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# Face Recognition: A Literature Review

**Gabriela Laura Salagean**[1]
**Monica Leba**[2]

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**Abstract:** *Face recognition is a crucial and rapidly evolving field within computer vision and artificial intelligence. The human face is one important element for recognizing a person in a group. The mechanism used by the human brain for face recognition is not yet fully understood, making it a complex problem. Over the past decade, there have been significant advancements in both the accuracy and applicability of face recognition systems. Deep learning techniques, particularly convolutional neural networks (CNNs), have played a pivotal role in achieving state-of-the-art performance in face recognition tasks. This paper proposes a review of research on face recognition techniques, algorithms and existing applications, with their advantages and disadvantages. It also includes a comparison of the results obtained with various algorithms and the related limitations. In the last part, it presents future directions of development in the field of face recognition.*

## 1. INTRODUCTION

Face recognition is a topic that has been and will be studied by many researchers from various field points of view. The human face is one of the most important elements for recognizing a person in a group. It exhibits particular, unalterable physical characteristics that can be captured in a photograph.

People recognize faces with the help of two components: the sensors which are inside the eyes and the processor, which is the brain. The mechanism used by the human brain for face recognition is not yet fully understood, making it a complex problem.

Face recognition is a crucial and rapidly evolving field within computer vision and artificial intelligence. Various algorithms have been implemented and face recognition applications have been developed. Over the past decade, there have been significant advancements in both the accuracy and applicability of face recognition systems. Deep learning techniques, particularly convolutional neural networks (CNNs), have played a pivotal role in achieving state-of-the-art performance in face recognition tasks.

No matter the method or algorithm chosen, all researchers use the three main stages of facial recognition: face detection, feature extraction and face recognition.

The evolution of facial recognition techniques can be grouped into five significant phases described in Adjabi et al. (2020) research paper:

**Phase One:** 1964 - American researchers Bledsoe et al. studied facial recognition based on human markers obtained through manual measurements.

[1] Doctoral School, University of Petrosani, street Universității, no. 20, 332006, Petroșani, Romania
[2] Faculty of Mechanical and Electrical Engineering, University of Petrosani, street Universității, no. 20, 332006, Petroșani, Romania

**Phase Two:** 1988 - Artificial intelligence was introduced, specifically the use of linear algebra in facial recognition algorithms. This leap facilitated a more systematic approach to the analysis of facial features, laying the foundation for more accurate methods.

**Phase Three:** 1991 - Alex Pentland and Matthew Turk from the Massachusetts Institute of Technology (MIT) presented the facial recognition algorithm called Eigenfaces, which uses the statistical method of principal component analysis (PCA) to represent facial features, allowing significant progress in accuracy and reliability.

**Phase Four:** 1998 - Defense Advanced Research Projects Agency (DARPA) implemented the FERET program. FERET encouraged innovation and provided a sizeable database of 2,400 images for 850 individuals.

**Phase Five:** 2011 - Deep learning was integrated into facial recognition.

## 2. RESEARCH METHODOLOGY

Face recognition: A literature review is an exhaustive investigation aimed at synthesizing the knowledge related to face recognition. This approach begins by identifying the current state of the art or knowledge in the face recognition field, explores existing gaps, and concludes by making strong arguments to provide directions for future research. Kitchenham and Charters (2007) in their Guide to conducting systematic literature reviews in software engineering proposed a plan for carrying out such research, which includes: Planning, Conducting, and Presentation of the results.

In the planning phase, we defined the research question: What is the best method or algorithm for facial identification?

To be able to answer this question, we studied articles that presented studies on the accuracy of facial recognition algorithms. We considered articles published in one of the scientific article databases Web of Science and Scopus from the last 5 years.

In the conduction phase, in order not to limit the search and to obtain the most relevant articles, we used the following keywords: algorithms for facial recognition, deep learning algorithm for facial recognition. We obtained 10 articles which were of interest to our research.

## 3. RESEARCH RESULTS

According to Jing et al. (2023) and our synthesis of recent literature, conventional facial recognition algorithms can be grouped into: local, global and hybrid algorithms. This classification was done according to the approach to feature extraction. Local algorithms - mainly focus on specific facial features such as nose and eyes. Global algorithms - focus on the whole face to generate feature vectors for classification. Hybrid algorithms - combine both local and global facial features.

Analyzing the published articles, we noticed that the most commonly used methods are Eigenfaces and Fisherface.

The Eigenfaces algorithm was one of the pioneering methods in the facial recognition field. This method was implemented by Turk & Pentland in 1991 and is based on creating an “eigenface”

based on a provided facial image and calculating the Euclidean distances between the face and the set of created eigenfaces. The self-face with the smallest Euclidean distance signifies the greatest similarity to the individual. A strong correlation is expected between the training data and recognition data. Çarıkçı and Özen (2012) implemented this method and the success rate for this method is 94.74% in specific conditions.

Fisherface or Fisher's Linear Discriminant (FLD) is based on face space dimension reduction using the Principal Component Analysis (PCA) method to obtain the feature image. Anggo and La Arapu (2018) implemented this method and the success rate of this method in facial recognition is 93%.

Sveleba et al. (2019) developed the system based on the Viola-Jones algorithm, used to detect people in a sequence of video images and local binary templates achieved 93% accuracy.

Shan and Gritti (2008) present in their paper the implementation of the LBP-Discriminative Histogram bins (LBPH) algorithm for the task of facial expression recognition and by adopting SVM with the selected multiscale LBPH bins, achieving an accuracy of 93%

After studying the articles on the accuracy of facial recognition of the methods presented above, we identify and agree with Jin and Sheeja (2019) and Himanshu and Prabhakar (2023) that these methods have limitations related to head orientation, lighting conditions, image quality, and occlusion.

To eliminate these limitations, researchers have proposed face recognition methods based on neural networks.

Deep Learning-based techniques represented a revolution in the field of facial recognition and have enabled the establishment of exceedingly precise and resilient facial recognition systems, effectively tackling a multitude of challenges, encompassing variations in lighting, facial orientations, and expressions.

Adjabi et al. (2020) classified the Deep learning methods into three primary categories based on the utilization of the technique and architecture:

a) Unsupervised or generative: auto encoder (AE), Boltzman machine (BM), recurrent neural network (RNN), and sum-product network (SPN);
b) Supervised or discriminative: convolutional neural network (CNN);
c) Hybrid: deep neural network (DNN).

Analyzing the selected articles, especially those using artificial neural networks (ANN), two analysis directions are outlined. The first direction focuses on the segregation of technologies applied at each stage of the facial recognition process, and the second focuses on heterogeneous solutions (the authors of the articles conducted tests to determine the stages in which the algorithm fits best, analyzed and sought to achieve higher levels of accuracy).

Karthick et al. (2021) implemented HAAR Cascade algorithm for face recognition and Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) as statistical data classifiers to develop facial recognition methods and achieved an accuracy level of 98% in both methods.

Jin et al. (2019) proposed a dual recognition approach (adding pedestrian motion recognition to the whole face recognition process) to improve the performance and accuracy of the system, the solution accuracy reached 77.4% compared to 67.7 % in solutions using only one approach.

The study made by Maharani et al. (2020) used HAAR Cascade and MobileNet for face detection, integrating the cosine distance method. In the facial recognition stage, they used Visual Geometry Group 16 layers (VGG16) learning transfer methods The accuracy rates varied across scenarios, with VGG16 achieving up to 100% accuracy in specific conditions. When they used Triplet loss FaceNet algorithms in the facial recognition stage, they achieved 82.20% accuracy.

DeepFace was proposed by Taigman et al. (2014) and was one of the first methods to achieve 97.35% accuracy. DeepFace uses 3 deep neural networks with 9 layers trained for facial recognition.

FaceNet was suggested by Schroff et al. (2015) and used a GoogleNet architecture network with a triplet loss function at the final layer. The method has an accuracy of 99.63 %.

Deng et al. (2017) implemented the marginal loss function using a network with ResNet-27 architecture obtaining an accuracy of 99.48%.

Method CosFace introduced a new loss function called large-margin cosine loss (LMCL) to conduct a ResNet-64 network to learn more discriminative features for face recognition and was proposed by Wang et al. (2018) This method has an accuracy of 99.73%.

ArcFace is a method developed for face verification and recognition tasks. In the variant implemented by Deng et al. (2019) it is based on a network with ResNet-100 architecture. It is specially designed to generate discriminative features for face recognition. It is widely used in computer vision for tasks involving facial recognition because it has an accuracy of 99.62%.

Ling et al. (2020) introduced an attention-based neural network (ACNN) to learn the global feature relationships of aligned facial images. This network aims to embed discriminative facial features, which intends to reduce the information redundancy between channels and focus on the most informative elements of facial feature maps.

Regarding the programming languages for implementing the algorithms, they were Matlab and Python.

## 4. FUTURE RESEARCH DIRECTIONS

Despite these advancements, several challenges remain in the field of face recognition. There is an ongoing need for more diverse and representative datasets to reduce bias in face recognition algorithms, single-sample face recognition (only one face representation for each individual in the training set) is one of the most challenging problems. Another challenge is related to facial aging because the aging process affects the shape and texture of the face. Another significant issue is the need to balance accuracy with privacy and security concerns. Striking the right balance between the convenience of face recognition technology and safeguarding individual privacy remains a complex challenge.

Researchers and practitioners must continue to address these challenges while striving for further improvements in accuracy and efficiency to enable the responsible and ethical deployment of face recognition systems in various applications, from security and authentication to human-computer interaction and healthcare.

## 5. CONCLUSION

Facial recognition algorithms are in continuous development, constantly improving their accuracy and reliability. These characteristics of algorithms are very important in security and privacy applications. The main purpose of this research was to provide a brief performance analysis of the most widely used facial recognition algorithms. The results of our study are especially useful for researchers and professionals who need to choose and implement the right algorithm in different contexts. Results demonstrate that models based on convolutional neural networks are superior in facial recognition tasks.

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