International Journal of Advanced Technology in Mechanical, Mechatronics and Materials (IJATEC)

Vol. 04, No. 1 (2023) 1-10

Institute for Research on Innovation and Industrial System (IRIS)

Development of a Smart Digital Advertisement Board Based on Face Recognition System

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Abstract. We develop a smart digital advertisement board system which allows the system to display advertisements based on the majority of age and gender classifications of the consumers. The system captures the faces of the crowd and the face recognition techniques used to classify the majority gender and age of the crowd and then shows appropriate advertisement from the database to the advertisement board. A DNN model that is built, trained, and validated is used to recognize and predict the age and gender of the visible faces through image input or webcam using face photo dataset known as audience dataset. Several testing and analysis have been done onto the system in order to demonstrate the effectiveness and reliability of the system in displaying suitable advertisement for the public. The system can get gender accuracy of 77.82% and 86% for female and male respectively. And 68.78% accuracy for age recognition. The recognition speed is less than 1.3 second for up to 9 faces in an input image.

Keywords: face recognition; age and gender recognition; smart advertisement; DNN; OpenCV

DOI: 10.37869/ijatec.v4i1.100
Received 13 July 2023; Accepted 17 July 2023; Available online 18 July 2023
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1. Introduction

Advertisements (also referred to as ads) are a common yet powerful tool in the business sector to showcase their own product or service that they offer to the public in a cost- effective and efficient manner. It also can be used to spread a message or awareness about a particular topic, typically noticeable on highway billboards, public transports, newspapers, radio, internet and on many more countless public platforms. Useful and complete information such as the prices, benefits, and features help in bringing confidence for consumers and businesses to purchase services and products. Bovée mentions that "Advertising is the nonpersonal communication of information usually paid for and usually persuasive in nature about products, services or ideas by identified sponsors through the various media" [1].

In the people's economic activity, ads truly became an important factor. Without realising, advertising involves in stimulating the growth of economy. It creates an economic chain reaction that produces jobs and direct sales among those industries who promote their products and services. According to IHS Global Insight Inc., "In 2012, advertising accounted for $5.6 trillion of the $33.8 trillion in US output and supported 21.1 million of the 136.2 million US jobs." "Every dollar of ad spending will generate, on average, almost $22 of economic output sale." [2].

With the current advancements of technology in today's world, ads have been evolving rapidly with more innovative techniques capable of replacing traditional forms of advertising in order to reach audience more effectively and contribute to the success of most companies. One such.

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ISSN: 2720-9008

innovation, referred to as digital advertising, generates brand awareness, and reaches consumers using data-driven strategy. Fuxman said that "Digital advertising, on internet and mobile gadgets, has outpaced the traditional media advertising and for the first time in 2013 generated more advertising spending than television advertising" [3]. The availability of faster broadband, affordable smartphones and the wide coverage of internet supports the growth of digital advertising. In Malaysia, the Malaysian Communications and Multimedia Commission (MCMC) mentioned in their report that "Total advertising spend in Malaysia rose 22% in the first half of 2008 amounted to RM2.9 billion from the same period in 2007. Advertisements spent on the Internet medium in the first half of 2008 were worth RM14.9 million" [4].

Despite the rapid evolving of innovation, ads displayed in public locations may not reach to its targeted consumers. Digital billboards or banners display multiple ads, but the sequence of these ads is not effectively controlled, therefore the probability of displaying suitable ads to a crowd of consumers is low. Apart from this issue, traditional ads may be outdated after a period of time, switching to a newer content (poster, banner, billboard, etc) require time, money, and manpower. Therefore, this paper is written to implement image processing algorithm to classify gender and/or ages based on human face recognition, to interface the algorithm for selecting and actuating a proper advertisement database to be displayed and to develop a framework of smart digital advertisement board with an optimum performance based on its performance analysis of parameters like accuracy, speed, etc.

With the availability of modern and cutting-edge technologies such as smartphones, and the constant decreasing price/performance ratio of computer vision systems, face recognition systems have been gaining a huge amount of attention in various industries [5][6]. A face recognition system is an automated process where a computer is programmed to detect a human face digitally from a photo or video, and recognise the face based on a dataset. Facial features such as the eye, nose and mouth are extracted and compared [7]. It is now being actively researched in the field of pattern recognition, image processing and computer vision.

Generally, there are three main processes in a face recognition system. A face detection or localisation determines and locates if a particular image (or a frame in a video) contains a face or not [5]. Once a face is detected, a feature extraction process involves extracting features by transforming image pixels into useful vector representation [8]. In the final process, a face recogniser locates the best match for the detected face in a database. Many developers and researchers have utilised various methods and approaches to build their algorithms. Yang and Huang [9] in their research utilised a knowledge-based multiresolution hierarchical method that consists of three levels. This method uses a course-to-fine technique in order to reduce computation power and resources. Using 60 images based on this method, 50 images containing faces have been detected successfully while false positive appeared on 28 images. Kotropoulos and Pitas [10] introduced a similar localisation method to detect the boundary of a face. A test set containing video sequence of 37 frontal facial views of different people with single face in an image sequence is extracted from a database, and the proposed method managed to deliver a successful detection rate of 86.5%. Yow and Cipolla [11] developed a Gaussian filter with Bayesian network method that uses six facial features (eyebrows, eyes, nose and mouth) to model the face in low resolution. A successful rate of 85% with a 28% false detection rate is achieved, featuring 110 facial images with different viewpoints, orientations, and scales. Haar feature-based classifiers, first proposed by Viola and Jones [12], is a machine learning based object detection method used to detect objects in images. Guo proposed a method for face recognition using Support Vector Machine (SVM) [13]. Ahonen et al [14] utilises a CSU Face Identification Evaluation System [15] with slight modifications to test full-frontal face images obtained from the FERET database.

2. Research Methodology

This paper is based on an age and gender recognition project designed by Sawant Mahesh [16], in which the deep neural network (DNN) model is originally trained and validated by Hassner & Levi [17]. The predicted gender is either 'Male' or 'Female', while the predicted age is one of the range of ages: (0-3), (4-7), (8-14), (15-23), (24-36), (37-46), (47-58), (59-99). A total of 26580 photos is used from 2284 subjects of different ranges of ages. To detect faces, the protobuf file that contains

the trained weights of the model, both in binary format (.pb) well as in text format (.pbtxt), is called. To recognise the age and gender, the caffemodel file defines the internal states of the parameters of the layers, while the prototxt files describe the network configuration.

The original project is then modified to allow advertisements to be displayed based on the outcome of the recognition model. Figure 1 shows the flowchart for displaying advertisement.

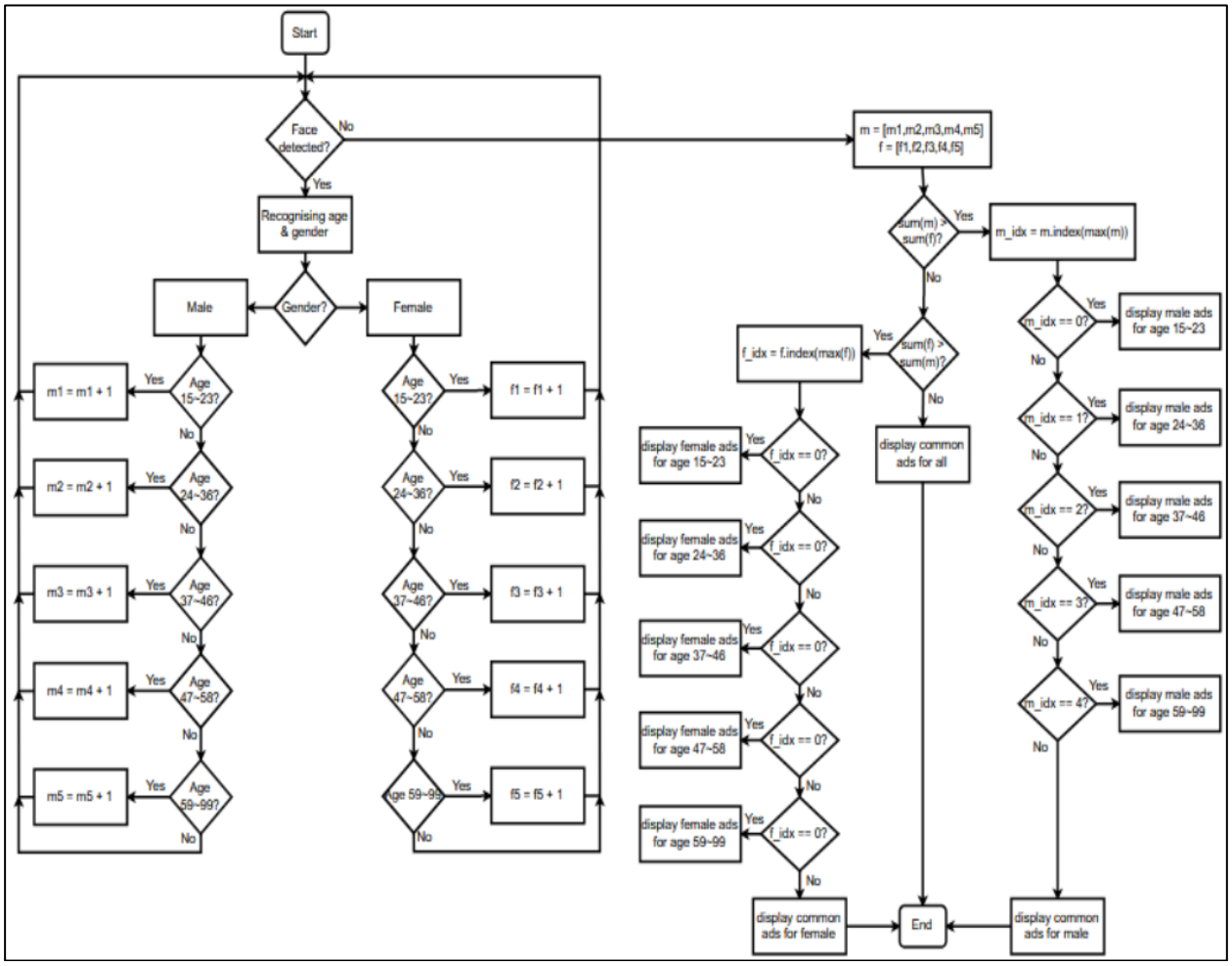

Figure 1. Advertisement Displaying Flowchart

With the complete code, the system is run with image input and webcam to see its advertisement output. Some captures of the output are shown in Figure 2.

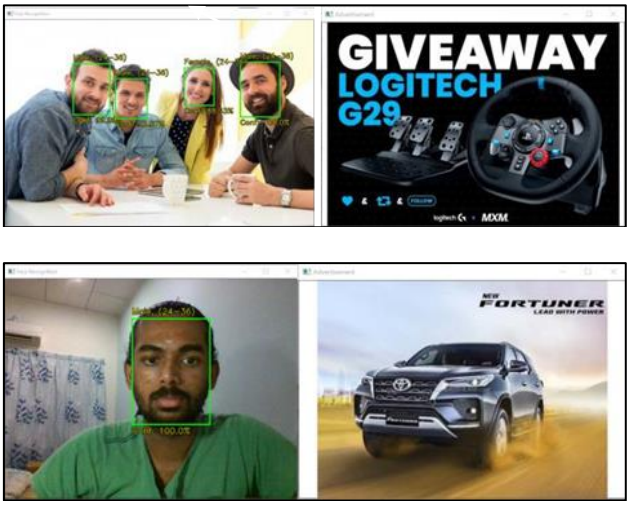

Figure 2. Capture of images

3. Results and Discussions

In order to validate the reliability of this system, several analyses of parameters like accuracy and speed have been done based on the image input as well as webcam input.

3.1 Image Input

Using facial images as the input for the face recognition python code, some analysis such as the age and gender accuracy, recognition speed, face distance, face pose and illuminance analysis are done to evaluate its performance.

a. Gender accuracy

The database used for this validation test consists of 478 female and 486 male facial images. Some of the images in the database are shown in Figure 3.

Figure 3. Samples from the male dataset

All the data collected are stored in a confusion matrix shown in Table 1.

Table 1. Confusion matrix

		Predicted		Σ
		Male	Female	
Actual	Male	419	67	486
	Female	106	372	478
Σ		525	439	964

From the female dataset, 372 faces are correctly recognized, which brings an accuracy of 77.82%. However, from the male dataset, 419 faces are correctly recognized, which brings an accuracy of 86.21%. The false recognition of gender could be caused by several factors. Some humans tend to have both masculine and feminine looks, although they may identify themselves as one of the genders. As the model is trained to classify the gender to be either male or female, it may not provide a correct recognition to androgynous faces. On uncommon occasions, the length of hair does affect the outcome of the recognition process, despite the model only captures the faces' region of interest (ROI) which includes the forehead, eyes, nose, cheeks, and lips, before going through the recognition process. For males with long hair, or females with short hair, the model may incorrectly predict the gender.

b. Age accuracy

A set of 221 images selected from the above dataset, ranging from age 0 to 99 and consisting of both genders are used to test the system's accuracy in age recognition. Some samples are shown in Figure 4.

Figure 4. Samples from Age 0 to 99

The number of 152 images out of 221 have been correctly recognised, which is an accuracy of 68.78%. Compared with gender accuracy it is lower due to the difficulty in recognizing the exact age from the various category of ages. This could also be influenced by several factors, such as make-up.

c. Recognition speed

Different number of faces in an image will cause different recognition speed. In order to analyse how long it takes for the system to perform recognition, a difference in timestamp before and after image processing is measured to get the time duration. Figure 5 shows some sample images with diferent number of faces.

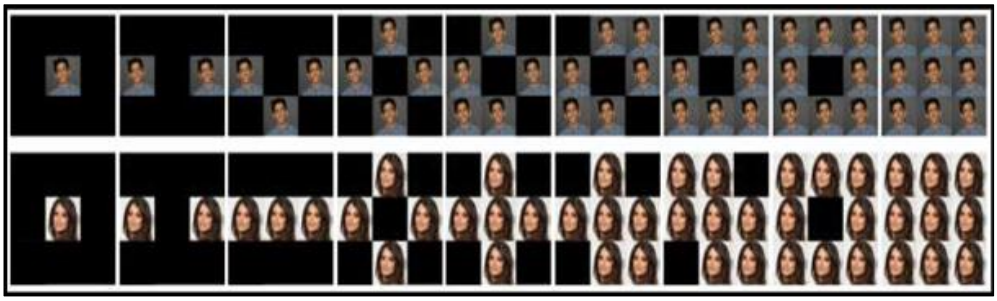

Figure 5. Samples of images containing different number of faces

This analysis is performed four times using four different faces: young male, young female, old male and old female, and an average time is taken from five attempts on each number of faces. All the recognition time are plotted in Figure 6.

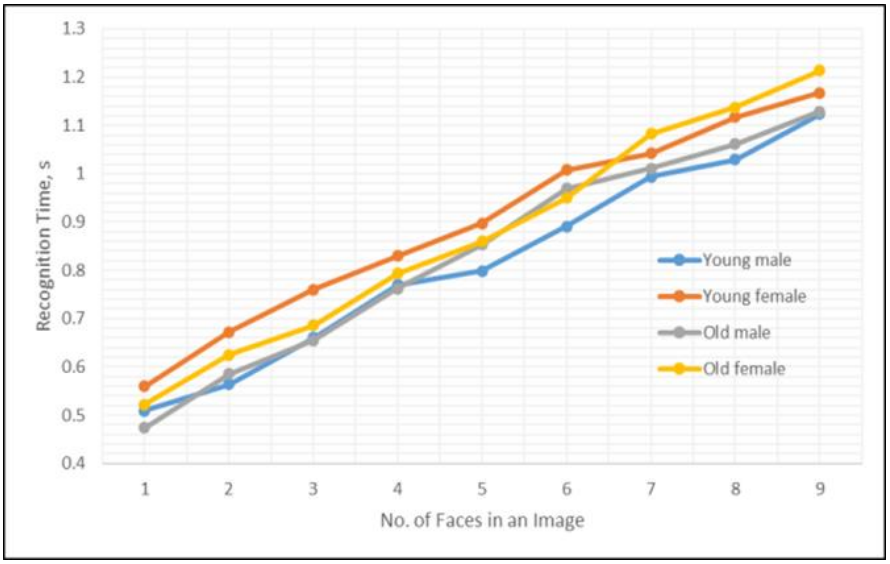

Figure 6. No. of faces in an image versus recognition time

From the graph above, the female faces (young and old) tend to take slightly longer time in recognition in comparison with the male faces.

3.2 Webcam

Similar to the image input analysis done above, some analyses are also done to evaluate its speed and accuracy.

a. Face distance

The distance of the detected faces from the camera will also affect the output of the system. To analyse this, five attempts on recognition output is recorded while altering the distance from the webcam to the face. Some samples of the webcam capture are shown in Figure 7. All the confidence level are plotted in Figure 8.

Figure 7. Samples of webcam capture with various distance

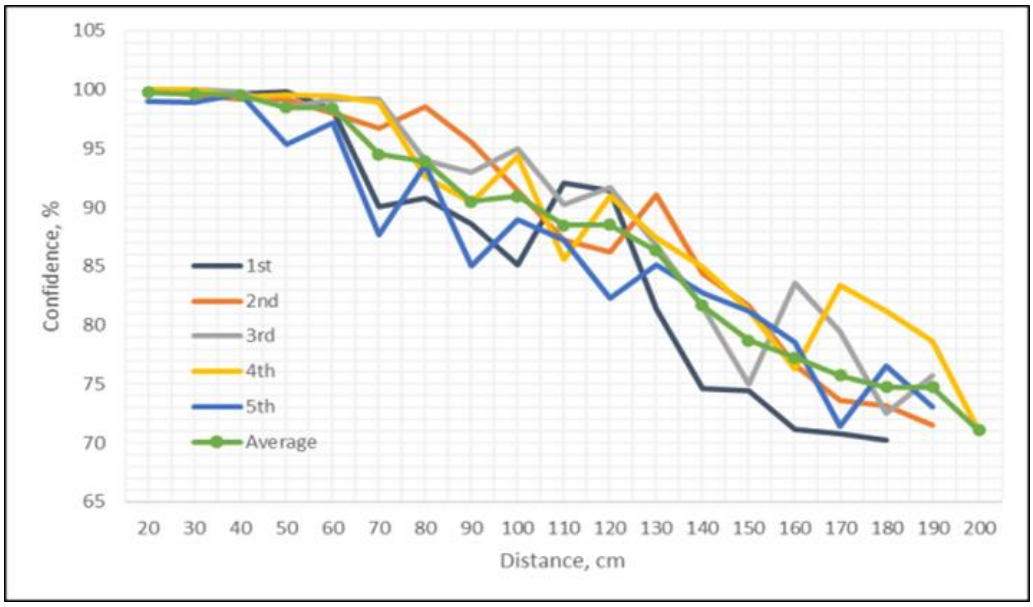

Figure 8. Distance between webcam and face versus confidence level

From the plotting above, it is noticed that as the distance increases, the confidence level drops gradually. After an average of 200 cm from the webcam, the system is unable to detect any presence of faces due to insufficient size of the facial size.

b. Face pose

Similar to the face distance, the face pose will also affect the confidence of the face recognition. To analyse this, the recognition output is recorded while changing the pose of the face from left to center to right This is attempted for five times, and an average is obtained. Some samples of the webcam capture are shown in Figure 9. All the confidence levels are plotted in Figure 10.

Figure 9. Samples of webcam capture for different poses

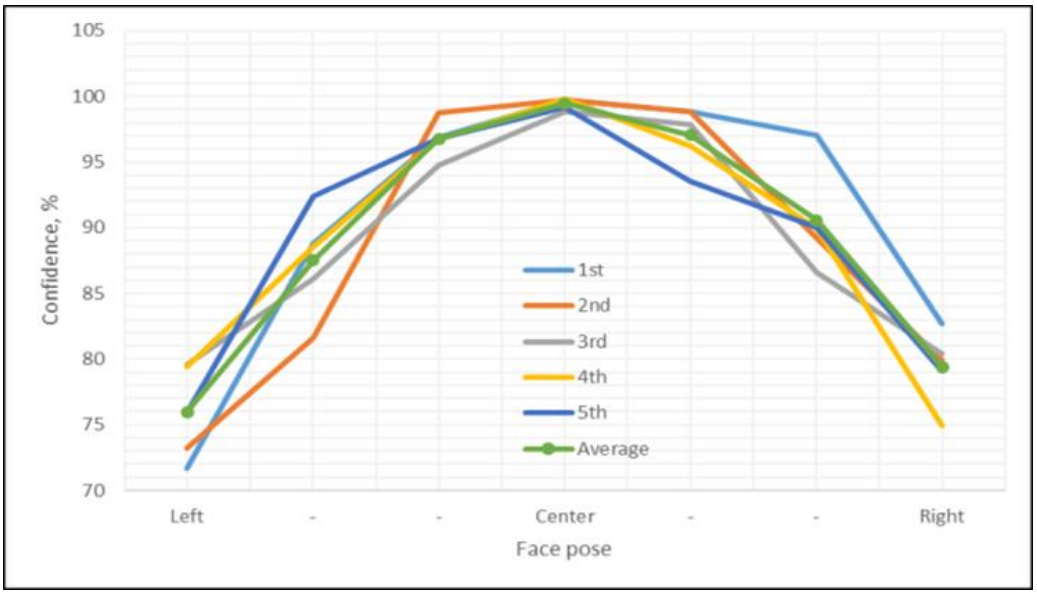

Figure 10. Face pose versus confidence level

From the above analysis, it is deduced that as the frontal face rotates towards the left or right side, the confidence level drops gradually to as low as 70%, until the system is unable to detect the presence of the face.

c. Illuminance

Apart from the above analysis, the light intensity or the illuminance of the surrounding will also influence the face recognition confidence. To analyze this, the recognition output is recorded while controlling the number of active light sources in the room in order to adjust the room brightness and to obtain different illuminance readings. The illuminance value is monitored using a lux meter smartphone application. Each illuminance is attempted five times, and an average is obtained. This analysis is done in two conditions, with and without the background lights. Some samples of the webcam capture are shown in Figure 11. All the confidence levels are plotted in Figure 12 and Figure 13.

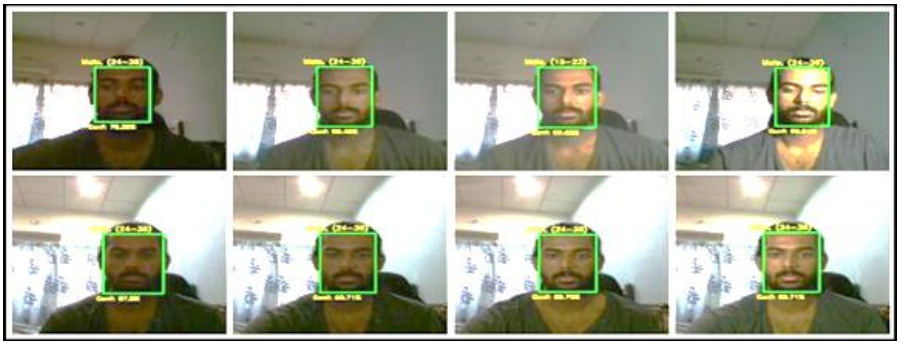

Figure 11. Illuminance without background light versus confidence level

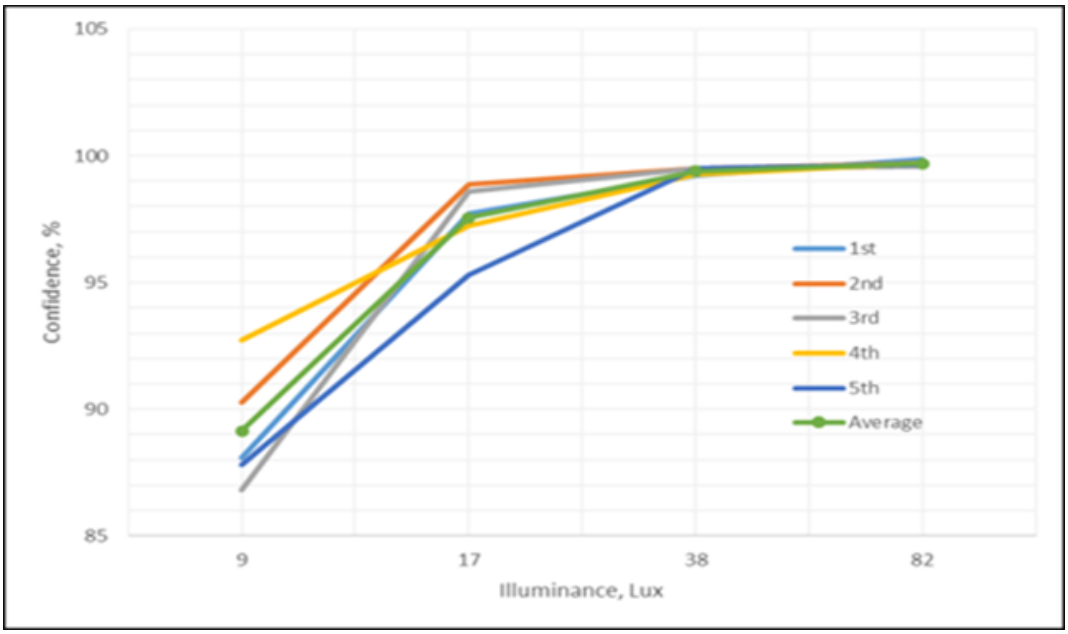

Figure 12. Illuminance with background light versus confidence level

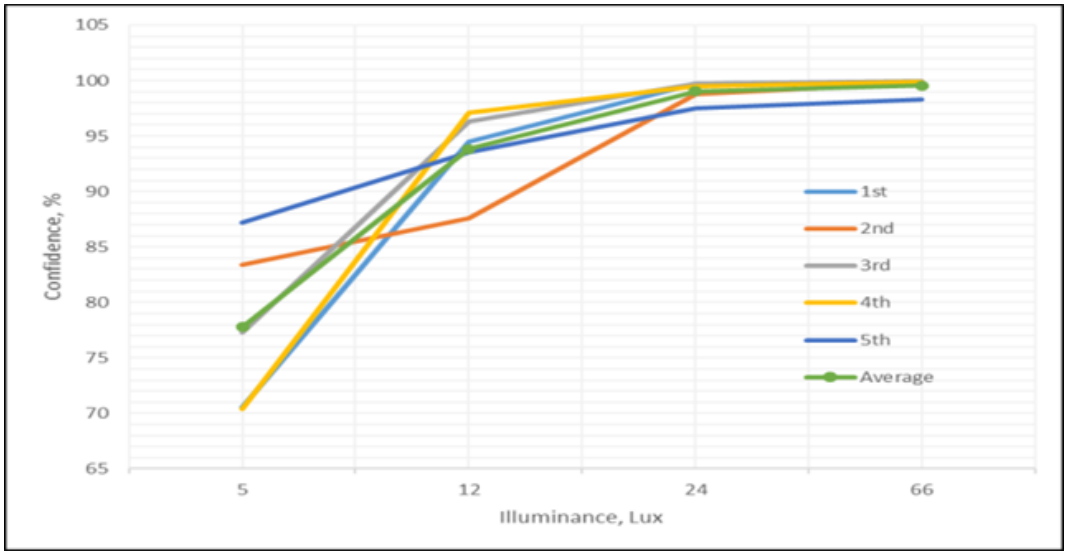

Figure 13. Illuminance without background light versus confidence level

Based on the analyses above, the amount of light fall onto the face will not much affect the confidence unless there is no source of light radiating onto the face. As shown in Figure 12, having an active general light source is sufficient to ensure proper face recognition even if no targeted light source is present. Figure 12 and 13 shows that the confidence level can be improved marginally by having better and intentional light source.

Accuracy and speed are crucial for face recognition. From all the analysis done, the average accuracy obtained is 77.6%. The constraint of this system lies in the recognition of the age group. The human face ages rapidly since newborn but as they mature into adulthood, the growth rate reduces. While teenagers and senior citizens are conveniently recognizable, young adults and the middle aged could fall in the same age category. Another factor that could influence the outcome of the recognition system is cosmetics. Make-ups such as powder and lipsticks could alter the appearances and make faces especially younger women to have a matured look, thus causing misjudgement of age by the system. Apart from that, faces that possess both masculine and feminine qualities also tend to cause false recognition of gender. To overcome this issue, larger databases with faces of androgynous feature should be used for training and validating the model. In terms of speed, more faces detected in a frame at a time would require more processing time. On average, it takes 0.52s to recognise a single face in an instance. An additional of 0.1s is taken for

additional faces. From the recognition speed analysis, female faces tend to require longer time for the system to recognise as compared to male faces. This could be due to the presence of facial cosmetics. Apart from time analysis, the distance between the camera and the face could also be another influencing factor of the system output. As the facial image reduces in size due to the increase in distance, the confidence level of the output drops gradually. A distance too far from the camera range could not yield any outcome. The lower the confidence level, the higher chance of the system producing a false positive output. Different face pose could also affect the confidence. As this model is trained using frontal face database, the confidence level drops to as low as 70% when the system detects only one side or partially. The system may also fail to detect the presence of a face when it is positioned in an inexact way. In addition to that, the surrounding brightness could also influence the confidence. It is shown that some amount of background light is important to ensure that the face recognition does not produce a false positive outcome.

4. Conclusion

With the rapid development and the increasing popularity among enthusiasts, face recognition is gradually becoming an emerging technology has evolved with better processing power and lower in equipment costs. This field of computer vision will soon be an active part of various domains, from big-scale applications such as marking attendance of factory workers in a manufacturing plant, to identifying shoplifters in a store. Although this technology could be at times challenging, it can help in saving time and resources when it is implemented in a right approach.

In comparison with other biometric techniques, it possesses a better user-friendly approach with low processing time, thus suitable for capturing data in a fast-moving environment. For this purpose, precision and scalability are an important factor when considering an investment for this technology. Various algorithms and models have been built and trained using artificial intelligence such as machine learning and deep learning, since its existence by companies, each competing to present a higher efficiency and higher accuracy systems.

The utilization of face recognition in smart advertisement board has been achieved in this report by using DNN to recognize the age and gender of the detected face and matching the output with a set of advertisements in order to display an appropriate advertisement. Several analyses have been done to understand how effective and reliable this system can be used in the related applications. Although there are many ways that this system could be improved, it will soon be part of the marketing strategy used by businesses in order to promote the services and products to the right consumers.

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