Machine learning models in people detection and identification: a literature review

Modelos de aprendizaje automático en la detección e identificación de personas: una revisión de literatura

Modelos de aprendizado de máquina na detecção e identificação de pessoas: uma revisão de literatura

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Abstract

Introduction: This article is the result of research entitled "Development of a prototype to optimize access conditions to the SENA-Pescadero using artificial intelligence and open-source tools", developed at the Servicio Nacional de Aprendizaje in 2020.

Problem: How to identify Machine Learning Techniques applied to computer vision processes through a literature review?

Objective: Determine the application, as well as advantages and disadvantages of machine learning techniques focused on the detection and identification of people.

Methodology: Systematic literature review in 4 high-impact bibliographic and scientific databases, using search filters and information selection criteria.

Results: Machine Learning techniques defined as Principal Component Analysis, Weak Label Regularized Local Coordinate Coding, Support Vector Machines, Haar Cascade Classifiers and EigenFaces and FisherFaces, as well as their applicability in detection and identification processes.

Conclusion: The research led to the identification of the main computational intelligence techniques based on machine learning, applied to the detection and identification of people. Their influence was shown in several application cases, but most of them were focused on the implementation and optimization of access control systems, or tasks in which the identification of people was required for the execution of processes.

Originality: Through this research, we studied and defined the main machine learning techniques currently used for the detection and identification of people.

Limitations: The systematic review is limited to information available in the 4 databases consulted, and the amount of information is variable as articles are deposited in the databases.

Keywords: Machine Learning, People detection, People identification, Software, Performance.

Resumen

Introducción: Este artículo es el resultado de la investigación titulada " Desarrollo de un prototipo para optimizar las condiciones de acceso al SENA-Pescadero utilizando inteligencia artificial y herramientas de código abierto", desarrollada en el Servicio Nacional de Aprendizaje en 2020.

Problema: ¿Cómo identificar las técnicas de aprendizaje automático aplicadas a los procesos de visión por computador a través de una revisión bibliográfica?

Objetivo: Determinar la aplicación, así como las ventajas y desventajas de las técnicas de aprendizaje automático enfocadas a la detección e identificación de personas.

Metodología: Revisión sistemática de la literatura en 4 bases de datos bibliográficas y científicas de alto impacto, utilizando filtros de búsqueda y criterios de selección de información.

Resultados: Técnicas de aprendizaje automático definidas como Análisis de Componentes Principales, Codificación Local de Coordenadas Regularizada de Etiquetas Débiles, Máquinas de Vectores de Soporte, Clasificadores en Cascada de Haar y EigenFaces y FisherFaces, así como su aplicabilidad en procesos de detección e identificación.

*Conclusiones***:** La investigación permitió identificar las principales técnicas de inteligencia computacional basadas en machine learning aplicadas a la detección e identificación de personas. Su influencia se mostró en varios casos de aplicación, pero la mayoría de ellos se centraron en la implementación y optimización de sistemas de control de acceso, o tareas en las que se requería la identificación de personas para la ejecución de procesos

Originalidad: A través de esta investigación se estudiaron y definieron las principales técnicas de machine learning utilizadas actualmente para la detección e identificación de personas.

Limitaciones: La revisión sistemática se limita a la información disponible en las 4 bases de datos consultadas, y la cantidad de información es variable a medida que se depositan los artículos en las bases de datos.

Palabras clave: Aprendizaje automático, Detección de personas, Identificación de personas, Software, Rendimiento.

Resumo

Introdução: Este artigo é o resultado da pesquisa intitulada "Desenvolvimento de um protótipo para otimizar as condições de acesso ao SENA-Pescadero usando inteligência artificial e ferramentas de código aberto", desenvolvida no Serviço Nacional de Aprendizagem em 2020.

Problema: Como identificar técnicas de aprendizado de máquina aplicadas a processos de visão computacional por meio de uma revisão bibliográfica?

Objetivo: Determinar a aplicação, bem como as vantagens e desvantagens das técnicas de aprendizado de máquina voltadas para a detecção e identificação de pessoas.

Metodologia: Revisão sistemática da literatura em 4 bases de dados bibliográficas e científicas de alto impacto, utilizando filtros de busca e critérios de seleção de informações.

Resultados: Técnicas de aprendizado de máquina definidas como Análise de Componentes Principais, Codificação de Coordenadas Locais Regularizadas de Rótulos Fracos, Support Vector Machines, Haar Cascading Classifiers e EigenFaces e FisherFaces, bem como sua aplicabilidade em processos de detecção e identificação.

Conclusões: A pesquisa permitiu identificar as principais técnicas de inteligência computacional baseadas em aprendizado de máquina aplicadas à detecção e identificação de pessoas. A sua influência foi demonstrada em vários casos de aplicação, mas a maioria deles foram focados na implementação e otimização de sistemas de controle de acesso, ou tarefas em que a identificação de pessoas era necessária para a execução de processos.

Originalidade: Através desta pesquisa, foram estudadas e definidas as principais técnicas de aprendizado de máquina atualmente utilizadas para a detecção e identificação de pessoas.

Limitações: A revisão sistemática é limitada às informações disponíveis nas 4 bases de dados consultadas, e a quantidade de informações é variável conforme os artigos são depositados nas bases de dados.

Palavras-chave: Aprendizado de máquina, Detecção de pessoas, Identificação de pessoas, Software, Desempenho.

1. INTRODUCTION

Computer vision is currently one of the trends of interest in both research and industry [1]. With this type of process, information is obtained to emulate human capabilities in sections of images and videos. The detection of people is one of the main applications of computer vision processes, with influence in security and surveillance, as well as in the identification and tracking of people in video frames [2].

To perform processes related to the detection and identification of people, both image processing and computational learning techniques are generally employed [3]

[4]. In processes in which it is sufficient to detect people in a region of interest or for trajectory tracking, processing techniques such as background subtraction are applied [5], in which the moving object is separated from the background of the image by segmentation and thresholding [6]. However, in processes in which the identification of people is required, learning tools must be applied, such as machine learning and deep learning, in which a group of data (images of a dataset) are subjected to training in order to identify patterns for identification or classification [7]. Computational learning is linked to biometric tools, due to the unique characteristics of human body sections, in which easy characteristics of people are usually used to train the data [8].

Machine learning is one of the most relevant types of artificial intelligence, because the systems learn from data instead of learning by explicit programming [9]. The better the training data, the more accurately the system will generate models. The relation between the amount of data and the quality of the data is important, that is to say, it is not sufficient to simply use a large database, but it is also necessary that these do not generate over-learning. Depending on the application, machine learning can be classified into two main groups: supervised learning and unsupervised learning [10] [11] [12]. In supervised learning, the aim is to identify a pattern in the data, which have labels that define their origin and characteristics. In unsupervised learning, data without labels are used, in which iterative learning is used to analyze the data without the need for human support. An alternative to these learning styles is reinforcement learning, in which instead of learning from the dataset, the system learns by trial and error [13] [14].

This paper presents a documentary review of the techniques used in processes of detection and identification of people based on machine learning. 4 high impact bibliographic databases were consulted, and after filtering by both search filters and selection criteria, the techniques were identified in 50 articles and their application in a real environment was analyzed.

2. METHODOLOGY REVIEW

Figure 1 shows the graph that represents the methodology to be used for the literature review. First, a preliminary review is carried out in which scientific articles related to person identification systems using machine learning tools are searched for. Subsequently, the results obtained in the literature search are classified by determining the most commonly used techniques. Finally, the techniques found are analyzed and discussed, considering the possibilities of implementing the technology.

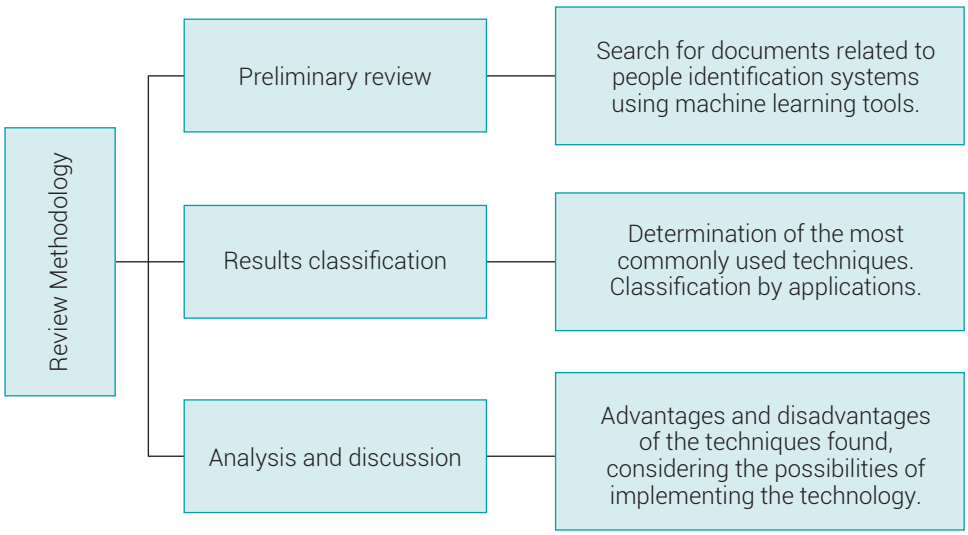

Figure 1. Methodology.
Source: Own work.

A) Preliminary review

The documents were selected through of a manual search in various bibliographic databases and scientific publishers. The pages used for the preliminary review (IEEEXplore Digital Library, Springer, ScienceDirect and Scopus) are listed in Table 1, in which the link to access the web page is also shown. It is important to emphasize that the Google Scholar database was not used because, although it presents a large amount of information, it does not differentiate between the origin of the original file of the article, which would generate redundancy when it comes to quantifying the searches by database. The articles surveyed have been published since 2012.

Table 1. Access link to Databases.

Databases	Access link
IEEEXplore Digital Library	https://ieeexplore.ieee.org/Xplore/home.jsp
Springer	https://link.springer.com/search
ScienceDirect	https://www.sciencedirect.com/
Scopus	https://www-scopus-com. /search/

Source: Own work.

Likewise, the selection of articles was made using search filters. The filters correspond to keywords related to the research topic. The keywords used were: "F1: Machine learning", "F2: People identification" and "F3: Facial". With this, a purification of articles was achieved, leaving in consideration only those related to people identification systems using machine learning tools.

B) Results classification

The articles are classified according to the machine learning technique used for the identification of persons. Likewise, only scientific papers that exceed the following inclusion/exclusion criteria are taken into consideration:

- C1: Investigations directly linked to people detection and identification (since in some cases the search keywords may yield other types of investigations) and which present high success rates in the processes.
- C2: Sufficient information to replicate the research (Clarity in the number of stages, layers, parameters).

C) Analysis and discussion

In this stage, the advantages and disadvantages of each of the techniques found in the systematic literature review are identified. The technological trends in the use of machine learning technologies in people identification systems, and the challenges of these technologies versus their deep learning counterparts, are also discussed.

3. CLASSIFICATION OF INFORMATION

Table 2 shows the list of scientific papers found in bibliographic databases and scientific publishers, taking into account the search filters (F1: Machine learning, F2: People identification) and the inclusion/exclusion criteria C1 and C2.

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Table 2. List of bibliographic databases and scientific publishers.

Parameter	Database			
	IEEEXplore Digital Library	Springer	Science Direct	Scopus
F1	1076	1240	2047	3706
F1+F2	497	785	1141	1054
F1+F2+F3	26	335	256	473
C1	19	26	18	22
C2	14	14	10	12

Source: Own work.

Figure 2 shows the total consolidation of scientific documents searched and filtered for the literature search. Section A shows the reduction of documents of interest when applying the search filters, going from a total of 8069 documents with the first search filter, to 3477 with the second filter, being reduced to 1090 with the third search filter. Similarly, section B illustrates the reduction of documents when applying the selection criteria, going from 1090 with the search filters, to 85 with the first selection criterion, and reduced to a total of 50 scientific documents when applying the second selection criterion.

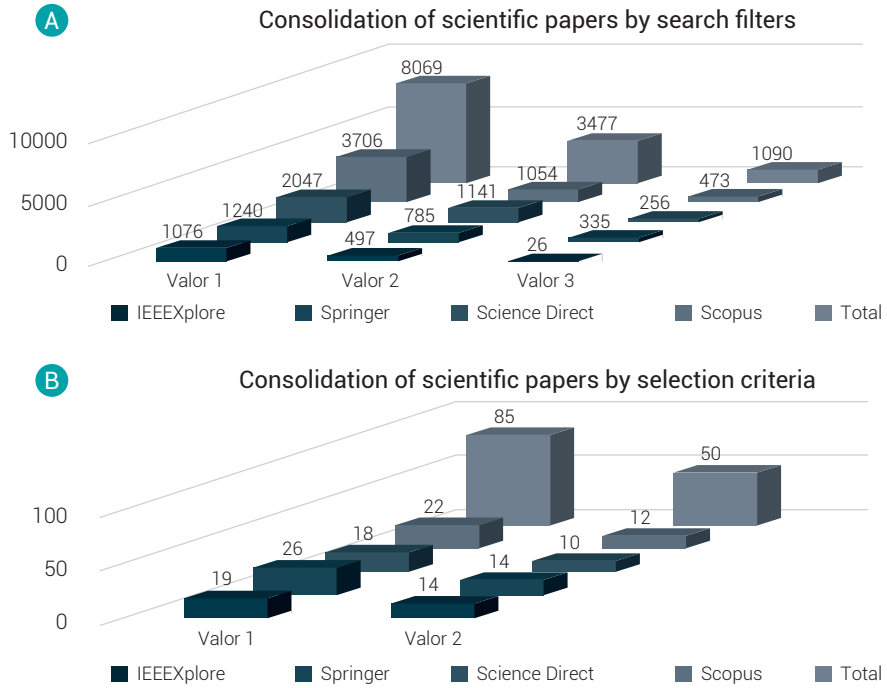

Figure 2. Consolidation of scientific papers.
Source: Own work.

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Following the proposed methodology, the most commonly used techniques in the processes of detection and automatic identification of people using machine learning based tools are determined.

4. PEOPLE DETECTION AND IDENTIFICATION TECHNIQUES

The papers considered in the systematic literature review are classified according to the main technique used, such as Principal Component Analysis (PCA), Weak Label Regularized Local Coordinate Coding (WLRLCC), Support Vector Machines (SVM), Haar Cascade Classifiers and EigenFaces and FisherFaces.

A) Principal Component Analysis (PCA)

This is a technique used to delineate a data set, but in terms of other variables [15]. Figure 3 shows the working principle of the PCA technique, since a first principal component is located in the direction of maximum variance, while the second component is located orthogonal to the first one [16] [17].

Chawda et al. developed a system for unique face identification using PCA-based algorithms to represent the faces economically [18]. For the process, they developed a database in which feature extraction was improved using PCA algorithms, thus eliminating overfitting problems when predicting trends in the data. In general terms, they used the algorithm as a dimensionality reducer, with accuracy obtained up to 97% and 99% in the tests performed. On the other hand, Halder et al. [19] developed a system in which the detection of people's facial features was applied to recognize emotions based on facial action points. Initially they created a model with information from 10 people, and 36 points were marked along and across the face, with facial expressions in the form of 36 x 36 distance matrices; emotions are then evaluated by relating the first principal component to 6 previously selected components. The first principal component is the direction in which the points present the maximum variance, while the second component is the direction orthogonal to the first component. In this way, the methodology is replicated to find the following principal components. The hit rate obtained fluctuated between 85% and 100%. Sharma et al. used the PCA technique to seek improvement in face validation by taking into account factors such as partial occlusion of the face, variations in brightness levels and variety of postures [20]. For this, they used principal components for feature extraction and made use of

several machine learning algorithms complementary to the validation process. As for the results, they varied the ratio of the dataset, starting with 60:40 and obtaining accuracy level variants between 89 % and 93 %; for the ratio 80:20, the accuracy fluctuated between 91 % and 97 %, while for the ratio 90:10, the values fluctuated between 97 % and 100 %.

Additionally, Bao and Gao used the PCA technique as the foundation of their work but gave a Kernel approach (KPCA) with training sample reduction based on sparse learning [21]. They employed the ORL and YALE facial feature information databases with mean error rate of 3.8 % and variance of 0.4 %. Additionally, this technique achieves space savings and optimizes the kernel structure with acceptable performance, even in tests applied to medical imaging processes. Shanthi et al. [22] studied a series of algorithms that are applied in face identification processes using drones. When applying PCA, the dataset is subdivided into training and validation, and a two-dimensional matrix is generated in which the rows and columns represent the data and features, respectively. In addition, the covariance matrix is obtained to obtain eigenvectors, which are ordered from highest to lowest according to the significant features. In this way, the implementation is facilitated and processing costs are reduced.

Bakshi and Prabhu employed the PCA algorithm for face recognition in an access control System [23]. For feature extraction, the use of this algorithm was defined because it contributes significantly to the reduction of data in images with 8-bit intensity in two dimensions, so that an image of 256 x 256 is converted into a vector with a single dimension of 65,536. The system was enhanced with a graphical user interface. In addition, Zhu et al. elaborated on the use of PCA and developed an improved principal component analysis (IPCA) method [24]. The developed technique was complemented by a line regression classification (LRC) algorithm using least squares to determine the label of each class with the minimum error. To test the robustness of the method, performance tests were developed on 3 different datasets with detection and classification successes varying between 82.3 % and 95.8 %. The IPCA algorithm reduced the training time, and uses the class mean instead of a specific image belonging to the class. Finally, Saleem et al. developed a system based on face recognition inspired by the contribution in crime detection and human tracking processes [25]. For this, the Euclidean distance between eyes, nasal structure and lip separation were analyzed as the main components. For a low number of training stages, the system presented accuracies of more than 82%, which could be improved by progressively increasing the number of training stages.

B) Weak Label Regularized Local Coordinate Coding (WLRLCC)

This is a technique aimed at answering the problem of label propagation dependent on the graph construction process [26]. Generally, sparse features and weak labels are used simultaneously for the enhancement of image labels containing similar information [27] [28].

Wang et al. [29] focus their research on automatic face annotation, for the retrieval of a large number of images with facial features available on the Internet. They apply the WLRLCC model for sparse feature learning with weak label regularization. The processing system is complemented with optimization algorithms. Additionally, with scalability in mind, they employed an offline approximation scheme, which significantly reduces the annotation time. Along the same lines, Sakharkar and Bodkhe in their study on various techniques for real-time face detection [30], show the importance of unified learning schemes with graph-based regularization. In complement to the above, sparse reconstruction schemes for final annotation are mentioned.

On the other hand, Nandhagopal and Priyanka [31], in their comparative study of automatic annotation techniques for social network images, add the importance of the WLRLCC algorithm due to its orientation towards the learning stages of encoding as well as for learning all labels. In addition, they present this model as an effective tool for transductive learning problems because of its applicability at large scale using small amounts of images, as well as its use for higher rank images in large scale databases.

C) Support Vector Machines (SVM)

It is a technique based on supervised learning algorithms, especially focused on classification and regression processes [32] [33]. The principle of operation is based on the separation of classes to the cleanest spaces by means of hyperplanes [34], in which the new samples are placed according to a vector defined between the points of the classes (called support vector) for the classification between some of the classes according to the space [35].

Kulandai and Sree used the Support Vector Machines technique in addition to create a Histogram of Oriented Gradients (HOG)-based face recognition system, whose images for validation were tested with variations in pose and brightness level. First, they applied image preprocessing techniques for facial alignment and normalization, and after the application of HOG, they trained the system with only 369 images, validated with 41 images. By applying SVM, an efficiency of more than 90 % was achieved in the classification [36]. Likewise, Rayani and Rajakumar [37], used SVMs considering

that the main research challenge was their reliability in variant illumination, in which accompanied by PCA for multilevel searches, they achieved classification hits higher than 85%. With SVM, they achieved better results than 12% of the methods developed in the literature. Chen et al. [38] in their study focused on face modeling with name attributes employing an improved SVM model, based on a matched face pyramid and support vector representation to model a relationship between names and faces. The developed SVM method follows the AdaBoost structure, in different feature channels. The training images that have been misclassified take a higher weight iteratively, reaching relationship hits exceeding 80% in most of the tests.

Similarly, Gavriilidis et al. [39] employ a cascade of SVM classifiers for human detection focused on HOG-based healthcare applications and evaluated with the INRIA database. The training set consisted of two classes, with which they achieved true positive hits of 91.38 % onwards, and false positives of at most 1.57 %. The results are promising considering the signal capture devices used, such as a 2.5-D time of flight (TOF) camera sensor and their need to avoid human obstacles. Shmaglit and Khryashchev [40] developed a study concerning gender classification using adaptive features in facial images using nonlinear SVM classifiers with RBF kernel. For the extraction of the region of interest (face) an adaptive feature extraction algorithm according to the LDA method is used. Additionally, AdaBoost is used to develop the face detection system automatically. The position of the face for detection is fully frontal with people in the age range between 18 and 65 years, with images originally in RGB color space. The developed method showed superior class classification accuracy of almost 91 % when an extended dataset of 5000 shots was used.

Additionally, Chambino et al. [41], in their study of multispectral face recognition for classification, employed linear and radial basis support vector machines. The tests were run for two datasets with training epochs of 10 and 50 for each of these. With the adjustment of hyperparameters such as smoothing, regularization and kernel coefficients, a classification efficiency of up to 99.89 % was achieved, improving the performance by applying techniques such as k-nearest neighbors, in which a maximum performance of 99.63 % was obtained. Campomanes et al. [42], in their identification system for interaction with people with learning disabilities, employed a support vector machine with linear kernel as a multiclass strategy, achieving a run rate of 0.417 seconds, second only to the logistic regression method, and a classification efficiency (true positives) of up to 95.9 % with a threshold value of 0.85. Abdulrahman and Eleyan developed a system for facial expression recognition using SVM [43], as this technique allows for easy distinction of expressions that tend to show similar characteristics such as anger or disgust. They achieved hits fluctuating between 76.2 %

and 98.8 %, and recommended the adjustment of data for head motion to improve the performance of the system.

Arafah et al. [44] developed a system for the detection of facial features in cases in which veiling is used. In general terms, it was based on preprocessing stages such as resizing, brightness enhancement, grayscale conversions and histogram equalization, so features were extracted by HOG, and classification was performed using multicategory support vector machines. This classifier presented a hit percentage of 75.08 % with occlusion and 94.46 % without occlusion. In addition, Adegun and Vadapalli in their facial micro expression recognition system [45], perform a comparison between support vector machines and the Local Binary Pattern (LBP) technique, finding that the latter presents better performance in terms of accuracy, precision and image retrieval, and is also 0.2996 seconds faster in mean training time. That is, it improves the process when using temporal features.

D) Haar Cascade Classifiers

This is a commonly used method for object detection and represents one of the most widely used machine learning methods for person detection and identification. It is based on the training of positive and negative images in a cascade mode, in which instead of focusing on the search for the class in question, it focuses on discarding all those images and sections of images that do not contain the class, speeding up the detection and classification process.

Dixit et al. [46] used this technique on images preprocessed by Contrast-Limited Adaptive Histogram Equalization. The identification of faces was performed using a Binary Robust Invariant Scalable Key-points (BRISK) descriptor. The developed method generated detection hits from 95.8 % to 100 %. Atmaja et al. developed a face recognition system in an unmanned aerial vehicle [47]. They employed a conventional Haar-type feature-based classifier. With this methodology, the correct detection of faces and their classification in a lower flying position of the vehicle is achieved, and as the altitude increases and the vehicle moves away, the reliability decreases due to the tilt angle. Applying this technique in UAV applications presents a number of additional drawbacks to the training process. Likewise, Kumar et al. focused on security applications, and employed Haar-type cascade classifiers for suspect identification [48]. The research raises the need to reduce computational costs as well as training time; they propose a methodology based on the use of the Viola-Jones method where faces are detected, similarity properties in faces are extracted using Haar features, and

AdaBoost is used for redundancy elimination. The acceptance rate in classification is up to 95 %.

Zunair et al. [49] designed and implemented a multi-featured attendance system for real-time visualization. The classifier with Haar-like features is conventionally used to supplement an access system based on RFID technology. Gautam et al. [50] focused on tools for smart building security. They used 1296 images with the frontal section of the face, and 2100 images with sections not corresponding to the frontal sections. By varying the orientation, the detection rate was almost 84 %, while the accuracy was 96.66 %. The system was complemented with a hybrid algorithm for deep learning between Haar classifiers and a skin detector. Rehman et al. [51] studied face detection based on regions of interest by margins. For this application, the system based on Haar classifiers showed lower performance with respect to techniques such as Joint Cascade and Multi-task Cascaded Convolutional Networks. The hit rate ranged from 89.516 % to 98.122 %. Likewise, among these techniques, the Haar-type feature classifier showed the longest processing time, being on average 1.3 seconds slower than the other techniques.

Souza et al. [52] developed an emergency management system based on face recognition. After capturing the image, the face is segmented and the face is detected using the Haar-like feature algorithm, and a validation is done in the database. It is a common application with detection and validation success rates above 90%. Similarly, Wati et al. [53] investigated the security of biometric authentication by facial recognition. They emphasize the advantages of using Haar classifiers, in which the features are assisted by the integral calculation of the image, which improves the processing speed. They also emphasize the use, in addition to the Haar classifier, of the AdaBoost algorithm for the selection of the best features and calculation of the threshold value of the classifier. Along the same lines, Shetty et al. studied face recognition by Haar-type cascade classifiers and LBP Classifiers. They relied on the pre-trained OpenCV models and after image loading and conversion to grayscale, the image is subjected to the classifier. The tests were performed with images containing multiple faces (between 5 and 20) obtaining variant hits between 80% and 100%, improving with respect to the LBP classifier in which the classification accuracy rate in some cases was 73.33%.

E) EigenFaces and FisherFaces

EigenFaces is a technique in which, based on the orthogonality of the dimensions [54], the vectors that contain the best information from a data set are determined. FisherFaces focuses specifically on face detection using a linear discriminant method

that takes into account factors such as the level of incident light and certain facial expressions [55].

Çarıkçı and Özen developed a face recognition system based on the EigenFaces method [56]. For this case, for each of the images with facial features, an eigenface is generated and the Euclidean distance between the current and previous eigenfaces is calculated, so that the ratio yielding the smallest distance indicates the identification of the person. The research was carried out using licensed software and the hit rate exceeded 94%. On the other hand, Leo et al. [57] propose an approach for face retrieval with a methodology based on two face recognition techniques: Eigenfaces and SIFT. To improve performance, the similarities delivered by each of the models are linearly combined. With Eigenfaces, the system was evaluated by the smallest Euclidean distance, while SIFT evaluates the similarity by the weighting of coincident points. On the other hand, Zhao et al. investigate face recognition using a set of polyharmonic extreme learning machines [58]. The developed method improves by 7.27 % on that developed in a conventional detection and identification system by the EigenFaces method, which achieved a reliability of 92.2 %.

Rodavia et al. [59] implemented a security system based on face recognition for web and mobile devices. The recognition is developed using Eigenfaces. In addition, a base of images is formed with the objective of assembling a covariance matrix. In this way, a dimension reduction is produced for the base images with respect to the original images. The quality of the system was measured taking into account the ISO9126 standard. Chamikara et al. had privacy preservation as a pillar for the face recognition system they developed [60]. The Eigenfaces method served as the basis for the development of a face recognition protocol called PEEP (Privacy using Eigenfaces Perturbation), with which a perturbation is generated to the eigenfaces, and sends to the servers only the perturbation information. The detection success ranged from 70% to 90%; a very good performance considering that the validation was done with a perturbation-based privacy configuration. Niu and He focused their study on athlete recognition based on feature extraction [61]. For method validation, they employed a variation of the EigenFaces and FisherFaces methods called Colour-EigenFaces and Colour-FisherFaces. With this, improvements in shape and color are achieved. The best performance among these techniques was given by applying Colour-FisherFaces, in which the recognition rate exceeded 80 % at the highest number of training samples.

Liu et al. [62] developed a system based on face recognition in which an intelligent method for light compensation was taken into consideration. In addition, they perform LED ray radiation sequence calculations. In this case, the EigenFaces method is employed after illumination control, and is complemented by principal component

analysis to obtain the vector characteristics of the face, and the Euclidean distance is calculated for identification. Likewise, Kukharev and Shchegoleva studied two-dimensional projection algorithms by investigating their history and implementation, finding a direct relationship between the EigenFaces method and the PCA algorithm [63]. Finally, Cheng and Song developed a method for face recognition based on sparse representation by FisherFace space [64]. The method starts with the transformation to 2D FisherFace space, followed by the use of supplementary matrices in order to counteract random pixels. In terms of accuracy and robustness, up to 99.3 % efficiency was achieved.

Figure 3 shows how the information from the scientific articles was distributed, taking into account the machine learning technique used. The PCA technique contributed 22% of the total number of documents queried, as did the EigenFaces (Ef) and FisherFaces (Ff) techniques. In addition, the cascading classifier technique was treated in 16% of the queried documents, while the WLRLCC technique was the technique with the smallest contribution to the review with 12% of the scientific documents. In contrast, the SVM technique was the technique that contributed the largest number of documents to the literature review with 28% of the documents.

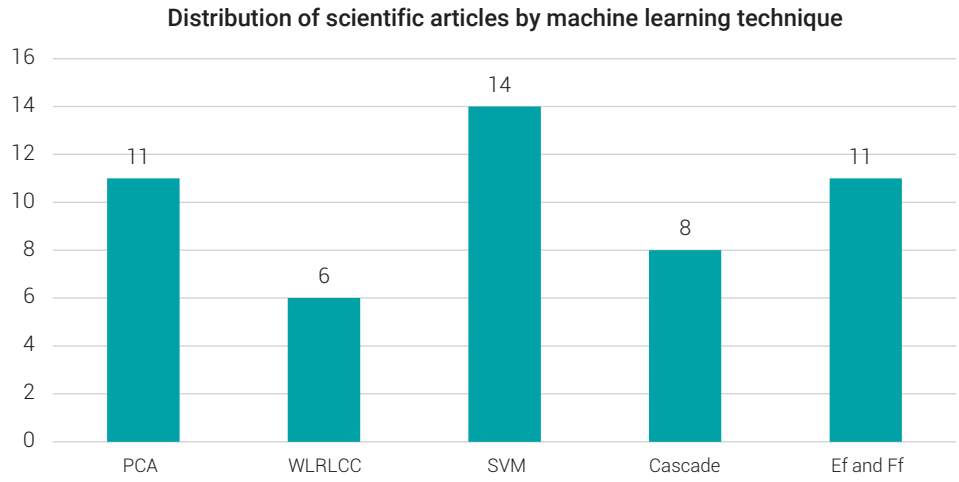

Figure 3. Distribution of articles by machine learning technique.
Source: Own work.

5. DISCUSSION

There is a tendency to use techniques such as Support Vector Machines, Principal Component Analysis, and EigenFaces and FisherFaces, as observed in more than

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70% of the investigations investigated. This is linked to the large amount of information available both on the web and in scientific articles and high-impact research, which allows the studies developed to be easily replicated. On the other hand, although the WLRLCC technique is also frequently used, it has disadvantages when it comes to its implementation, since it requires the extraction of more specific characteristics, which has a direct influence on execution times and computational requirements. On the other hand, the cascade classifier technique is shown to be a traditional technique that, even over time, will continue to be used due to its efficiency and ease of implementation on multiple platforms. The disadvantage of this technique lies in its comparison for the classification stages with deep learning techniques, which, although theoretically require a greater effort on the part of the machine, have been optimized in such a way that a balance has been found between the Hardware and software performance. In addition, it is considered necessary for the real implementation of detection and identification processes of people to design and execute hybrid algorithms based on machine learning techniques and algorithms, where the best features of various algorithms with a common goal are extracted, and they are assembled into a single one that is capable of improving the performance of each of these algorithms per individual. Likewise, it is proposed to complement the development of machine learning software with stages of physical characterization of the areas where the processes will be implemented, since the efficiency and performance in the processes is dependent on factors such as lighting and camera height, location and angle of inclination at the time of creating the data sets for training and image and video capture for operation.

6. CONCLUSIONS

The research identified the main computational intelligence techniques based on machine learning applied to the detection and identification of people. Their influence was shown in several application cases, but most of them were focused on the implementation and optimization of access control systems, or tasks in which the identification of people was required for the execution of processes. It was also identified that the techniques discussed are not only implemented independently, but in order to improve detection and identification processes, they are applied as a whole. The methodology used, in which the two inclusion/exclusion criteria are applied after the search filters, allowed for the debugging of the information, since in many of the databases consulted, efficient filtering is not achieved simply by using keyword filters, due to the large volume of information handled by these bibliographic databases.

Therefore, high-level information has been obtained with real applications for both the academic and industrial sectors, and which is fully replicable in tools based on both free software and licensed software. Similarly, a contrast between the application of machine learning techniques was identified, since only 3 techniques make up more than 70% of the information found, which invites future research to improve the processes based on WLRLCC and cascade classifiers in order to enrich the state of the art.

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