Table 3. Characteristics of articles selected

Author(s) (Reference #)	Title	C1	C2	C3
[10]	Automatic attendance monitoring system using facial recognition through feature-based methods (PCA, LDA)	HR	LR	LR
[11]	Automated attendance system using image processing	HR	LR	LR
[12]	Computer vision on identifying persons under real time surveillance using IOT	HR	HR	HR
[13]	Face detection and recognition-based e-learning for students' authentication: study literature review	HR	HR	LR
[14]	Face recognition-based attendance system using machine learning algorithms	HR	HR	LR
[15]	Human identification recognition in surveillance videos	HR	HR	LR
[16]	Improving the capability of real-time face masked recognition using cosine distance	HR	HR	LR
[17]	LBPH based improved face recognition at low resolution	HR	LR	LR
[18]	Real-time face recognition: A survey	HR	HR	LR
[19]	Recognizing Very Small Face Images Using Convolution Neural Networks	HR	HR	LR
[20]	The Real Time Face Recognition	HR	LR	MR
[21]	Fractional Krill–Lion algorithm-based actor critic neural network for facer recognition in real time surveillance videos	HR	HR	LR
[22]	Technology: Person Identification	MR	MR	HR

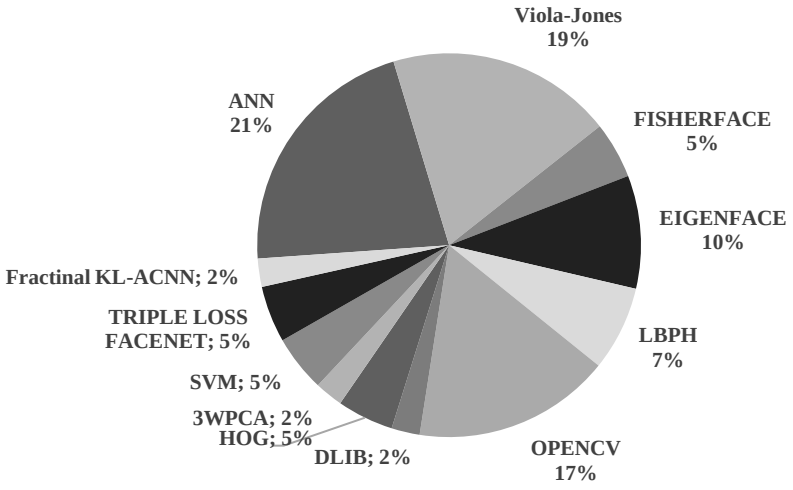

Figure 2. Most frequently identified algorithms

Accuracy is a percentage factor, and represents how much the system can correctly respond to the face samples presented to it. In short, the closer to the value of 100%, the accuracy is considered better, since it recognizes the entire sample according to what is identified in the database.

According to the set of selected articles, the best accuracy corresponds to 98% and was found in three of the articles. Worth highlighting is [10], which presents a solution using HAAR Cascade to classify and detect faces, then applying the Eigenface and Fisherface algorithms to control access and attendance of students in classrooms. The lowest accuracy found is 50%, a result of the experience of [11], who use the HAAR Cascade algorithms for classification/detection, extraction and facial recognition to identify students in the classroom to confirm attendance.

It is important to highlight that the 98% accuracy is also presented by [10], [13] and [14], who built their solutions using HAAR Cascade for detection and ANN for carrying out the complementary steps. It should be noted that the 3 articles that present an accuracy of 98% are from different authors that consider different scenarios and datasets. [10] uses the Olivetti dataset, [13] does not present the dataset used, and [14] built his own dataset with 11 people in different directions of gaze, containing a total of 234 images of 244x244. Considering the accuracy according to

a subset of selected articles, the average among the values was 93%, as shown in Figure 3.

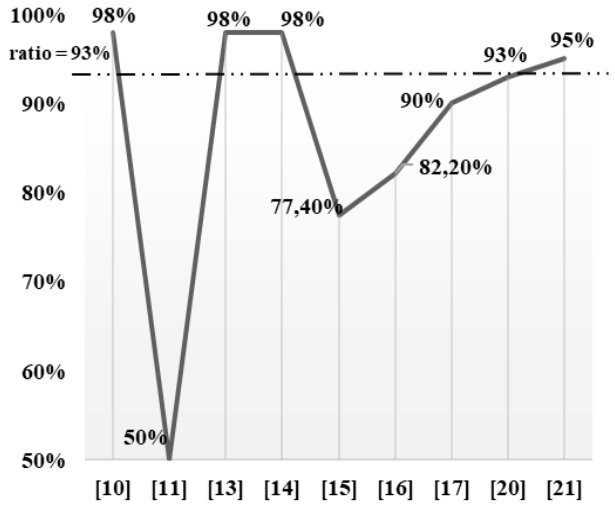

Figure 3. Accuracy ratio according to selected articles

From the verification of the algorithms and according to the solutions presented in the articles analysed, the facial recognition algorithms in real time are highlighted and detailed below. These algorithms correspond to the Artificial Neural Network (ANN), Viola-Jones, Eigenface, Fisherface, LBPH and the OpenCV algorithm library.

4.3. Real time facial recognition algorithms

According to the articles selected, for real-time facial recognition, there are a total of twelve different algorithms used in different solutions. Table 4 presents the algorithms used in each of the three stages of the facial recognition process.

It is possible to verify that there is a greater presence of the ANN and Viola-Jones algorithms, as they represent approximately 40% of the total (Figure 2). The database most used by the authors is the open-source library OpenCV, which has useful characteristics for carrying out the experiments, in addition to contemplating some of these algorithms - ANN, Viola-Jones, Eigenface, Fisherface and LBPH - which facilitate and streamline the development of most solutions. The conclusion is not exact about which method is most used, especially between the different phases of real-time facial recognition.

Artificial Neural Network (ANN)

ANNs correspond to computational techniques that present a mathematical model inspired by the neural structure of intelligent organisms [25] being comparable to the human brain and with the ability to learn from training, store knowledge and later reproduce and replicate such knowledge [26].

The first article on ANN was presented in 1943 by MC-Cullock and Pitts [27] and since then, several models have been developed to meet different purposes. There are several ANN architectures, including the Convolutional Neural Network (CNN), the Multilayer Perceptron Network (MLP) and the Recurrent Neural Network (RNR) [28].

Regarding CNNs, they are recognized for being artificial neural networks that have excellent performance to classify images, group them by similarity and perform object recognition within scenes. These are algorithms that can identify faces, individuals, and many other aspects of visual data such as street signs, fruits, and animals. In short, CNN is a deep learning approach with many hierarchical layers trained, which try to represent the structure in relation to the recognition of an image [29].

Hence, a CNN consists of a set of features extracted from the input image - which are layered using convolutions and subsampling -, and which in the end infers which class the input image will belong to.

According to [30], a CNN has at least three layers:

Convolutional Layer: responsible for filtering and extracting features starting from small portions of the input data, and then passing them on to the next layer in the form of feature maps;

Pooling Layer: layer dedicated to reducing the dimensions of the data received from the Convolutional layer, applying grouping layers;

Fully Connected Layer: present at the end of the network, performing its classification. It uses the features extracted from convolutions performed previously to perform the classification output of the network.

Currently, CNN has shown good levels of accuracy for applications such as face and image detection, video recognition and voice recognition; thus, becoming a relevant tool in the field of machine learning for these types of applications [30].

Viola-Jones

The Viola-Jones algorithm was developed by researchers Paul Viola and Michael Jones in 2001 [31], it is a low computational cost algorithm and is characterized by high performance in facial recognition in real time [32]. Its operation is based on the so-called HAAR filters, which represent the image in a feature space called HAAR features, to extract representative features of the face or a variety of objects [33]. Also known as HAAR Cascade, the Viola-Jones algorithm is implemented in the OpenCV library [34] and in OpenBR [35].

The facial recognition performed using the algorithm proposed by Paul Viola and Michael Jones is divided into three steps. In the first step, HAAR filters are used to create a spatial image that results in the full image. The second step is training using the Boosting classification method, which, in the case of the Viola-Jones algorithm, uses AdaBoost, a high-precision training classifier, to later

Table 4. Algorithms applied to the facial recognition process

Author(s) (reference #)	Title	Facial Recognition Phases		
		Detection	Extraction	Facial Recognition
[10]	Automatic attendance monitoring system using facial recognition through feature-based methods (PCA, LDA)	HAAR Cascade Viola-Jones	Eigenface Fisherface	Eigenface Fisherface
[11]	Automated attendance system using image processing	HAAR Cascade Viola-Jones	Eigenface Fisherface	Eigenface Fisherface
[12]	Computer vision on identifying persons under real time surveillance using IOT	Dlib	HOG +Dlib	ANN
[13]	Face detection and recognition based e-learning for students authentication: study literature review	HAAR Cascade Viola-Jones	3WPCA	ANN (CNN)
[14]	Face recognition based attendance system using machine learning algorithms	SVM	Eigenface	ANN (CNN)
[15]	Human identification recognition in surveillance videos	Viola-Jones	LBPH	ANN (CNN)
[16]	Improving the capability of real-time face masked recognition using cosine distance	HAAR Cascade Viola-Jones	ANN	ANN
[17]	LBPH based improved face recognition at low resolution	HAAR Cascade Viola-Jones	LBPH	LBPH
[18]	Real-time face recognition: A survey	HAAR Cascade Viola-Jones	LBPH	ANN (CNN)
[19]	Recognizing Very Small Face Images Using Convolution Neural Networks, 2020.	ANN (CNN)	ANN (CNN)	ANN (CNN)
[20]	The Real Time Face Recognition	HAAR like Viola-Jones	Viola-Jones	Viola-Jones
[21]	Fractional Krill–Lion algorithm based actor critic neural network for facer recognition in real time surveillance videos	Viola-Jones	LBP	ANN
[22]	Technology: Person Identification	HAAR Cascade Viola-Jones	HOG +Dlib	ANN (CNN)

obtain the most relevant characteristics of the integral image. Finally, the third step is the creation of the HAAR Cascade, which is a tree structure also known as cascade classifiers [33].

The Viola-Jones algorithm is also referenced by HAAR Cascade in OpenCV, because it uses the resources of HAAR features, which are masks that change the luminosity to characterize an object [36]. The masks capture variations in different directions and amplitudes to be trained using the AdaBoost algorithm to generate classifiers, one for each HAAR feature.

In their work Viola and Jones [31] present the three basic types of masks, as follows:

Characteristics of two rectangles: the numerical value is the difference between the sums of pixels contained in both rectangles. The regions have the same area and are adjacent;

Characteristics with three rectangles: the numerical value is the calculation of the difference between the outer and inner rectangles multiplied by a weight to compensate for the difference in areas;

Characteristics of four rectangles: the numerical value is the calculation of the difference between diagonal pairs of rectangles.

In summary, Viola-Jones, or Haar Cascade, is an algorithm for object detection that uses several classifiers.

Eigenface

Eigenface is the set of eigenvectors of a covariance matrix of a set of faces. According to [37], it is a method that seeks to delimit a set of characteristics independent of the geometric shapes of the face, such as the eyes, mouth, nose and ear and, for that, it uses the information of representation of the face.

Eigenface uses the PCA algorithm for dimensionality reduction, which is very convenient for reducing the magnitude of the data and, consequently, optimizing the number of images in the dataset. Also known as Karhunen-Loeve methods, PCA, when applied to facial recognition, is called Eigenface [38].

The PCA, from statistical analysis based on the existing redundancy and variance in the data, reduces the dimensionality of the data without changing the information, so that the result does not change. According to [39] the Eigenface algorithm is an appearance-based method, as it is an algorithm that does not require prior knowledge about what will be recognized, and as special detail is that the algorithm searches for the main

components at the time of recognition: the eigenvectors that describe a person's face.

However, it is important to highlight that the Eigenface algorithm is sensitive to lighting conditions and also to some types of noise, which compromises its efficiency and worsens the accuracy of the system [40].

Fisherface

The Fisherface algorithm is considered an evolution of the Eigenface algorithm [41]. Fisherface uses the LDA algorithm [42], which is an alternative to the use of PCA. The LDA algorithm is also known as Fisher Linear Discriminant Analysis (FLDA) [41], which is based on linear combinations of variables based on weight factors that determine which group the object belongs to [42]. Ref. [43] also highlited that the Fisherface algorithm is a useful statistical method for reducing dimensionality, preserving the information as much as possible.

LBPH

The Binary Local Pattern (LBP), initially presented by [44] and, later, by [45] introduced the LBP as a descriptor based on texture features extracted from regions of the face, which uses a binary pattern. When the LBP pattern is integrated into the HOG classifier, it is called LBPH, considering the composition of the LBP algorithm with the histogram.

LBPH is based on the local binary operator, whereby the operator allocates a label to each pixel value of each image, performing the comparison and checking if the neighboring pixel value is greater than the central pixel, returning a value of '1' in this case – but if the neighboring pixel is smaller, the value '0' is returned. At the end of all the comparisons, there is a binary number, which, converted to decimal, will form a histogram [46].

OpenCV

The open-source library OpenCV stands out in interfacing and working with facial recognition algorithms: Eigenface, Fisherface and LBPH [47], found in various applications.

OpenCV was created and developed by Intel Corporation for computer vision applications. The highlight for this library is the efficiency in real-time computer vision applications. This library is compatible with Windows, Mac Os and Linux operating systems and is also available for IOS and Android platforms, has interfaces for Python, C ++ and Java languages [47]. Its more than 500 functions are divided into five groups: image processing, structural analysis, motion analysis and object tracking, pattern recognition, camera calibration and 3D reconstruction.

5. Conclusion

Facial recognition, as described in this article, is divided into three stages, starting with detection, followed by feature extraction, and ending with facial recognition itself. A greater presence of Artificial Neural Networks (ANN) is identified for the facial recognition stage, with greater emphasis on the Convolutional Neural Network (CNN). However, the other steps are marked by well-defined algorithms, and for the detection phase, the Viola-Jones is the most used. For the feature extraction phase, the Eigenface and Fisherface algorithms are very present; they are based on the PCA. The use of composite solutions aims to improve the response time of the entire facial recognition system, achieve operational simplification and improve the response to eliminate the False Rejection Rate (FRR) and False Acceptance Rate (FAR).

Finally, the accuracy found in the solutions identified in the articles selected from the research had an expressive value, with a maximum of 98%, in three different cases, and 50% as the lowest accuracy value. A mean accuracy result of 93% was identified. However, it is not possible to determine which the best solution is, since these accuracies were obtained from different experimental models, that is, without standardization, which makes it difficult to determine a relationship between them.

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