Available online at https://jcst.rsu.ac.th
Formerly Rangsit Journal of Arts and Sciences (RJAS)

Journal of Current Science and Technology, January-June 2020 JCST Vol. 10 No. 1, pp. 21-33

ISSN 2630-0583 (Print)/ISSN 2630-0656

Effecting of environmental conditions to accuracy rates of face recognition based on IoT solution

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Received 18 February 2020; Revised 15 March 2020; Accepted 16 March 2020
Published online 31 Mar 2020

Abstract

There are an increasing number of Internet of Thing (IoT) solutions that are treated and supported us in communication, data storage, maintenance, monitoring, privacy, and security. Advances in face recognition have provided efficiency and security that can be developed through IoT devices for the cheaper prices than the past. Face recognition enables the development on the camera through Raspberry PI 3 importing a machine learning algorithm in the easy way. However, the use of a camera and a face recognition system on IoT can be particularly found missing detection and recognition problems. The challenges on developing the face recognition system has been encouraging, the accuracy progress of face recognition turn out to be many conditions. In our view, the developing recognition procedure is able to discovery the relationships of the factors related to the correctness of a face recognition system in the different conditions of image resolutions, distances, and illuminations. This article discusses the appropriate conditions for the better condition tasks of image resolutions and distances. Finally, we propose the operational semantic, which can calculate on the different environment conditions and shows results that demonstrate the better accuracy rates of the sufficient preparation for face recognition systems.

Keywords**:** *accuracy rate, distance, face detection, face recognition, image resolution, IoT, lighting*

1. Introduction

1.1 Purpose of the research

Internet of Things (IoT) is an intelligent invention of ubiquitous (Rukhiran & Netinant, 2018). The great technology allows us to connect any devices in everywhere and every time. The IoT have brought benefits in communication, data storage, maintenance, privacy, and security (Boltz, Jalava, & Walsh, 2010; Breitenbacher, Homoliak, Aung, Tippenhauer, & Elovici, 2019). The area of IoT refers to millions of other Internet connections called Object (Saleem et al., 2018). The massive growth of the objects is widely developed supporting many software, hardware devices, sensors and networks. The advances of IoT make in the fields of biometrics and automatic identify recognition. The personal recognition is based on physical attributes of a person such as faces, voices, fingerprints, and eyes. Using a face detection in biometric systems is an important challenging research area with many applications in an emotion foresting, a smart environment (Wojcik, Gromaszek, & Junisbekov, 2016) and a security system.

Face recognition is one of the most remarkable capabilities of a human vision. The powerful technology of a face detection has attracted a significant attention in different applications such as an information security, a video surveillance, cooperative user applications, a law enforcement, and a social network (Zhu, Zheng, Lu, & Lai, 2017; Nikan & Ahmadi, 2018). Face recognition is a biometric identification technique that can be practiced using a face analysis and pattern recognitions. Face analysis is a comparative method of an analysis face recognition using psychological (Brunelli & Poggio, 1993). Pattern recognition is a fundamental area of studying on a face recognition system to collect data sets, build categories, and compare similarities between categories and test data (Bora, Rahman, & Hazarika, 2015; Sun, Shen, Yang, & Liao, 2020). The accuracy of the face detection depends on many aspects. For example, the number of training samples for each tester is collected in a database (Ramachandra & Busch, 2017). The technology and algorithm can detect through the noise background (Devi & Hemachandran, 2013). In addition, the under control conditions are hardly attempted to control during the detection such as an expression variation of a human face (Geng, Zhou, & Smith-Miles, 2008). Since the face recognition is performed routinely and effortlessly in daily lives, many issues still remain to be addressed for improving the accuracy detection. Pereira, Anjos, and Marcel (2019) have mentioned that the major key of matching faces is found difficultly in the heterogeneous conditions. The relationships of image resolutions and distances do not investigate properly through the face detections and recognitions. Therefore, we aim to focus on study the factors related to the correctness of face recognition systems.

The challenges on developing the face recognition has been encouraging, the accuracy progress of a face recognition through a camera turn out to be many conditions. Although many researches have stated that viewpoint, illumination, expression, occlusion, clutter and accessories (Li, 2005; Mudunuri & Biswas, 2016; Wojcik et al., 2016) should be considered through as the technical challenges. Therefore, their researches have the different aims from ours. Moreover, measuring correctness impacts for a face recognition are based on differentiate from input dataset conditions. Our current research has focused on improving a face recognition system which is composed of the Internet of Things devices such a camera, Raspberry PI 3, and other hardware. Two specific research questions related to the issues has been elevated:

"What are the factors related to the correctness of face recognition?" and "Are the correctness depended on resolutions, light, and distances of the object to the camera?"

In this paper, we consider our biometric implementation to evaluate in the accuracy of a face recognition. The goal of our work is to evaluate the factors of an accuracy of a face recognition system based on the camera through Raspberry PI 3. We believe this research can represent the principle development of IoT face detection and provide the better solution of face recognition based on control conditions.

1.2 Research background and current situations.

This implement is based on the Internet of Things for a face recognition system. Therefore, there are many interesting studies to be concerns in research background and current situations.

1.2.1 Development of a face recognition

The Internet of Things known as IoT becomes an important part of the 21st century. This artifact is not limited to connect users to the Internet through many devices, objects, and services (Bassi, Bauer, Fiedler, & Kranenburg, 2013) on various essentials. By concerning on security implement, we find that face recognition deals with automatic recognitions and surveillance systems. The face recognition can be capable of uniquely identifying and verifying objects like human faces. Zhao et al. (2020) have proposed the facial expression recognition process as shown in Figure 1. There are 3 phases of a face recognition process: 1) initialization module for the system beginning is included providing a Raspberry PI and a camera configuration, 2) a load model module is a process of the trained model. Face detection is a major key of collecting all datasets of faces into databases, and 3) a recognition module consists of an image preprocessing, a facial recognition, and displaying results. The data preprocessing is defined as a facial classification of selecting techniques and algorithms to identify a face. Calvo, Baruque, and Corchado (2013) have assumed the external factors increasing the complexity of classification and recognition such as light conditions, background images, and temperatures. Moreover, the performance evaluations of a successful face detector should be able to identify and locate the faces unrelatedly of a position, a scale, an orientation, an age, illumination conditions, and image and video contents (Li, 2005).

Many researches focus on using biometrics for user authentication in IoT environments. Nikisins et al. (2015) have implemented a face recognition system on a raspberry PI using the Local Binary Pattern algorithm (LBP). The methodologies are to extract features histogram and compare the accuracy of a face identification. Another research also uses Histogram of Oriented Gradients (HOG) to prove for the accuracy of IoT solutions for a face recognition (Novosel, Meden, Emersic, Struc, & Peer, 2017). The feature vector of images is applied into a grayscale 2D matrix and stored in the database. The accuracy of a classifier evaluation is calculated the percentage of correctly classified faces. Mano et al. (2016) have applied IoT technologies of patient identification and emotional facial recognition for enhancing health smart homes. The system provides the efficient and cheap equipment such as smartphones, embedded devices (Raspberry PI) through a wireless connection and cameras. The paper also discusses the use of images and emotions that evaluate the rate of accuracy with a good convergence.

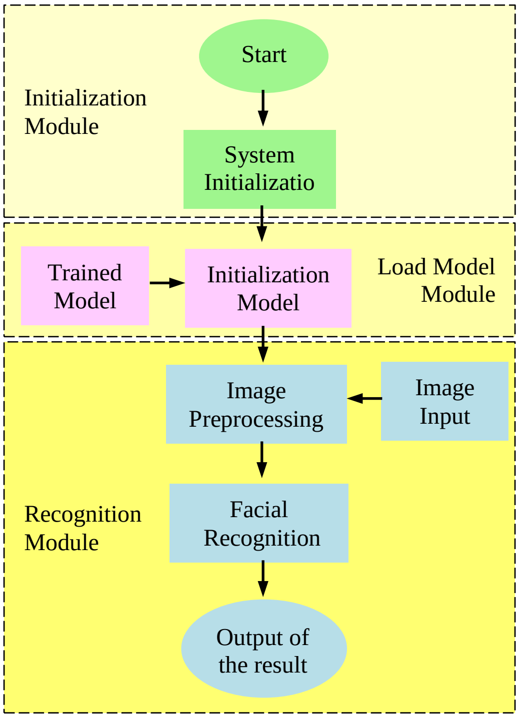

Figure 1 Facial recognition process

The most research projects of a face recognition are concentrated on improving the recognition accuracy in many ways. The image resolutions are studied on refining the performance of a face detection and avoiding the decreasing of accuracy rates. The sample-based methods aim to compare the contrastive loss optimization. The experimental studies are proved in many types of image resolutions (8 x 8, 12 x 12, 16 x 16, 20 x 20, and 112 x 96 pixels). The maximum pooling condition can be calculated in the formulas to find the appropriate settings (Sun et al., 2020). To improve the face classification, an algorithm is proposed in (Nikan & Ahmadi, 2018) to result the better performances in uncontrolled conditions of poor illumination, limited occlusion, and low quality images. The proposed technique is compared to other methods as well. Both of the controlled (indoor environments) and uncontrolled (outdoor environment) conditions such as illuminations, expressions, and glasses occlusions are examined through a variety of objects and faces in (Zhu et al., 2017). There are many methods of Illumination Invariant Descriptor (LGH) which are provided in this work. The results deal with the illumination problems from the homogeneous lighting to heterogeneous lighting.

Moreover, the accuracy rates of biometric recognitions have greatly improved the performances using other approaches in recent years, which lead us to understand the uncontrolled environments in real applications. Hand gestures are detected and tracked by many techniques. A sequence of images is studied to extract a hand region in the webcam or video files. By loading a statistical model, the OpenCV algorithm is provided to detect the faces and then the system can remove the face areas. Thus, the hand gesture can be detected during the testing stage only. The experiments show that the real-time detection and recognition achieve the better classification accuracy regarding to the resolution size (Dardas & Georganas, 2011). Also in Yao and Li (2015), the uncontrolled environments, including multiple hand regions, background moving objects, scale, and changing lighting conditions are major challenging task in hand gesture recognitions. Moreover, extending distance transform for hand tracking is studied by Kerdvibulvech (2015). A hand model for hand gesture recognitions is proposed to compute the chamfer distance for determining the likelihood of edges. The quantitative evaluation is measured for the error evaluations. The comparison of accuracy rates are studied by measuring from the different objects (fingertips and skin point between fingers).

1.2.2 Environment factors of the system accuracy

We mainly review related works of the face recognition accuracy in many factors. Sinha et al. (2016) have explored the different conditions such as colors, illuminations, and low resolutions can affect the correctness of a face recognition. Martinkauppi and Piettikainen (2005) have stated that the illumination variations can affect the face detection and recognition. Moreover, the different lightings can mark the color appearance. Zhu et al. (2017) have investigated the illumination invariant for a face recognition under heterogeneous lighting condition. The heterogeneous lighting is based on an arbitrary lighting direction, a magnitude, and the spectral wavelength. By assumption the experimental studies, the under lighting conditions are homogeneous such as having the same spectral wavelength. The samples of the uncontrolled lighting conditions are sunlight, electric lamp, and near-infrared camera (Liao, Yi, Lei, Qin, & Li, 2009). The investigation on degraded conditions for a face recognition was studied by Nikan and Ahmadi (2018). Poor illumination, low image quality, and partial occlusion were concerned using a combination of preprocessing techniques coupled to extract discriminative features from dataset. In order to improve the recognition rate, the changes in condition can affect the accuracy of face detection. The study in (Lemieux & Parizeau, 2002; Boom, Beumer, Spreeuwers, & Veldhuis, 2006; Zou & Yuen 2012; Marciniak, Chmielewska, Weychan, Parzych, & Dabrowski, 2015) have found that the image across different resolutions such as resolution reduction and blurring decrease could perform the depictions more recognizable. Moreover, Liu and Wilkinson (2020) have stated that human are able to recognize things and objects easily based on depiction, therefore, the methodologies of biometric recognition is to compare the resemblance images to the datasets.

2. Objectives

The aims of this research are 1) to investigate the factors related to the correctness of a face recognition system based on the camera through Raspberry PI 3, 2) to compare the evaluation of the accuracy of a face recognition, and 3) to propose the face recognition system based on operational semantics for better accuracy rates.

3. Materials and methods

3.1 System hardware setup

The proposed system is a biometric system for a face recognition. We use Raspbian as an operating system and a Python program to read the presence sensor's data. The hardware requirements are Raspberry PI 3 Model B+, 1GB of RAM, SanDisk SD Card of 64 GB, a Logitech C922 camera connected by a USB port of a Raspberry PI 3.

3.2 A processing flow of a face recognition

A processing flow of a face recognition shows in Figure 2. Figure 2 represents the processing flow for developing a face recognition system. A camera attached to a USB on a Raspberry PI captures digital image faces of a user. Each user will take 30 face images. All images are 320x240, 640x480, 1024x768, and 1920x1080 resolutions. The system consists of two processes:

- Face detection refers to the psychological process for detecting and locating the presence of human faces in images. In this paper, we consider the control conditions of an illumination, resolutions, and distances for training heterogeneous experimental studies. The algorithms are applied to train and collect them in huge datasets.

- Face recognition relates to identifying a person face from dataset images using facial features. The feature extraction consists of a pattern, segmentation, rendering, and scaling of faces that can be ready for a face identification.

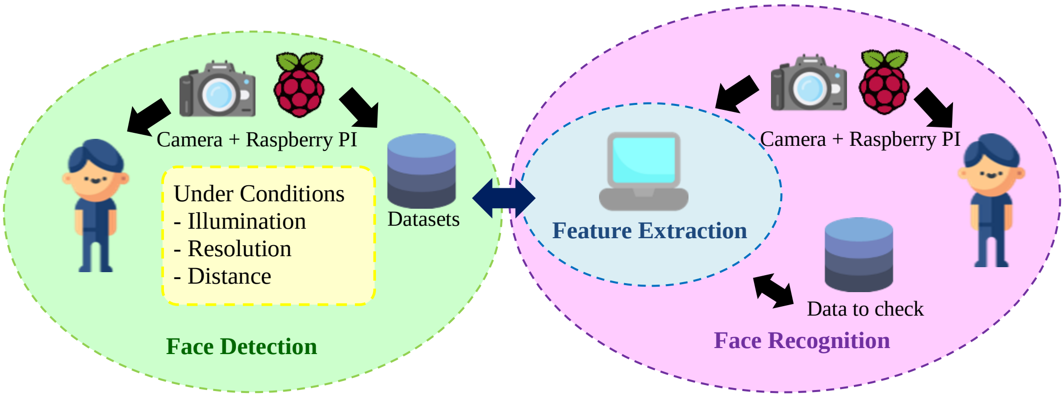

Figure 2 Face recognition processing flow

3.3 Methodology

We aim to study the factors related and caused to the correctness of a face recognition system. By assuming three factors of resolutions, distances, and illuminations, we provide a dataset of a user using face images in different conditions. The dataset can be as the follows:

- Images of the same resolution, light, and distance.

- Images of the different resolutions, the same light and distance.

- Images of the different resolutions and distances and the same light.

Based on the 75 face subjects, there are 5 types of image resolutions (320x240, 640x480, 1280x720, 1024x768, and 1920x1080 pixels) captured from the samples. Each resolution takes 30 frames of a sample subject face. We take the image from the heterogeneous lighting (1,500-2,500 lumens). Moreover, we capture the images from the 4 different distances (50 cm., 100 cm., 150 cm., and 200 cm.) as shown in Figure 3. The accuracy face recognition of an experimental study is trained by OpenCV machine learning algorithms.

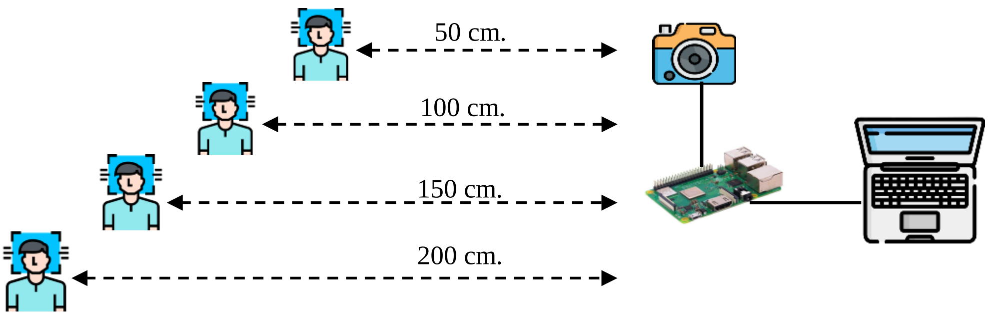

Figure 3 Operating conditions of face recognitions

The algorithm is a function that detects the objects (images) that we import the library to our python program. To create the face recognition datasets on premises, we used a camera to save the images to the database. Thus, we performed the different resolutions, distances, and lighting conditions for supporting this experiment. The preprocessing of a face detection was to convert all RGBs trained images to the grayscale images, to specific the image size, and to build the custom face recognition dataset. Then, the face recognition accuracy was tested to calculate the probability of the recognition system.

4. Results

In this experiment we have aimed at evaluating the accuracy of the three factors according to resolutions, distances, and an illumination. Figure 4(a) shows the recognition accuracy of the images which are affected by the resolutions, compared to the results of dataset at the resolution of 320x240. We used the radars to represent the comparison between an accuracy of dataset resolutions for 75 samples of face recognition and the different distances. By comparing the image resolutions through the different resolutions and distances (50, 100, 150, and 200 cm.), we used dataset 320x240 resolutions to compare with 320x240 resolutions of a face recognition.

. Figure 4(b) shows the comparison of accuracy for dataset 320x240 resolutions comparing to 640x480 resolution of a face recognition at the different distances. Figure 4(c) shows the comparison of dataset 320x240 resolution to compare with 1920x1080 resolution of a face recognition at the different distances.

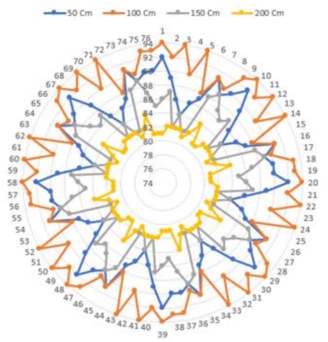

Figure 4(a) Dataset 320x240 detection 320x240

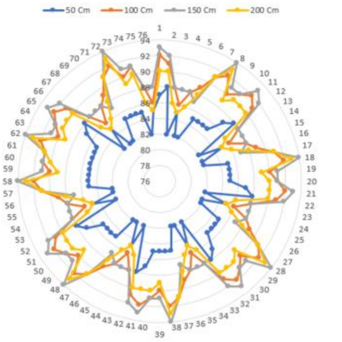

Figure 4(b) Dataset 320x240 detection 640x480

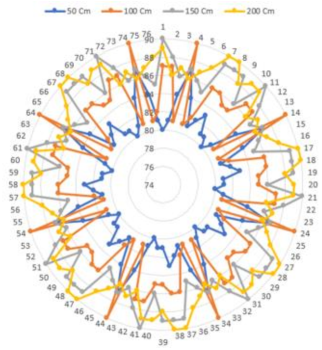

Figure 4(c) Dataset 320x240 detection 1920x1080

Figure 4(a), 4(b), and 4(c) shows the samples of accuracy rate results of comparison on the different resolutions at the different distances. Figure 6 shows the average of accuracy rates of a face detection with the different distances of dataset 320x240 resolution.

Figure 4(a) shows that the best accuracy rate of a face recognition is when the dataset 320x240 resolution is both used for a face detection and a face recognition. The face recognition can recognize faces up to the range of 100cm distances. Figure 4(b) shows that the best accuracy rate of a face recognition with the greater distance when the dataset 320x240 resolution and the 640x480 resolution of a face recognition are used for a face recognition system. The face recognition can recognize faces up to range of 150cm distances. Figure 4(c) shows that the best accuracy rate of a face recognition with the better longer distance when the dataset 320x240 resolution is used for a face detection and the 1920x1080 resolution of a face recognition are used for a face recognition system. The face recognition can recognize faces up to range of 200cm distances.

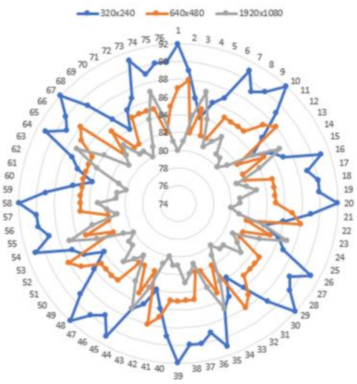

Figure 5(a) Accuracy rates of a face detection at 50cm of 320x240 VS 320x240, 640x480, and 1920x1080 recognition resolutions

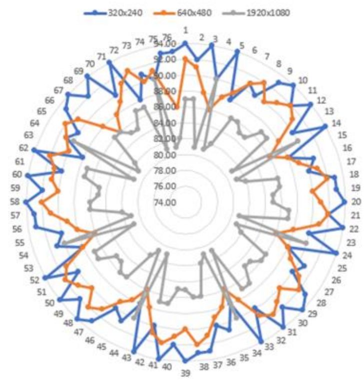

Figure 5(b) Accuracy rates of a face detection at 100cm of 1024x768 VS 320x240, 640x480, and 1920x1080 recognition resolutions.

Figure 5(a) shows the accuracy rates of a face detection 320x240 resolution at 50cm distance comparing to diversities of face recognition resolutions. The result founds that the higher resolutions of a face recognition is used, the less accuracy rates and distance of a face recognition occur.

Figure 5(b) shows the accuracy rates of a face detection 1024x768 resolution at 100cm distance comparing to diversities of face recognition resolutions. The result founds that the higher resolutions of a face recognition is used, the better accuracy rates and longer distance of a face recognition support. However, the different resolutions of a face detection and a face recognition must be different no more than 60-80%.

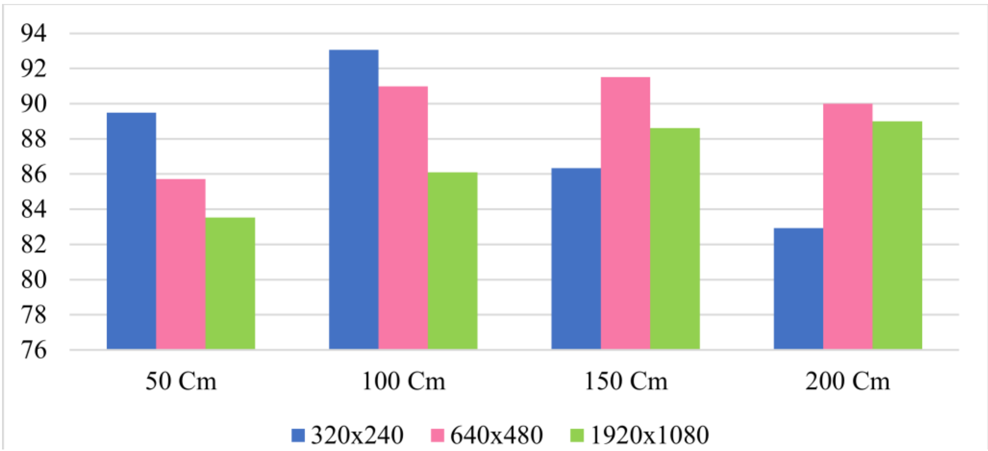

Figure 6 Average % Detection of Dataset 320x240

Figure 6 illustrates the average percentage of face recognition correctness varying distances from 50cm to 200cm. When the face detection has resolution of 320x240 pixels, the highest percentage of face recognition correctness has the same resolution of 320x240 pixels at the distance 100cm. Then, we change the face recognition resolution of 640x480 pixels. The highest percentage of face recognition correctness nearly has the same result as the resolution of 340x240 pixels, but the face recognition can extend the distance to 150cm. Moreover, when we change the face recognition resolution of 1024x768, 1280x720, and 1920x1080 pixels, we found that the percentage of face recognition correctness gradually decreased, but the distance of face recognition can be extended. The smaller resolution of face detection makes the distance of face recognition shorter with the higher percentage of face recognition correctness. The more resolution of face detection makes the distance of face recognition farther with the lower percentage of face recognition correctness.

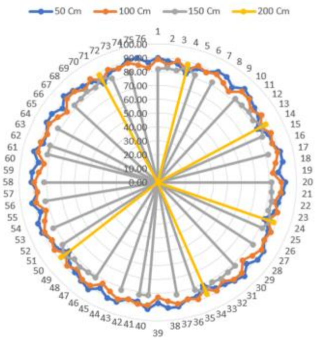

Figure 7(a) Dataset 640x480 Detection 320x240

Figure 7(a) shows that the different resolutions of a face detection and a face recognition are not more than 5 times. The accuracy rates of a face recognition are not varying, but the distances of a subject face are limited to no more than 100cm. Figure 7(b) shows that the different resolutions of a face detection and a face recognition are not more than 1 times. The accuracy rates of a face recognition are not varying, but the distances of a subject face are limited to no more than 150cm.

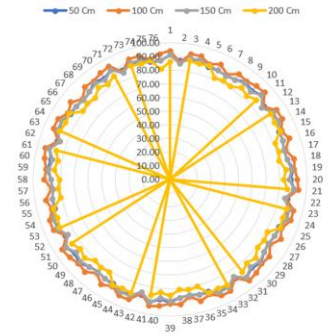

Figure 7(b) Dataset 640x480 Detection 640x480

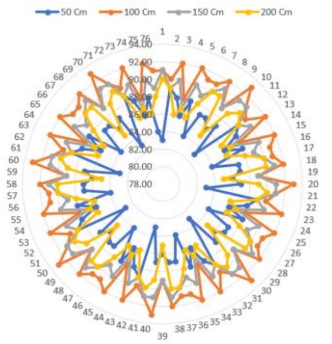

Figure 7(c) Dataset 640x480 Detection 1920x1080

Figure 7(c) shows that the different resolutions of a face detection and a face recognition are more than 5 times. The accuracy rates of a face recognition are varying, and the distances of a subject face are limited to no more than 100cm.

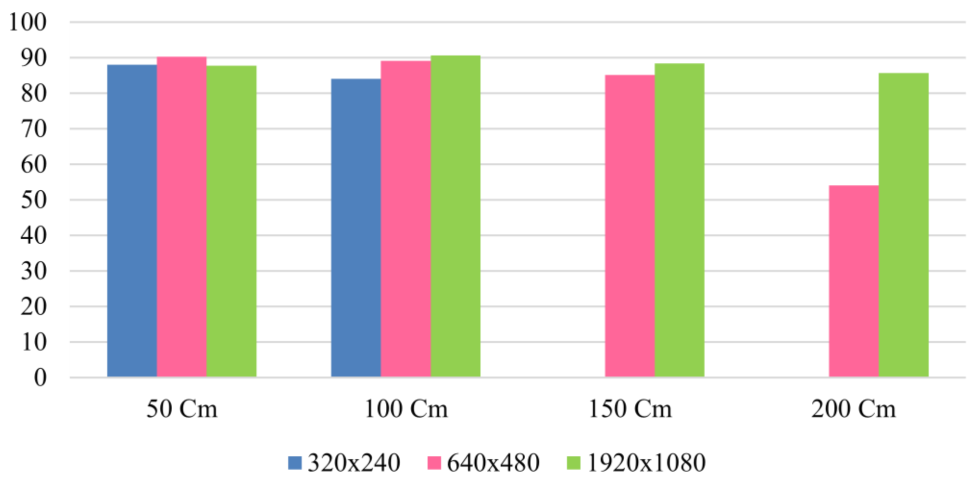

Figure 8 % Detection 640x480 at 50cm., 100cm., 150cm., 200 cm. VS 320x240, 640x480, 1920x1080

Figure8 shows the accuracy rates of the different face detection and face recognition resolutions. The accuracy rates of a face recognition depend on a face recognition resolution based on the face detection 640x480 resolution. The distances of a subject face are limited to no more than 100cm when the lower resolution of a face detection is used. The different resolutions of a face detection and a face recognition are not more than 5 times. The accuracy rates of a face recognition are not varying, but the distances of a subject face are limited to no more than 100cm. The different resolutions of a face detection and a face recognition are more than 5 times. The accuracy rates of a face recognition are varying, and the distances of a subject face are limited to not more than 200cm.

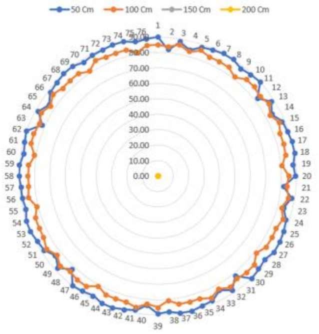

Figure 9(a) Dataset 1920x1080 Detection 320x240

Figure 9(a) shows that the different resolutions of a face detection and a face recognition are more than 25 times. The accuracy rates of a face recognition are not varying, but the distances of a subject face are limited to no more than 100cm.

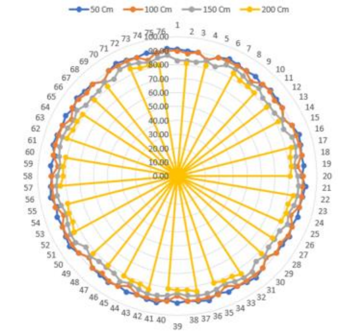

Figure 9(b) Dataset 1920x1080 Detection 640x480

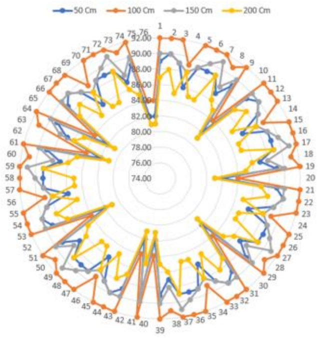

Figure 9(c) Dataset 1920x1080 Detection 1920x1080

Figure 9(b) shows that the different resolutions of a face detection and a face recognition are not more than 5 times. The accuracy rates of a face recognition are not varying, but the distances of a subject face are limited to no more than 150cm. Figure 9(c) shows that the different resolutions of a face detection and a face recognition are the same. The accuracy rates of a face recognition are not varying, and the distances of a subject face are limited to no more than 200cm.

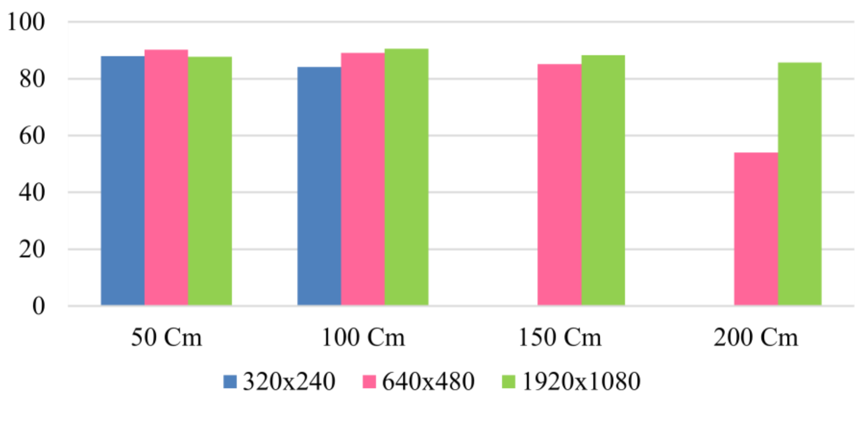

Figure 10 Dataset 1920x1080 detection at 50cm., 100cm., 150cm., 200 cm. VS 320x240, 640x480, 1920x1080

Figure 10 shows the result of a face detection resolution at 1920x1080 pixels in the different distances. The result confirms when the higher resolution of a face detection resolution is used, the better accuracy rate and longer distances of a face recognition support. However, if the different resolution of face detection and face recognition resolutions is more than 20 times, a face recognition system cannot recognize a face at longer distances. For example, when a face detection resolution 1920x10180 is used, a face recognition 320x240 resolution can recognize a subject face at shorter distances up to 100cm and lower accuracy rates. When a face recognition 640x480 resolution can recognize a subject face at longer distances up to 150cm and better accuracy rates. When a face recognition 1920x1080 resolution can recognize a subject face at longest distances up to 200cm and still have better accuracy rates.

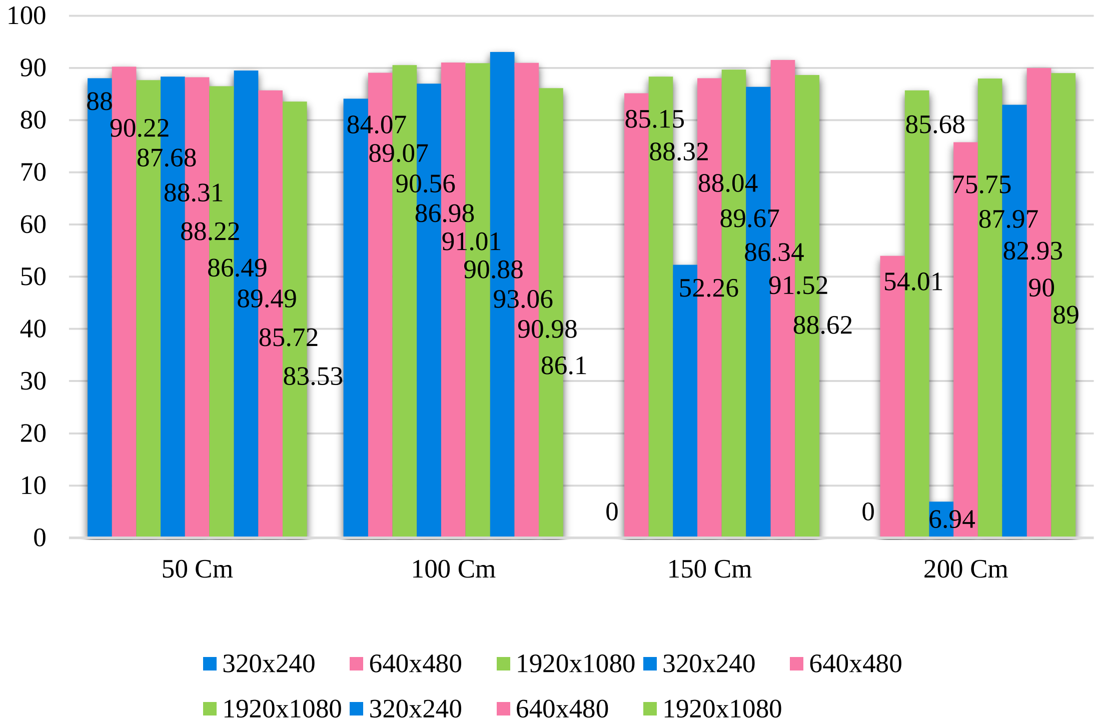

Figure 11 Dataset 320x240 VS 640x480 VS 1920x1080 detection at 50cm., 100cm., 150cm., 200 cm. VS 320x240, 640x480, 1920x1080 recognition

In Figure 11, each range of a face detection, there are three experiments of face recognition resolutions. The experiment is a face detection 320x240 resolution and three face recognition resolutions: 320x240 640x480 and 1920x1080 pixels respectively. Figure 11 compares all different accuracy rates in image resolutions through a variety of distances (50 cm., 100 cm., 150 cm., and 200 cm.). The Figure 11 indicates that the same image resolution of a face detection and in different distances has the significant higher or lower accuracy rates when compared to another distances. For example, we have found that a face detection 320x240 resolution and a face recognition 320x240 resolution have the highest scores at the 50 cm. distance when we compare the accuracy rate to the different distances. This suggests that the difference image qualities influence the comparisons of the distances and the availability of images and distance is limited. We believe that if a sufficient condition such as the right position or distance should be provided supporting the right image resolution both in face detection and recognition.

5. Discussion and conclusion

From the experimental tests, we have found that the accuracy rate of the image detection is referred to the image resolution supported, which is consistently related to Nikan and Ahmadi (2018). The image resolutions were used to validate the humane faces for the different conditions. In our research, we have established that the number of rows and columns expressing the image resolution effects on the recognition accuracy rates, including in face detection and face recognition. By analyzing the assumption, we have stated that the proposed conditions are able to improve the accuracy rates. With the higher resolution, the current study suggests that the short distance can increase the correctness rate detection. The accuracy rate also impacts on the homogeneous distance. We believe that the image processing size have a positive effect on face detection and recognition. In this case, the investigation is handled similarly to Liu and Wilkinson (2020). We have set the heterogeneous lighting (1,500 - 2,500 lumens). With the research result the brighter lighting condition also have a significant effect on performance and accuracy rates.

Therefore, we assign the operational semantics expressing from the face resolution, the accuracy correctness, and the distance. The formula of the corresponding is shown in Equation 1.

$$\text{Distance} * 100\ (\text{cm}) = \frac{\text{Face Detection Resolution} \circledast\!\!\&\& \ \text{Face Recognition Resolution}}{\%\ \text{Accuracy}} \quad (1)$$

By expressing our formula of the operational semantic, we may set the situation as follows: we assigned the conditions that the image resolution of the face detection resolution was 640x480 pixels, the image resolution of the face recognition resolution was 640x480 pixels, and the accuracy rate was 89.07 shown in the Figure 11. Thus, we solved the appropriate distance result using the Equation 1

$$= \frac{(640\text{x}480)/(640\text{x}480)}{89.07}$$

$$= \frac{1}{89.07} = 0.0112$$

Then,

$$0.0112*100 = 1.12 \text{ m.}$$

As previously stated, the appropriate distance for the image resolution of face detection and recognition was 1.12 cm. In addition, when we looked up in the experimental results of the Figure 11, we found that the accuracy rate of the dataset 640x480 pixels. The highest accuracy rate reached the score of 100 cm. Therefore, we believe that the appropriate distance of the face recognition through the 640x480 image resolution approximately between 100 cm. to 112 cm. Therefore, the experimental test of the face recognition is accepted by the accuracy rates test from the image resolutions and distances.

In this research, we have implemented a face recognition system using a Raspberry PI 3 for the better detection and recognition scenarios and metrics. Our experiments suggest that the developed recognition procedure is able to achieve the distances and accuracy rates in the different conditions of image resolutions, distances, and illuminations. We have reached a sufficient condition of accuracy evaluation for its application into a face detection. The recognition rates on the dataset are calculated by comparing the quality of the evaluation data. The correctness result of a face recognition has improved by the experiment tests. We have discovered the formula of the sufficient preparation for the better condition tasks of image resolutions and distances. The future research will continue to focus on investigate the solutions of the lighting conditions that can relate to the different image resolutions and distances. Moreover, we aim to implement the real face recognition of a personal examinees verification system.

6. References

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