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Research Article

Effectiveness of Feature Extraction Techniques for Facial Identification

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Abstract:

Criminal activities and crime tenancy are increasing in the society when the technology and population increases. The process of identifying and determine criminals and avoiding them from involving in criminal activities are tedious task for police as well as public. Therefore, criminal tracking system is also needed to strengthen. Apart from traditional system, now a days the police and government is also implementing technology based tracking system for criminal identification. An efficient facial feature extraction algorithm and face identification algorithm are needed for this identification system. In this research, the performance of principal component analysis and local binary pattern algorithms are analysed with the support of convolutional neural network.

1. Introduction

Criminal activities like assault, abuse, kidnapping robbery and rape are the hazards for social control and socioeconomic structure. Many criminals may involve in multiple crimes and repeatedly they might involve in such activities. The most efficient method of identifying a criminal and restricting them is facial recognition, a proved biometrics authentication systems. It technically recognize and validate people from images or videos. Face finding, positioning, preprocessing, feature identification and recognition are the part of this technique [1].

This system classifies face into various pixels and recognize patterns and compare it to the photos of the persons which stored in predefined database [1]. Even though it is a complex task due to the diversity in posture of the images and evidence collected from different people and technical changes made by other elements such as environment, lighting and weather conditions [2].

Many face image processing and recognizing algorithms overcomes steeplechase difficulty in identifying optimal influences and dissimilarities of faces to differentiate one from all other faces. Capturing face posture and comparing it with repository is a challenge since all faces have typical parts like eyes, ears, nose, mouth, and etc. in the same place [3]. Apart from these practical difficulties, facial recognition is widely used in offices for attendance purpose, home automation, banking, security and surveillance and law enforcement [4-6].

2. Related Works

A. B. Shetty et. al. made a comparison of Haar Cascade and Local Binary Pattern for face recognition and identified that Haar Cascade is accurate than Local Binary Pattern in their study [7].

Andrew Fredrick Nyoka at.el. proposed face recognition system with libraries called Dlib and Haar Cascade for suspect identification by comparing live image, still picture and videos. In addition, they used Convolutional Neural Network (CNN) as facial recognition algorithm. The system uses a django framework and initially train the dataset by initializing Local Binary Pattern Histogram. Based on execution time, confidence, accuracy and quality of image, they suggested that Haar Cascade library is more effective than Dlib library [8].

The authors concentrate on feature selection, the first stage of Haar cascade classifier to detect and identify faces of individuals even if they are wearing masks or glasses [9]. It increased the applicability and effectiveness of the system. This innovation made a step stone in security and law enforcement system by reducing the difficulty faced by conventional facial recognition techniques [10,11].

The authors discussed about principal component analysis (PCA) and Linear Discriminant Analysis (LDA) [9]. Due to the unavailability of thumbprints, principal component analysis (PCA) is implemented for criminal identification. Haar classifier with weak classifiers are used to distinguish faces with dissimilar qualities and rotations. Face detection and identification is made by CNN and IMDB dataset with a storage of AWS cloud. It focused to improve face image quality during the training phase. For face recognition, they used linear subspace techniques (Eigenface) and neural networks. Singh, Gurlove, and Amit Kumar Goel used PCA as a statistical dimensionality reduction method in face recognition, where it decomposed face pictures into orthogonal modules called as eigenfaces. But, PCA needs full frontal face and so it is effective in data reduction. LDA follows data separation technique and is used for the discovery of discriminative structures during face recognition. LDA can directly work with 2Dimentional images. It was discussed about the challenges such as image quality, pose variations, occlusions and different facial expressions [12]. Also it discussed about the advancements and potential benefits of PCA and LDA in face recognition. The authors suggested PCA for feature extraction and neural network for facial recognition 400 images and 50 eigenfaces are used to produce 97% accuracy in recognition (Oracle Research Laboratory (ORL) face database) [13]. The suggested solution exhibits head orientation sensitivity that causes mismatches with possible rotations of face. Therefore, it overcomes the performance of fuzzy ant as well as k-means and fuzzy C-means algorithms. A deep learning system, FaceNet, is introduced by the authors to support criminal recognition and other security systems [14]. FaceNet model typically used to convert face images into Euclidean, where distance space is for face similarity comparison. This model trained with triplet loss where, the distance is small in similar faces and large in dissimilar faces. In testing phase the model achieved 90% accuracy with different types of images and videos. The manuscript [15] explain about the development of a home security system with Generative Adversarial Networks (GAN), a facial recognition software to make deft judgements. This software uses an android mobile application to establish remote connect with the user and make smooth interaction. An ESP8266 module is also used to give access control for door opening system. If an unauthorized attempt is made to open door, an alarm sound will generate. It shows 80.55% accuracy in testing.

3. Feature Extraction for Facial Recognition

Feature extraction techniques are used in any image processing is to extract more precious information for the accurate prediction. Many researchers used mathematical models and various techniques for feature extraction. The efficiency of classifying and recognizing images are analysed below for further research.

3.1 Principal Component Analysis

Principal Component Analysis (PCA) is an appearance-based feature extraction technique where, the entire face image is considered instead of local features [16]. It take high dimension image data and identifies the dependencies between the variables as orthogonal coordinate axes and even in low dimension, it keep without loosing information [17]. It can be determined by computing eigenvectors and eigen values of the covariance matrix.

Standardization

Standardization technique is used to convert captured images into a standard format where, two dimensional image into one dimensional grayscale image vector. That is, nXn will be moved into $nX1$. The vector V consists of all converted one dimensional images.

Therefore, the mean vector is,

$$mV = \frac{1}{N} \sum_{i=1}^{N} V_i$$

Where,

$$i = number\ of\ images\ in\ database\ (1, 2, 3 \dots \dots N$$

The deviation of the image from mean image is determined.

Covariance Matrix Computation

It is to identify the joint variability between multiple variables of the images are identified.

$$Covariance(a_1, a_2, a_3) = \sum_{i=1}^{N} \frac{(a_1 - a_{\bar{1}})(a_2 - a_{\bar{2}})(a_3 - a_{\bar{3}})}{N-1}$$

Figure 1. *online sample images for feature extraction using PCA.*

The eigen vector of the covariance matrix can be calculated by,

$$\in A = AXA$$

Where, A is a diagonal matrix to represent eigen values of CA.

$$A = diag[\lambda_1, \lambda_2, \lambda_3 \ldots\ldots\ldots \lambda_n]$$

```
[ 1.3497148e+00  1.0167032e+00  1.7700939e+00  5.3824764e-01
  8.9965385e-01  4.2523506e-01 -9.1153061e-01 -9.9022102e-01
  4.9279031e-01 -4.8618343e-02 -4.2826623e-02 -5.7587868e-01
  2.4591373e-01 -4.1432958e-03 -2.7739742e+00 -3.7471718e-01
 -1.6069140e+00  2.7751367e+00 -3.9734650e+00 -1.2851217e+00
 -1.2128751e-01  2.3745762e-02 -9.6040642e-01 -3.2187498e-01
 -3.5324553e-01 -1.2979769e+00  3.3487520e-01 -9.9934295e-02
 -2.6302042e+00  1.1946218e+00 -8.7365758e-01 -1.0567000e-01
  7.6478362e-01  2.1158603e+00  1.3360038e+00  1.0995264e+00
 -3.5852718e-01  2.2306950e+00  5.1781404e-01 -1.7724466e+00
  6.6970462e-01 -4.9686217e-01  1.1890316e+00  2.2028750e-01
 -1.9568156e+00  1.1699631e+00  7.8484732e-01  8.9660281e-01
  2.1733463e+00  1.9340749e+00  4.4534035e+00  8.2118228e-02
  1.5593919e+00  2.1476722e+00  1.0993716e+00 -1.6873212e-01
 -1.5850314e+00  1.2519500e+00 -1.3472126e-01 -9.2188239e-01
  1.5680910e+00 -8.6618531e-01 -3.2524389e-01 -8.4371172e-02
 -4.0636473e+00  2.5421090e+00  2.0595226e+00 -1.3989323e+00
 -1.5022169e-01  9.2893904e-01 -7.1271025e-02  1.3160447e+00
  1.6441277e+00 -1.2656958e+00  3.3900187e+00 -1.2082136e+00
 -1.3820928e+00  2.2269521e+00 -3.5690546e-01  8.8320352e-02
 -9.4522762e-01 -3.3591566e+00  1.7028781e+00  4.2766887e-01
  9.8443758e-01  2.3460910e-01 -1.7699506e+00 -4.8761487e-01
  5.3522563e-01  3.4288416e-01 -1.8257396e+00 -5.0173974e-01
 -5.1942104e-01 -1.7242609e+00 -1.9279726e-01 -3.2423815e-01
  3.4425166e-01  2.1370654e-01 -1.0687368e+00  6.8244612e-01
  1.8088673e+00 -1.7153476e+00  1.6261767e+00  1.3154145e+00
 -1.5390501e+00  1.6679480e+00  8.5339624e-01  1.8764344e+00
 -3.2702115e-01  5.6518537e-01 -1.6494524e+00  8.8881597e-02
  1.1191366e+00 -1.6056672e+00 -2.8104761e-01 -1.5892315e+00
  1.8859613e-01 -7.1929890e-01  9.2462623e-01 -4.3753076e-02
  3.8505694e-01 -2.0502975e+00 -8.3596315e-03 -1.8233823e+00
  4.2984101e-01 -3.7475267e-01 -1.2433647e+00  2.1328247e-01
  7.8152098e-02 -1.0663559e+00 -2.4296358e-01  1.3140870e+00
 -9.4207060e-01 -4.0045708e-01 -2.4870199e-01 -3.9325330e-01
  5.4631847e-01  2.1320245e-01  2.5558668e-01  2.9932779e-01
  3.1098565e-01  1.1294494e+00  3.8095149e-01  7.8978175e-01
 -1.4947204e-01  4.9693215e-01 -1.9031798e+00 -4.5853084e-01
  8.0582160e-01  7.4610412e-01]
```

Figure 2. *Generated diagonal matrix.*

The corresponding eigen vector can be identified as,

$$AX = \lambda X$$

Where,

$$A\ and\ X - Eigen\ vector, \lambda - Eigen\ value$$

Selecting Eigen faces

The eigen values associated with each eigen face represents how much the images in the training set vary from the mean image in that direction.

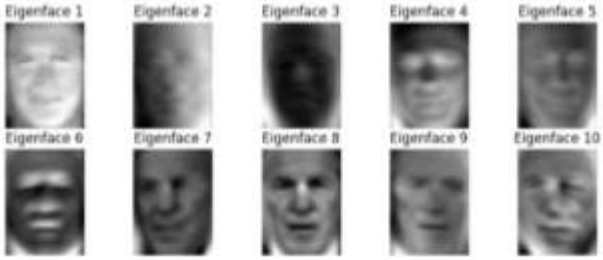


Figure 3. *Eigen face generation in PCA.*

3.2 Local Binary Pattern

Initially Local Binary Pattern (LBP) is used as a texture descriptor and in later stage it has been used for image analysis. It become famous because of the computational simplicity, the tolerance to the natural effects on images and needed single scan of the image.

Texture Descriptor

It is defined as an ordered set of binary comparison of centre pixel and its eight surrounding pixels of a given coordinating point, $(C_p(a_i, b_i))$ [18].

That is, the pixels are labeled through thresholding 3X3 neigbourhood for all pixels with a centre and eight binary value around it to represent different spots on face like curved and flat areas.

The resulting 8 bit LBA code can be defined by,

$$LBA\left(C_p(a_i, b_i)\right) = \sum_{n=1}^{8} N(x_n - x_i)2^n$$

Where,

x_n represents the gray scale of 8 nearer pixels and x_i represents the gray scale of C_p

$$N\ function = \begin{cases} 1\ if\ a \geq 0 \\ 0\ if\ a\ < 0 \end{cases}$$

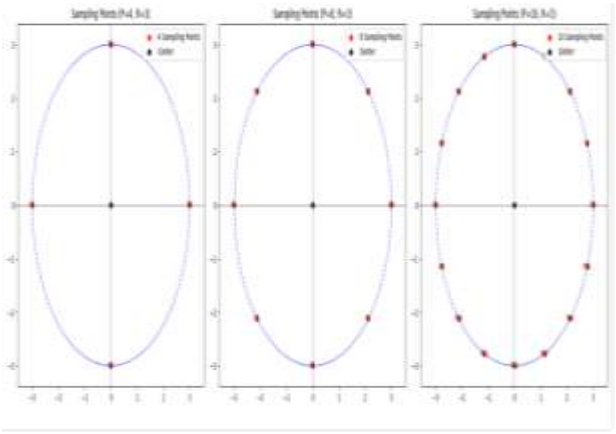
Patterns Extension

Apart from this, LBP is extended to make neighbourhood at circular and bilinear interpolation level. Therefore, it can handle any number of samples and radius in neighbourhood.

That is,

sample points and R radius of the circle is (S,R)

The following figure shows different sampling points and radius:



(a) (b) (c)

Figure 4. *(a) S= 4 and R = 3, (b) S= 8 and R= 3, (c) S=16 and R= 3.*

Adjoining pixels are addressed by the set {$P1$, $P2$... Pn},. Where n shows the quantity of nearby pixels, which is a bunch of focuses equally disseminated on a circle a ways off of R from the middle pixel. Deeply and is every one of the pixels in the picture.

It starts at the adjacent pixels and is clockwise or in a particular direction with respect to the other pixels. Counterclockwise. Must be retained for all other pixels. For example, if you use 3 x 3 blocks or patches, you will see 8 pixels around the center pixel. This contrasts the force of and the middle pixel multiple times and converts the result of the correlation with double. The edge work is applied when the worth of the thing that matters is more noteworthy than or equivalent to the limit for the worth acquired from the contrast between the worth of the middle pixel and the pixel worth of the nearby pixel. ,

Threshold yield is 1, and in the event that the worth is not exactly the limit, yield is zero, which is the kind of example created around the focal point of pixels, like edges, corners, or blotches. After the limit is applied to the distinction esteem, the result will be zero or 1. Since the upsides of all adjoining pixels are 0 or 1, the totaled upsides of all neighbors around the focal pixel structure the twofold code. The paired code for this piece is, which is changed over to decimal organization to get the last worth of the middle pixel. This change is performed by duplicating the worth of each piece by 2i. Where i is the list of pieces {0 ... n-1}, similar to an articulation.

$$LBP = \Sigma\,(-\,i{=}p{-}1\;i{=}0)2i,\; s\,(v)\,\{1\;v \geq 0\;0\;v < 0\}$$

where v is the contrast between the force worth of the adjoining pixel and the power worth of the middle pixel, is the sweep size, is the quantity of contiguous pixels, and s (v) is the limit work.

4. Performance Identification

The performance of both the extraction algorithms can be compared by using an efficient face recognition algorithm. Here a deep learning

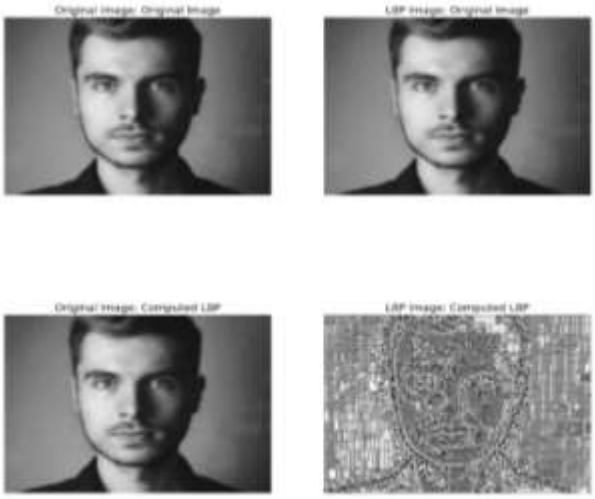


Figure 5. *sample image and LBP computed images.*

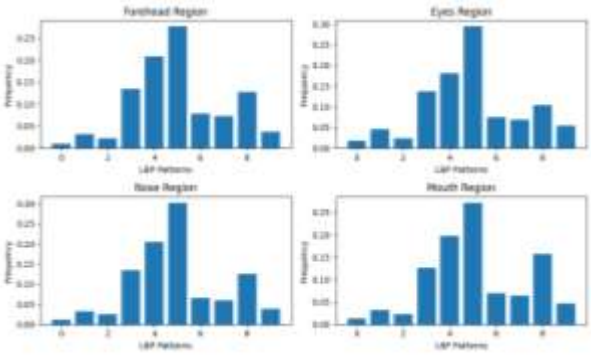


Figure 6. *Histogram for extracted features - forehead, eyes, nose and mouth.*

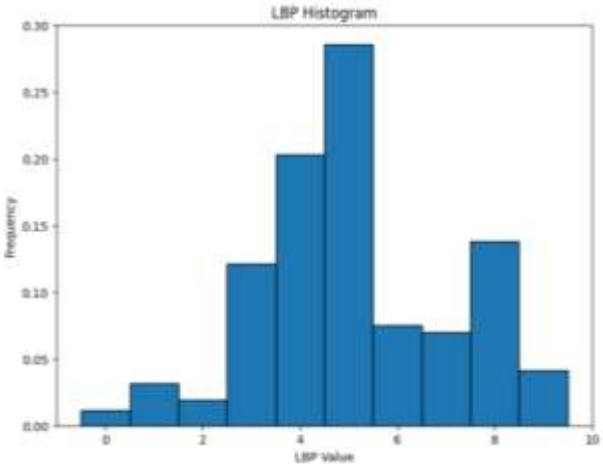


Figure 7. *Histogram for combined features.*

computer vision algorithm known as Convolutional Neural Network (CNN) is implemented to identify the performance of PCA and LBA. CNN consists of five stages where the first stage accepts the images with high and low features extracted by PCA and LBA separately. Then it converts into non-linearity to make linear values into different perception of the neural network. The third step is pooling layer to reduce slip size and parameter number calculation [19]. The flattering layer prepare the data at the input of the fully connected layer where, the learning process is takes place. In this research, CNN performs age classification with 2 fully connected convolutional layers and one output layer. The first layer is having 96 nodes and 7 as kernel size. But, the second and third layers are formed with 5 and 3 kernal size and 256 and 512 nodes respectively. The age classification network is a softmax type which has 8 nodes to represent age groups such as (11-20), (21-30), (31-40), (41-50), (51-60), (61-70), (71-80), (81-100).

5. Experimental Results

Extracted features of PCA and LBP are given to CNN for age classification. The model is trained with online images and tested by using the images which are collected from Kaggle.com. The group images and individual images are used for testing purpose. Both the feature extraction algorithms are classifying face and no-face images and in face images, the features are extracted and that features are given to CNN. Figure 1 shows the online images collected for Principal component analysis. Here 256 images are used for this feature extraction. Figure 2 shows the diagonal matrix of the eigen vector and generated eigen faces are shown in figure 3. Figure 4(a) shows pattern extension of LBP with 4 sampling points on a circle of radius 3, figure 4(b) represents 8 sampling points on a circle of radius 3 and figure 4(c) is for16 sampling points on a circle of radius 3. Figure 5 shows the sample image and LBP computed pixel image. Figure 6 represents histograms for extracted important features such as forehead, eyes, nose and mouth and figure 7 is for the combined histogram.
Figure 8 shows individual images and 9 shows group images of testing cycle where 8(a) and 9(a) are the outcome of age classification technique with PCA as feature extraction. 8(b) and 9(b) shows the outcome of LBP and CNN. Figure 9(a) is PCA+CNN age classification of group of people and figure 9 (b) is LBP+CNN age classification of group of people. Figure 10 shows the classification accuracy of principal component analysis and Convolutional Neural Network.

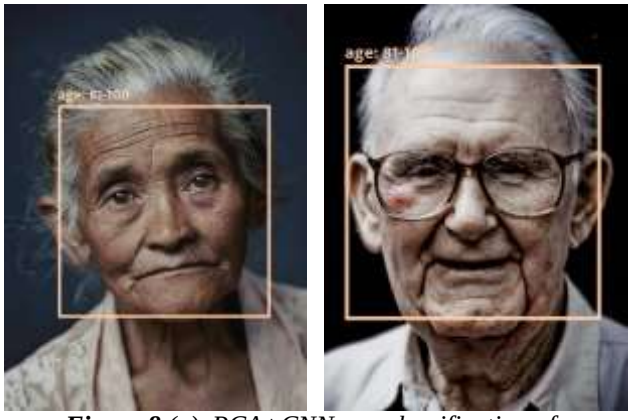
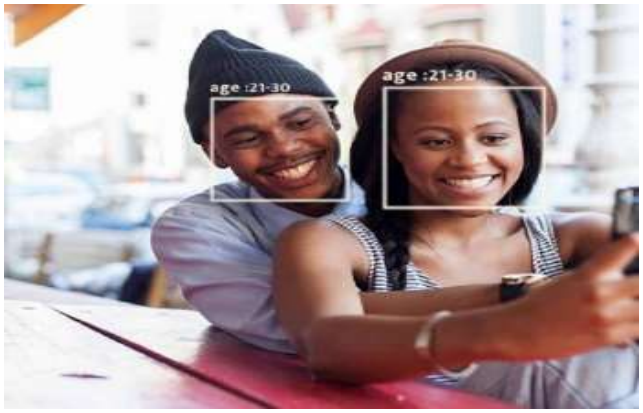


Figure 8 *(a). PCA+CNN age classification of individuals. (b). LBP+CNN age classification of individuals.*



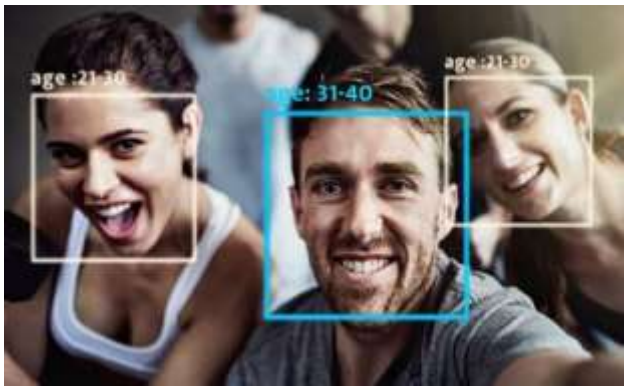


Figure *9(a). PCA+CNN age classification of group of people. (b). LBP+CNN age classification of group of people.*

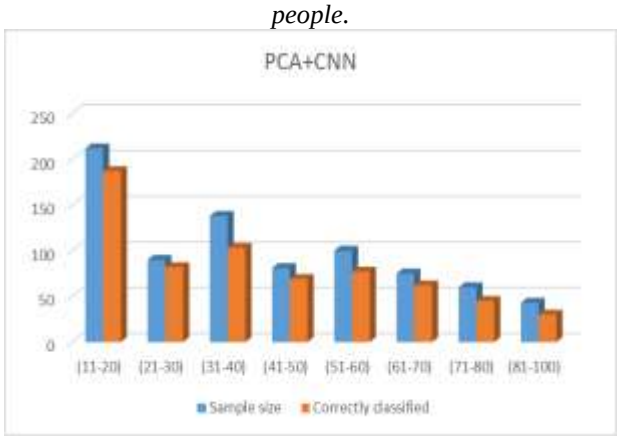


Figure 10. *Age classification accuracy in PCA and CNN.*

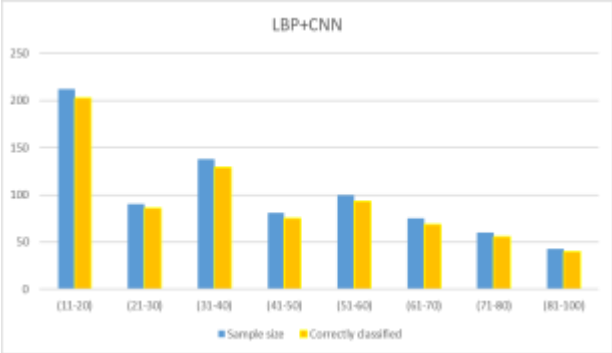


Figure 11. *Age classification accuracy in LBP and CNN.*

This testing stage includes 8 classes of dataset and each class represents different age group. In first age group (11 to 20), 212 images are used for testing and out of that 187 images are correctly classified. Similarly, in the age group of 21 to 30, 82 images are correctly identified with age and the total images in this category are 90. In 31 to 40 age group, 103 are correctly predicted form 138. In 41 to 50 age group, 81 images are given and 6 are correctly identified. In 51 to 60 age group, out of 100, 77 are correctly identified with age. In 6th category (age category is 61 to 70), 62 are correctly predicted from 75. In 71 to 80 age category, 60 facial images are given and 45 are correctly identified with age. In last category, i.e. 81 to 100 age group, 30 are correctly classified from 43.
Figure 11 shows the performance of Local Binary Pattern with Convolutional Neural Network. The same number of images are given as input here and this hybrid method shows better performance than the previous one in all age categories. It correctly identified 203, 86, 129, 75, 93, 69, 56 and 40 faces images from the age group 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80 and 81-100 respectively.

6. Conclusion

In this research work, initially face detection and feature extraction is made with PCA and LBP and the extracted feature values are given to a specially designed CNN architecture. The performance between hybridization of PCA, CNN and LBP, CNN are compared with individual and group images. The facial identification along with age classification is implemented here in Python. The performance of both the models are represented with bar chart and comparatively, the combination of LBP and CNN shows better results in each age categories. In future studies, we will focus on using this hybrid method for criminal identification. Similarly, this methodology can be used by police and government for criminal identification system. Convolutional neural network has been widely used in different application and reported [20-28].

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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