several studies in which it was used in many different aspects. According to [24], Haar can be applied in real-time video streaming just as what their study focused on. Through the use of moving vehicle that was tested in different scenarios, it came up with the result of 94%, 92%, and 87%.

METHODOLOGY

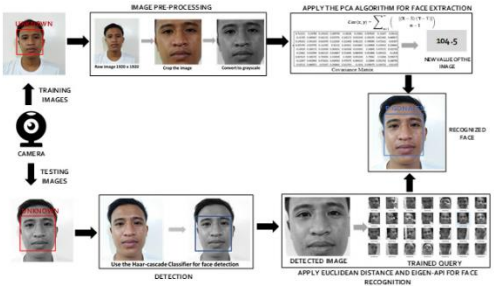

Figure 1: Conceptual Framework

Figure 1 shows the flow of the prototype model in this study where the model captures an image in a real-time video set-up using 13 megapixel-camera. The face image was detected using Haar Cascade Classifier then the image was then resized to 300x300 and converted into grayscale. After which, to optimize the search space, Principal Component Analysis (PCA) was used to reduce the dimension of the image by using the formula of the covariance matrix. It allows the model to get the weighted vector of each image so that it can represent the new image with a new value. Once the extracted images were fed in the rapid miner to test the accuracy, the Euclidean distance and Eigen-API was used – the image was utilized in identifying the distance between the inputted weight vector and weight vectors of the training sets. The model analyzed the data in the database and when the nearest value was matched, it would automatically place the name of the subject on the screen.

Figure 2: Training Datasets

Building datasets: The figure shows and represents the building of the training datasets in this study. A smartphone with a 13megapixel-camera was used to capture the 10 face-image subjects in different lighting conditions such as fluorescent, flashlight and candle lights. Angle variations of 45% up and downward and left and right angle and distances of 1 meter, 2 meters and 3 meters. To sum up, the study accumulated 240 trained datasets. The variations of datasets caused the increase of the detection accuracy.

Feature Extraction: The images were pre-processed by converting the RGB to Grayscale to 300x300 and optimized the memory space for the facial features. PCA was applied to optimize the search space which produced the eigenvector of an image using a covariance matrix.

Features Classification: Support vector machine was operated using Radial Basic Function to classify the features. The study fed the data to the Rapid Miner to build the model and test the accuracy of the face features.

Figure 3: Face Detection

Face Detection: The study used Haar-Cascade Classifier Algorithm to detect the face images captured using OpenCV. The face images were pre-processed in terms of dimension reduction and conversion of the image type to optimize the search space.

Figure 4: Face Recognition

Face Recognition: The eigenvector of the face image was compared to the training datasets – the closest or the nearest match to successfully perform the recognition. This gave a signal to servo motor, spinning 90 degrees to unlock and lock the door.

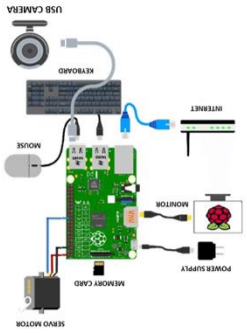

Figure 5: Architecture

*Prototype Architecture**:*** This figure shows the prototype architecture that used the camera to capture images, monitor and connect to view the interface of the prototype. The memory module which held the images' training datasets, the access log-in report, the internet module for monitoring purposes, and other peripheral devices which would be used for interaction. The servo motor was designed for the rotation in unlocking and locking the prototype door. Furthermore, the Raspberry PI Controller device allowed all the components connected together to communicate with the prototype model in order to achieve the objectives of the study to utilize the face image for door unlocking and locking option.

Prototype Model: The model used the tools for the realization of the study such as OpenCV as the main open source library compiling the programming functions for face detection, and Haar-Cascade Classifier for training and detecting face image. Visual Studio also served as the programming platform while the Principal Component Analysis focused on face extraction. C# programming was then utilized to make the functions of the system, Raspberry Pi Model with Raspberry PI OS was used as the microcontroller for the door-access. The prototype was placed beside the door in a 1.5 from the ground and connected to a magnetic lock on the top of the door.

$$\text{NR} = \frac{NU}{NS} * 100 - 100$$

Metrics of evaluation: The study tested the prototype using the formula above where the number of recognitions would be calculated by the number of unrecognized subjects divided by the number of subjects multiplied by 100. Ten (1) subject was used for the testing of the prototype in different lighting conditions, angle variances and three type of distances of about 1 meter, 2 meters and 3 meters.

RESULT AND DISCUSSION

Table 1: Frontal Recognition Accuracy

Distance	**Light**		
	Fluorescent	***Candle***	***Flashlight***
1 meter	100 %	100%	100%
2 meters	100%	100%	100%
3 meters	100%	100%	100%
Average	**100%**	**100%**	**100%**
TOTAL AVERAGE: 100%			

Table 1 shows a 100% recognition accuracy in various lighting conditions and distances. This result was comparable with the existing studies which recorded a rate of 100% in near distance using fluorescent light [16]. Moreover, this study provided a 100% accuracy in other types of methods used in this study because in Frontal view, it clearly detected the features of face.

Table 2: Upward Recognition Accuracy

Distance	**Light**		
	Fluorescent	***Candle***	***Flashlight***
1 meter	100 %	100%	100%
2 meters	100%	60%	80%
3 meters	100%	60%	80%
Average	**100%**	**73%**	**87%**
TOTAL AVERAGE: 87%			

Table shows the recognition using fluorescent light consistently marked a result of 100% too which implied that this method outperformed other lighting considerations. In other methods like the candlelight and flashlight, there was a negative effect on its distance. The candlelight resulted in a 40% decrease, the warm light caused to compliment the skin tone of the subject cause it produced warm light that seemed to be difficult to detect for those who have a dark skin while in a flashlight, a 20% decrease in accuracy for the eyes became smaller when the subject faced upward, the angle of the flashlight is only spread in front.

Table 3: Downward Recognition Accuracy

Distance	**Light**		
	Fluorescent	***Candle***	***Flashlight***
1 meter	100 %	80%	100%
2 meters	100%	60%	80%
3 meters	100%	60%	80%
Average	**100%**	**80%**	**87%**
TOTAL AVERAGE: 89%			

This table shows that through the use of the first method of lighting which is fluorescent, it still brought about a 100% recognition rate in different distances and lighting types than the other two methods – giving a negative effect for candlelight with results from 20% to 40%, due to the two candle, it produced a lot of shadow at the back of the subject's head when it's too far. On the other hand, flashlight affected the doubling of the chin of the subject, making it hard to detect – marking a 20% accuracy when facing downward for there was no spread of light at the bottom.

Table 4: Left and right Recognition Accuracy

Distance	**Light**		
	Fluorescent	***Candle***	***Flashlight***
1 meter	100 %	100%	100%
2 meters	100%	60%	70%
3 meters	100%	40%	70%
Average	**100%**	**67%**	**80%**
TOTAL AVERAGE: 82.3%			

Table shows the recognition for fluorescent significantly turned in a performance rate of 100% recognition accuracy for various distance and lighting conditions. In the candlelight method, the movement of shadows to the other side of the face made the eyes very hard to detect when facing left and right, with about 40% to 60% decrease for the right side is brighter that the left side. A negative effect also occurred on the flashlight when the subject had small eyes and facing the side – having a 30% decrease in recognition. It also caused an unequal spread of lights on both sides. The left side was brighter than right for there was little lighting form the outside that leaked through the holes.

Table 5: Overall Accuracy

Angle	**Light**		
	Fluorescent	***Candle***	***Flashlight***
Frontal Angle	100 %	100%	100%
Upward Angle	100%	73%	87%
Downward Angle	100%	80%	87%
Left -Right Angle	100%	67%	80%
Average	**100%**	**80%**	**88.5%**
TOTAL AVERAGE: 89.5%			

Table shows the summary result by computing every average result of the given conditions from frontal to right recognition angles. As observed, for the flashlight illumination, there was a little difference in the results between the fluorescent light and flashlight – the flashlight indicated the angle where the light could spread only in specific angles. When it was tested, some shadows formed and some of the features were detected well. However, when it comes to the fluorescent light, it covered and dispersed the light all over the room thus, making the face more visible and defined. Lastly, the illumination of the candle light, posed a great possibility of decreasing the accuracy rate even though two (2) candles were used based on the observation. According to the Study of Illumination, the flame was not always stable which implied differences in detecting the face once the light was flashed towards the face. Also, it built more shadows that made it harder to be detected. It resulted to an overall rate of 89.5%.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the experiments conducted, the study showed that the proposed model has a better performance when the subject was facing towards the camera – acquiring a 100% accuracy rate. However, when the subject tended to face left and right sides or the subject happened to be one to three (1-3) meters away from the model with some false detections. It both resulted to a rate of 82.3% in recognition accuracy. Moreover, when the subject was facing upward or downward angles and in one to three (1-3) meters away from the model, it may also tend to note false detections – accumulating a result of 88% rate of accuracy. Over all, the result of the 4 experiments conducted marked an 89.5% Accuracy Recognition rate. To further improve the performance of the study, it is highly recommended to consider the following:

- Building of various positional form of features.
- Utilization and application of other face detection and recognition approaches to determine which among the options can provide better results.
- Consideration of the detection of subjects wearing make-up and accessories.
- Usage of a high-end camera for greater accuracy rate of detection.

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