Improving Facial Identification System Based on YOLOv8 Deep Learning Algorithm

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Abstract

In recent years, the interest in biometric identification systems has increased, due to the worry about security matters in the world. Face recognition technique is one type of biometric identification technology and is considered the most widely employed .it represents one of the most significant pattern recognition technologies that use characteristics included in facial images or videos to detect the identity of individuals. Recently, it has become more important as it is used in many security applications. In recent years, Most of the traditional facial identification algorithms have faced limitations in identification and verification accuracy. As a result, this work presents a sophisticated system for face identification adopting a novel algorithm of deep learning: You Only Look Once version 8 (YOLOv8). This algorithm can detect the face identity of different individuals with different positions with high accuracy. The face identification technique consists of four main phases which are the image acquisition phase, preprocessing phase, features extraction phase, and classification phase. The YOLOv8 model has been trained for head pose images (HPI) datasets consisting of 1700 images divided as training, validation, and test images of 1190, 255, and 255, respectively. The experimental results show proposed algorithm achieved a significant improvement in face identification accuracy of 99% of mean average precision in which outperforms many state-of-the-art face identification techniques.

Keywords: face-identification, artificial intelligence, deep learning, convolutional neural networks, you Only Look Once (YOLO).

تحسين نظام التعرف على الوجه بناءً على خوارزمية التعلم العميق YOLOv8

هدى صدام متكال ، احمد هاني يوسف، عماد طارق الشيخلي

الخلاصة:

في السنوات الأخيرة، زاد الاهتمام بأنظمة تحديد الهوية البيو مترية، وذلك بسبب القلق بشأن الأمور الأمنية في العالم. يعد التعرف على الوجوه أحد أنواع تقنيات التعرف على القياسات الحيوية والأكثر استخدامًا على نطاق واسع وتمثل واحدة من أهم تقنيات التعرف على الأنماط التي تستخدم الخصائص المضمنة في صور الوجه أو مقاطع الفيديو للكشف عن هوية الأفراد. في الآونة الأخيرة، أصبحت أكثر اهمية حيث تستخدم في العديد من التطبيقات الأمنية، للوصول إلى الأشخاص. في السنوات الماضية واجهت معظم خوارزميات التعرف على الوجه التقليدية قيودًا في دقة التحديد والتحقق. ونتيجة لذلك، يقدم هذا العمل نظامًا متطورًا للتعرف على الوجه يعتمد خوارزمية جديدة للتعلم العميق: أنت تنظر مرة واحدة فقط، الإصدار الثامن . يمكن لهذه الخوارزمية اكتشاف هوية الوجه لأفراد مختلفين بمواقع مختلفة بدقة عالية. تتكون تقنية التعرف على الوجه من أربع مراحل رئيسية هي مرحلة الحصول على الصورة، ومرحلة المعالجة المسبقة ومرحلة استخراج الميزات، ثم مرحلة التصنيف .تم تدريب النموذج المقترح على مجموعات بيانات صور وضعية الرأس التي تتكون من ١٧٠٠ صورة مقسمة إلى صور تدريب وتحقق واختبار ١١٩٠ و٢٥٥ و٢٥٥ على التوالي. تظهر النتائج التجريبية أن الخوارزمية المقترحة حققت تحسنًا كبيرًا في دقة التعرف على الوجه بنسبة ٩٩٪ من متوسط الدقة ، وهو ما يتفوق على العديد من تقنيات التعرف على الوجه الحديثة.

1. Introduction

Face identification (or face biometrics) has become one of the most significant biometric techniques utilizes distinctive features of human faces to identify or verify an individual's since it is easy to capture and implement compared with other types of biometrics[1-3]. It presents a challenging problem in the field of image analysis and computer vision, and as such has received a great deal of attention over the last few years because of its many applications in various domains [2]. It offers several advantages over other biometric methods face recognition can be done passively without any explicit action or participation on the part of the user since face images can be acquired from a distance by a camera [1]. The face identification can be formulated as follows [3,5]: Given an input face image and a database of face images of known individuals[2], then determine if the identity of the person in the input image is available or no[4,5]. The proposed face identification system consists of four main phases which are the image acquisition phase[4], preprocessing phase, features extraction phase, and classification phase[6]. Means the image acquisition phase detects the Face in the image where the image or video is captured to find the face of the person[7], then the image of the face is preprocessed to enhance the images[8], then extract the best features that represent the user's face image[9]. In the recognition phase, the identifying features in each face image are extracted in the same way as in phase one and compared with existing face features in the database to ensure the identity of each input face image [2,3].Several techniques and algorithms have been developed to improve face recognition performance, Such as Local Binary Pattern (LBP) [4], Principal Component Analysis (PCA) [5], Local Binary Pattern Histograms (LBPH) [6], K-Nearest Neighbor (KNN) [7], and Support Vector Machine (SVM) [7,16]. Recently, deep learning algorithms have been highly effective for computer vision applications because of their efficiency in detecting various types of objects. Deep learning is a subfield of Machine Learning (ML)[7] and Artificial Intelligence(AI) [20] that mimics the way that the human brain gains certain types of knowledge[9].

Due to the weak efficiency of facial recognition systems due to the traditional algorithms used, in addition to the many challenges in facial images in terms of facial expressions, beards, and wearing glasses, used advanced model deep learning (YOLO) to build the face identification system and test it on difficult datasets[7,23]. The CNN deep learning model predicts class probabilities and bounding boxes for all the objects demonstrated in sample images by looking only once at the image [9,22]. For that reason, YOLO takes its name from You Only Look Once [10]. YOLO is one of the most effective algorithms in the field of object detection[11,21]. The deep learning algorithm "You only look once" version 8 was used in this research[22], as this technology can recognize individuals' faces with high accuracy in the face identification system in various facial positions, even in low-quality images[24,25]. This work provides an robust contribution to improving the performance of biometric identification systems in general and facial recognition systems in particular through the use of advanced and modern deep learning algorithms that achieve high accuracy, efficiency and speed in recognizing objects.

2. Related Works

This section presents some face recognition and identification-related works, focusing on the state of the art in this field.

In 2018 Yan et al.[12], Presented a combination of two methods to create a new model for recognizing faces. Markov Stationary Features (MSF) and Vector Quantization (VQ) approaches. The VQ algorithm was performed to quantify the face image's sub-regions into 33 levels. The Multiple Image Sub-Regions (MSR) are combined with the MSF-VQ method to provide features with position information and relations. SVM was utilized for the classification stage. This approach used five types of datasets: FERET,and Yale-B face images. The recognition accuracy for each database is 96.40%, and 93.69, respectively. is hampered by the lack of a comprehensive evaluation of the employed methodology, and the absence of scrutiny regarding the selection and rationale of this approach.

Allagwail et al., in 2019 [4], Introduced the study of face identification with symmetric training images of the face dependent on the Gabor filter, and Local Binary Patterns (LBP) were employed. In addition, local binary pattern-based 2D discrete wavelet transforms with a single-level Gaussian low-pass filter are. The datasets (ORL and Yale) were used. The performance results showed 9٨% identification for both datasets. The limitation of the study lies in the absence of an Examination of the limitations associated with each methodology of feature extraction which restricts the applicability of the findings.

Ling et al., in 2019 [13], proposed using a Convolutional Neural Network (CNN) that relies on self-residual attention for selecting features to recognize faces. This method concentrates on the long-range dependencies of face images by decreasing information redundancies and focusing on the most significant components of the space function and channels. The datasets employed in this work were LFW, Age DB, and CFP. The results of the performance to recognize faces were LFW (95.83%), Age DB (93.47%), and CFP (93.6%), respectively.

Deeba, F., in 2019 [6], Presented a system based on the Local Binary Pattern Histograms (LBPH) technique to recognize faces in the proposed system. This technique is split into three main steps: face detection, facial feature extraction, and image categorization. The framework of the face recognition system uses the HAAR CASCADE algorithm for detection and uses image processing to prepare images. A dataset of face variants was used as a database to train pictures and save images of various persons (30 images per person). The result showed that the accuracy of the face recognition rate was 80 %.

Karanwal Sh. Al., in 2022 [14], Indicated a developed system for face identification by fusing features computed from the HE LBP, LBP, and RD-LBP approaches. After the fusion of these features, the PCA is done to reduce the number of features extracted. The Support Vector Machine (SVM) is used for classification, and images of the face are taken from the ORL and GT datasets. The dataset of the ORL and GT identification accuracy is 97.16% and 91.33%, respectively.

Gautam, G. et al., in 2023 [15], Proposed a model for autism spectrum disorder screening using facial images using YOLOv8 deep learning on a Kaggle. This method achieved a higher accuracy of 89.64% in classification. These results indicate that utilizing the YOLOv8 deep learning model for screening autism spectrum disorder in facial images of children is an effective and cost-efficient method (ASD) to facilitate early intervention.

W. Li. et al., 2024 [18] Introduced a novel deep learning model, named Hyper Face, has been for hyper spectral face recognition. The Hyper Face model is composed of four primary modules, including a pre-fusion module, an encoder, a fusion module, and a decoder. The experimental results demonstrate that the Hyper Face model surpasses other approaches on both the CASIA and Q-FIRE datasets. deep face recognition method effectiveness is challenged by the lack of a recognized analysis with alternative approaches.

Finally, the above researchers attempted to recognize faces using different techniques to improve the accuracy and performance of facial recognition systems. but these studies are limited and do not achieve high accuracy in the facial recognition system and efficiency in performance Due to the absence of a comprehensive examination of the generalization potential and potential weaknesses of the selected algorithmic models. As a result, this study proposed a new model used to detect and recognize human faces based on the advanced YOLOv8 deep learning algorithm, which has high speed and accuracy in detecting and recognizing objects and improves the accuracy of the face recognition system.

3. Facial Identification based YOLOv8 model

The initial phase of the facial identification system involves facial detection, its main function is to identify the facial area in an image for subsequent processing [16]. The image is meticulously analyzed to identify specific landmarks or features on the face, referred to as nodal points [7]. These nodal points, crucial elements of the facial geometry of the individual, such as the distance between the eyes or the width of the nose[8], are utilized to create a face template – a digital representation of the unique features of the face [9]. The model works with multiple images for the region of the face to be identified as the input images[10,17].. labeling the dataset, and optimizing the model as seen in Figure (1). The Facial Identification System includes several distinct steps, as outlined below:

3.1 Face Detection

This step is responsible for identifying face images in input frames captured in various environments[8]. The face detection method used in this stage must be capable of handling the many factors that effect to variability of the face image [11].as shown in figure (2).

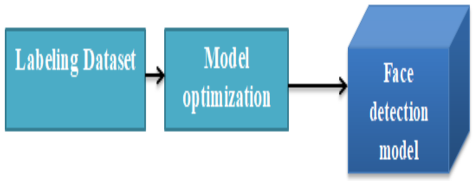


Figure (1): The process of Face detection

(a) (b)

Figure (2): Sample of face detection
(a) original image, (b) face detection

3.2 Preprocessing Stage

Preprocessing data is a significant step that prepares the data for subsequent processes, such as image feature extraction and classification, to train the model [1]. Various techniques have been employed during preprocessing to improve the quality of the extracted features[10]. In the case of real-time facial recognition, preprocessing must account for variations in size and illumination[12], color and geometric transformations[13], standardization, and normalization[14]. See figure (3), shown a sample of contrast enhancement in the images

Figure (3): Improve image contrast in the pre-processing step.

Resampling is used to ensure that all images have the same size, which is crucial for deep-learning models based on CNNs[15]. See Figure 4(a & b) Shows the Image scaling problem in the face detection stage and the image scale of the model training dataset.

Figure (4): Image scaling problem. (a) Face images obtained in the face detection stage and (b) Image scale of the model training dataset.

3.3 The Feature Extraction Stage

The feature extraction stage represents a significant part of face identification systems[15]. It has estimated face image characteristics using a training scheme based on deep learning algorithms[5]. These deep learning algorithms are designed to be used in both face analysis and recognition tasks[16]. The outputs from these layers are fed into a series of pooling layers to reduce the data for the next convolutional layer. The output layers include one or two fully connected layers [17,19].

3.4 Classification Stage

The image containing the face is provided to the model file as input. Then, the region where the face is detected is set as output, and bounding box information is acquired. Finally, the trained Yolo model extracts a 3D feature map. The features extracted are compared with the suspect individual features in the database, and then the classification of these features and the match final score is taken based on the similarity of facial features. The face identification is performed on the frames of the image files given as input to calculate the similarity score. This score is determined by whether the face image of the individual is matched; otherwise, it is not reached, considering there is little or no similarity. The identification is recorded in a database in (Excel) format so that it can search later for which persons were identified in the images. See Figure (5) demonstrates the complete process steps.

4. You Only Looks Once Model

YOLO is one of the most popular deep learning models for real-time object detection and image recognition[9]. It represents a rising computer vision model since 2015. YOLO was created by Ali Farhadi and Joseph Redmon at the University of Washington[10]. The YOLO algorithm has become one of the most common models in object detection[14].

The work of the YOLO algorithm is mainly based on principles of regression[15], which predict and analyze the approaches in the entire image, such as speed, and accuracy in identifying objects [16]. The YOLO algorithm uses a CNN to predict class probabilities and bounding boxes for all objects in sample images, doing so in a single pass[18]. Originally designed for object detection, YOLO has become popular in classification fields due to its fast inference[10]. YOLOv8 represents the latest version of YOLO and uses cutting-edge developments in deep learning and computer vision to provide efficient, flexible, and high-performance real-time image classification and object detection [17]. Its deep CNN architecture includes novel features and improvements such as the Cross Stage Partial Network (CSP Net) backbone architecture[18], the Feature Pyramid Network (FPN) neck structure[20], and the Pyramid Attention Network (PAN) head architecture, which enable it to handle scale variations and occlusion more robustly [21,22]. YOLOv8 divides input images into a grid of cells and predicts a set of bounding boxes in each cell, then selects the most likely ones for each object[24]. To augment images during training, the model shows a little different of the images at each epoch[21]. With a focus on size, accuracy, and speed, YOLOv8 is an excellent option for various visual AI applications [25]. The full details of the YOLOv8 network are demonstrated in Figure (6).

4.1 Key Parameters of YOLO

The basic parameters that must be designed are the training epoch, the rate of learning, Image Size , and the size of batches. The system achieves better performance when increased epochs of training, the duration of training is increased. The learning rate represents the number of steps. when the learning rate is low, the slower the algorithm converges, and the accuracy is high. When the learning rate is high, the algorithm converges faster, so the accuracy is reduced; the learning rate in these experiments was 0.001 for the YOLOv8 networks, size of image was 640 640, size of batches was 16.

5. Experimental Setup

In this section, the proposed face identification system based on YOLOv8 has been presented with materials and methods that are used in this system:

5.1 Dataset

The head pose images (HPI) dataset was employed [19]. This dataset comprises 2790 monocular face images of 15 people with pan and tilt angle variations from +90 to -90 degrees.

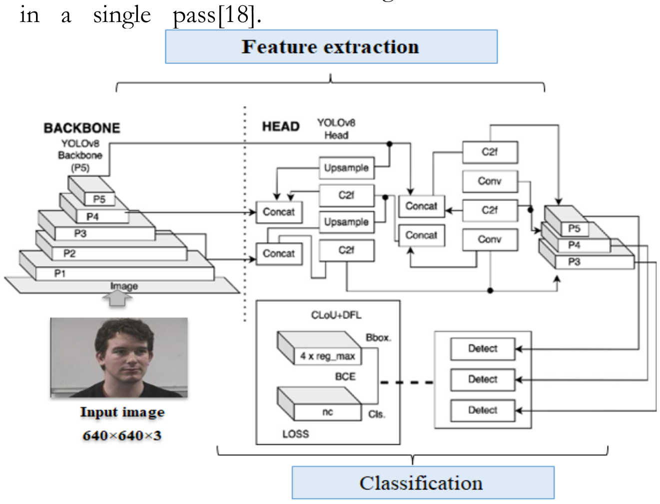


Figure (5): The proposed system of Face identification.

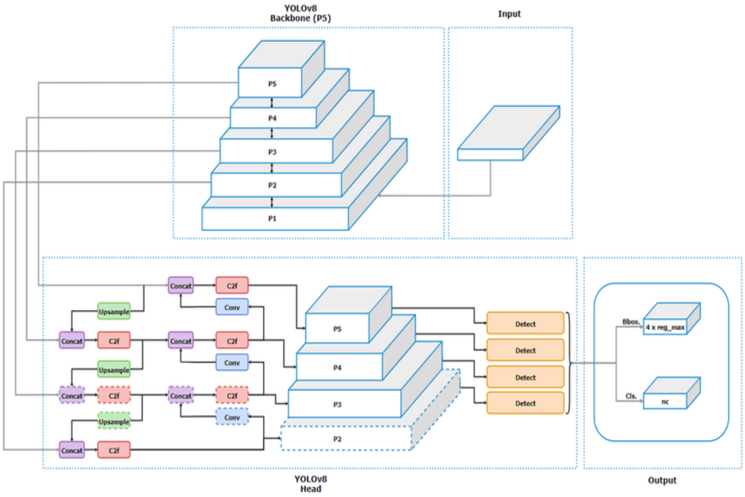


Figure (6): The architecture of YOLOv8 [17]

For every person, there are two groups of 93 images (93 different poses). The purpose of having two groups per person is to be able to train and test algorithms on known and unknown faces. People in the dataset have different skin colors and wear glasses or not. Furthermore, the background is neutral and uncluttered to focus on facial details. Face positions on each image are labeled in an individual text file. Figure (7) depicts a small sample of this data. The number of data used from this data set is 1,700 images, and it has achieved almost high accuracy. Some of the images have the position of the face that does not allow it to be identified or recognized, and the image quality is insufficient. As a result, the images of the entire group of girls were not used.

5.2 Training Process for the Face Identification Model

The training of the facial identification model includes the following steps: data labeling, model optimization, and a training step. The HPI dataset is utilized considerably in face identification tasks. Images are organized based on 17 classes; much of this data is used to achieve better results. These classes names are (face_ID1, face_ID2, face ID3, face ID4, face ID5, face ID6, face ID7, face ID8, face ID8, face ID9, face ID10, face ID11, face ID12, face ID13, face ID14, face ID15, face ID16, face ID17) as shown in Table(1) the sample dataset of different classes.

The face identification process includes data labeling to classify the location of the object in a rectangular area.

Table (1): Samples Data Classes for Classification

Faces Class	Images Number
Face ID1	100
Face ID2	100
Face ID3	100
Face ID4	100
Face ID5	100
Face ID6	100
Face ID7	100
Face ID8	100
Face ID9	100
Face ID10	100
Face ID11	100
Face ID12	100
Face ID13	100
Face ID14	100
Face ID15	100
Face ID16	100
Face ID17	100

Therefore, the location of the object in the image (in this case, the face of the person) is determined by drawing a rectangle with two points (right-top and left-bottom) in the coordinate system. The information about the object in the image is stored in data-containing structures such as TXT, and CSV, which include a file with the same name as the class and information of the image.

Figure (7): Samples of HPI dataset of different classes.

6. Performance Metrics

Many metrics have been adopted to evaluate the performance of the proposed model utilizing the YOLOv8 algorithm. The identification is evaluated based on precision, recall, F1-score, and mean average precision (mAP). Equations 1 to 4 outline these metrics, where APk represents the average precision of class k, and n represents the total number of classes. Equation (5) illustrates the computation of the F1-score. The F1-score is the harmonic mean of precision and recall, and it is a perfect performance measure for imbalanced data since it considers how distributed the data is, where (R) represents recall, and (P) represents precision.

$$\text{Preecision} = \frac{\text{TP}}{\text{TP} + \text{FP}} \times 100\% \qquad \dots.(1)$$

$$\text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}} \times 100\% \qquad \ldots\ldots(2)$$

$$\text{Average Precision(AP)} = \int_0^1 \text{P (r) dr} \qquad \ldots\ldots(3)$$

$$\text{mean Average Precision (mAP)} = \frac{1}{C}\sum_{k=1}^{k=n} \Delta R(k)\, R(k) \qquad \ldots(4)$$

$$\text{F1 Score } \frac{1}{\frac{1}{2}\left(\frac{1}{p}+\frac{1}{R}\right)} = \frac{2 * P * R}{(P+R)} \qquad \ldots\ldots(5)$$

where:

- **TP:** represents the number of positive samples predicted as positive.
- **TN:** Indicated to the number of positive samples predicted as negative.
- **FP:** refers to the number of negative samples predicted as positive.
- **FN:** represents the number of negative samples predicted as negative.

7. Experimental Results

As mentioned before, seventeen target face images from the validation set were selected to represent the identification of faces. Specifically, 1700 images have been used.

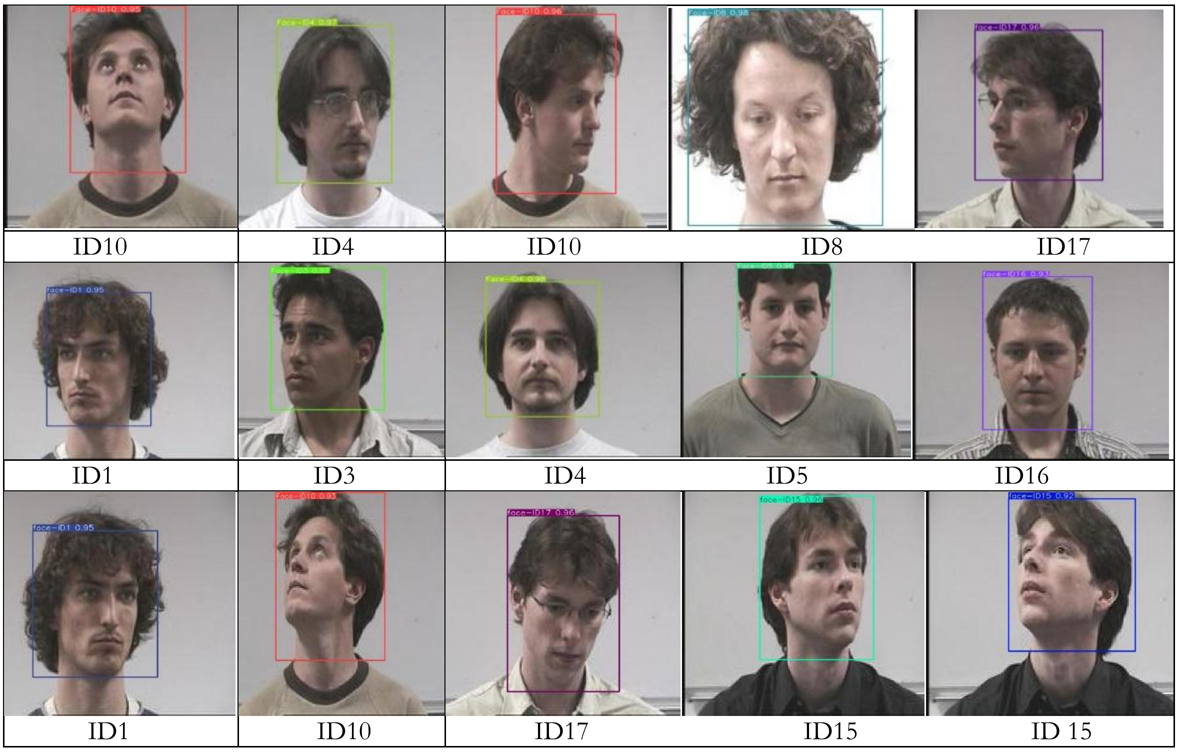


Figure (8): Results of the Face identification process for the HPI dataset.

This dataset was divided into 70% training data (1190 images), 15% validation data (255 images), and 15% test data (255 images) to achieve high performance, as shown in Table 2.

Table (2): Dataset for faces

Training set	Testing set	Validating set
1190	**25٥**	**25٥**

The identification results can be increased to a certain extent to ensure the efficiency of the face recognition system in complicated scenes.

Figure (8) the results of the identification system were efficient in recognizing faces in complicated scenes and different face positions. For instance, the system can identify the persons wearing classes with high accuracy, as seen in ID 4 (Figure 8), which was recognized with and without glasses with high accuracy rates of 98% and 97%. On the other hand, the face identification system can identify faces with different positions, as seen in the face for ID 10; it achieved a recognition rate of 95% and 96% in both images despite different face positions, respectively. Besides, ID1 achieved a recognition rate of 95% in two images with different facial Rotations. Finally, ID15, ID17, and ID3 achieved a recognition rate of 96% for each of them, whether wearing glasses or other complicated facial scenes. Figure (8) shows the results of face identification for different persons for the HPI dataset, in addition to an identification accuracy rate for each one.

Figure 9, (a) presents the results of the HPI dataset where the valid box/ loss (box_loss), valid/ classification loss (cls_loss), and valid/loss (dfl_loss), where achieved low loss function at 0.7, 0.2 and 1.3 respectively.

Train/ (box_loss), train/loss (dfl_loss), and train/ classification loss (cls_loss), where achieved low loss at 0.2, 0.1 and 0.2 respectively.

Table (3): Results of the Training dataset

Face Class	P	R	mAP	F1-score
Face ID1	0.97	1	0.995	0.787
Face ID2	0.977	1	0.922	0.975
Face ID3	0.975	1	0.995	0.980
Face ID4	0.967	1	0.995	0.977
face ID5	0.972	1	0.995	0.977
Face ID6	0.789	1	0.995	0.978
Face ID7	0.99	1	0.995	0.987

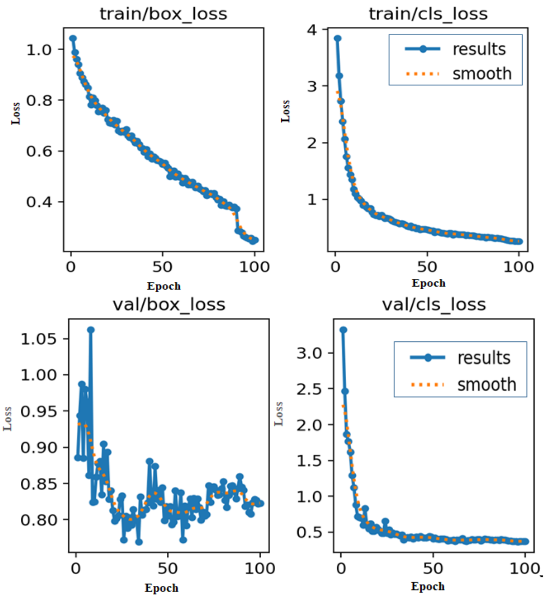
Face ID8	0.789	1	0.995	0.989
Face ID9	0.972	1	0.995	0.783
Face ID10	0.971	1	0.995	0.977
Face ID11	0.967	1	0.995	0.971
Face ID12	0.969	1	0.995	0.961
Face ID13	0.963	1	0.995	0.964
Face ID14	0.965	1	0.995	0.960
Face ID15	0.973	1	0.995	0.970
Face ID16	0.972	1	0.995	0.976
Face ID17	0.971	0.75	0.945	0.970
All classes	0.963	0.985	0.992	0.97

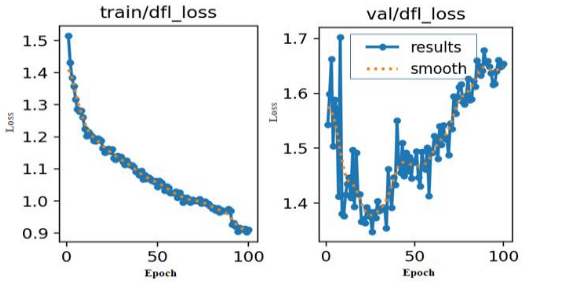
While in Figure 9 (b), shows mAP-50, and mAP 50 -95 achieved accuracy at 98.7 and 96.2. metrics/ precision, and metrics/ recall, achieved an accuracy of 98, 94.8. shows the extent the YOLOv8 algorithm can locate the center of the face. In addition, the extent to which the bounding box predicts the face. On the other hand, it allows Classification loss and the algorithm to predict a face correct class. The model rapidly improves precision, recall, and average accuracy, leveling off about 100 epochs.

A normalized confusion matrix is also made to assess the effectiveness of the proposed model's classification, as seen in Figure (10).

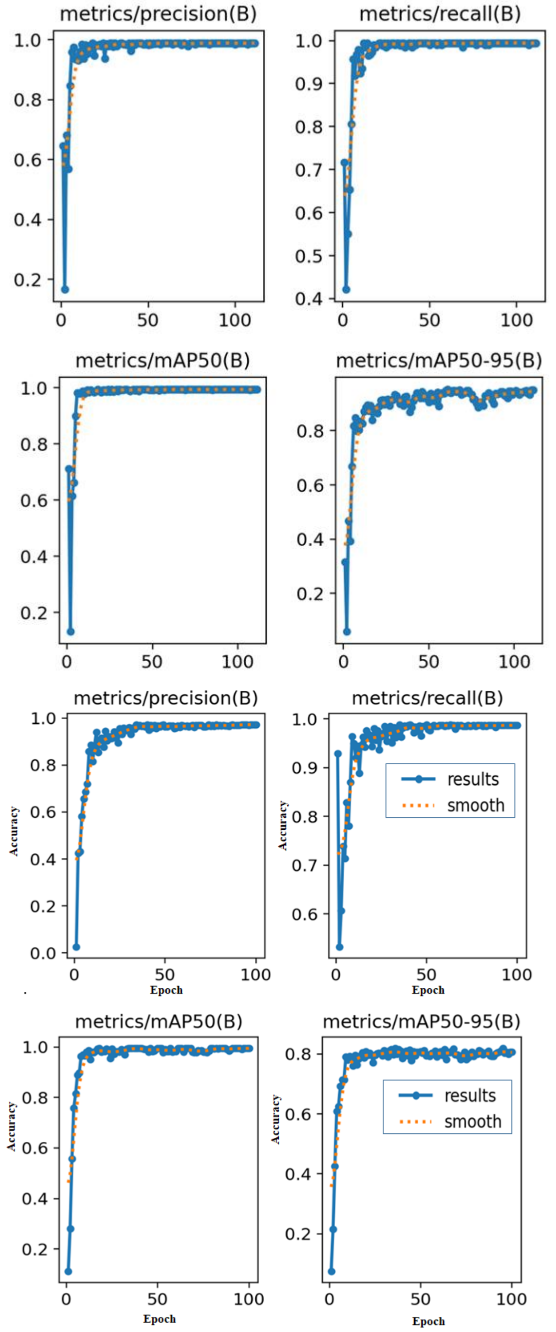
The Performance Comparison curve exhibits the Precision-Recall plots for all face categories of the designated query image.

This graphical representation serves as an effective tool to compare and contrast the precision and recall values of each face class. The curve offers a clear overview of the performance of the face classes in the selected image and demonstrates how to algorithm works in accuracy in different position in faces. See Figure 11.





(a)



(b)

Figure (9): Results of YOLOv8 algorithm in HPI datasets (a) Plots of box loss, abjectness loss, classification loss in the training, validation sets (b) plots of precision, recall, and mean average precision (mAP)in the training, validation sets.

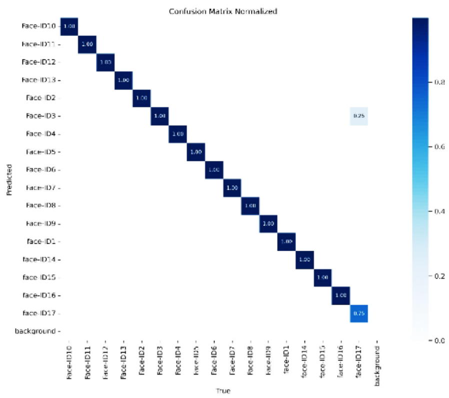


Figure (10): Confusion matrix normalized

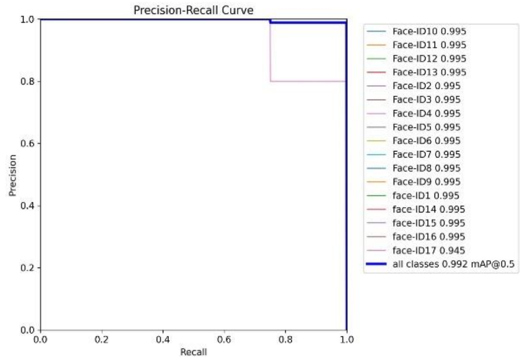


Figure (11): Precision-Recall curve

Although YOLO is an accurate and fast algorithm. but, divides the image into separate cells and restricts the number of faces and bounding box predictions within each cell. This imposes spatial constraints, making it challenging for the algorithm to predict closely spaced faces in this work.

Finally, this work achieved the best results, as shown in Table (4) The total precision was 97 %, the Total Recall was 98%, and the Total mAP was 99%, which is very high compared to other works using the YOLOv8 model.

Table (4): The total precision, the Total Recall and the Total mAP.

Model Training	Time (min)	precision	F1-Score	recall	mAP
YOLOv8	**56m and 2s**	**97%**	**99%**	**98%**	**99%**

8. Conclusions

In conclusion, this research represents a significant leap forward in face identification, leveraging the capabilities of Artificial Intelligence (AI) and Deep Learning (DL) to address challenges facing face recognition algorithms in dealing with different facial positions. It introduced a state-of-the-art facial recognition system, which employs an advanced YOLOv8 deep-learning algorithm. Testing on the HPI datasets showed an impressive increase in accuracy, particularly when identifying different facial positions. Through experimentations, discovered that the YOLOv8 algorithm provides a great balance between real-time speed and exceptional accuracy for object detection across various identification datasets. This algorithm is working significantly in terms of face identification accuracy and false detection rate, which meets the requirements of speed and high accuracy when identifying faces in complex scenes. the proposed system excels in creating generalized representations of objects, making it ideal for applications requiring efficient and robust identification and from far distances and public places.

In future studies, the same work can be used for several security applications where access to the system's privileges requires authentication in real time to track down those who are conducting unlicensed business can be use other types face recognition algorithms and use other dataset so that the system can recognize a higher number of faces at once, making the system significantly more effective.

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