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A Comprehensive Survey and Detailed Study on various Face Recognition Methods

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Abstract – *Face Recognition which is still one of the challenging topic in Computer Vision and Image Processing field remains an open problem as the recent advancements has not yet reached high recognition performance in real world environment. With the usage of technologies for Computer Vision and Image Processing, Face Recognition has gained more interest due to it applications and concerns on high security. Human Face can be considered as a key identifier in various fields and Computational models of face recognition can be applied to a wide variety of problems involving security system, Identification of criminals or suspects, image and film processing, and human computer interaction. This field of computer vision and image processing involves recognition of face from image or a video source. Several algorithms and methodologies for face identification have been developed having their own pros and cons. In this paper, we will provide review and survey of some famous major face recognition algorithms, methodologies developed so far. This paper will study various face recognition algorithms developed and is categorized into 5 aspects, first involving introduction and review on existing history, second gives the technical details on methods, approaches developed so far, third gives benefits and applications of face recognition system, fourth one is the limitations involved in face recognition algorithms and fifth is the conclusion. It is our hope that by reviewing existing algorithms, we will see even better method developed to solve this fundamental problem.*

***Key Words*: Face Detection, Face Recognition, Eigenfaces, LDA, ICA, LBP, SNoW, Neural Network**

1. INTRODUCTION

With the rapid increase of computational powers and development in sensing, analysis, equipment and technologies, computers are becoming smarter. Several research projects and commercial products have demonstrated the capability for a computer to interact with human in a natural way by looking at people through cameras. Identification of a human being using biometrics has been proved to be one of the best methodologies yet developed and is one of the key area of research or say interest. Biometric based techniques have emerged as the most promising option for recognizing individuals in recent time. Identification of an individual or entity and object through biometrics provides better results and also various features.

Biometrics based technologies include identification based on physiological characters (such as face, iris, retina, finger prints, finger geometry, hand veins, hand and palm geometry, voice etc.) and behavioural traits (such as gait, signature and keystroke dynamics). Among all the features of human being, used as identification, Face Recognition seems to have more advantages over other biometrics based methods. And so it is one of the key research interest in computer vision and image processing. Many applications rely on the performance of digital image processing systems like biometrics authentication, multimedia, computer human interaction, security applications etc.

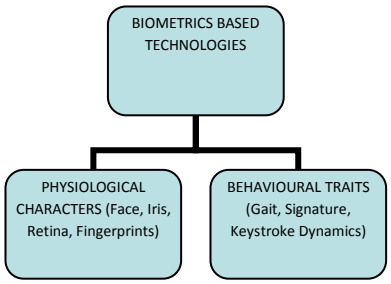

Figure 1.Types of Biometrics Based Identification

Human Face Identification (HFI) among a set of images, is an area of research which has many challenges but has received great deal of attention over the last few years due to its many applications in various domains. As Human Face is a complex multidimensional structure and is a rich source of information about human behaviour, it requires good computing techniques for its recognition. Also Human Face displays emotion, indicate feelings, regulate social behaviour, reveal brain function etc.

1.1 ADVANTAGES OF BIOMETRIC BASED RECOGNITION METHODS

Biometric based techniques have now emerged as promising option for identifying individuals for authenticating people and granting access to physical and virtual domains over others like passwords, PINs, smart or plastic cards etc. Benefits of Biometric face recognition methods are as below:

A. Better Security and No More Time Fraud

B. Automated System with Easy Integration

C. High Success Rate, User Friendly Systems and Convenient Security Solution

D. Beneficial for security and surveillance purposes

E. Face recognition can be done passively without any explicit action or participation by user. Face images can be acquired from a distance by a camera.

F. Facial features like individual biological traits cannot be misplaced forgotten, stolen or forged.

G. Iris and Retina identification require expensive equipment, voice recognition is susceptible to background noises, signatures can be tampered or forged or modified but face recognition is totally non-intrusive and does not carry any such risks.

2. FACE RECOGNITION METHODS

There are various methods used in face recognition. Each and every method has different features under different conditions like illumination, expression and pose change. In this section, classification and detailed study on various methodologies developed is provided.

2.1 CLASSIFICATION OF FACE RECOGNITION METHODS

Face Recognition Methods (Approaches) are classified/divided into following four categories [1][2][3][6].

A. **Knowledge Based Methods**: This method can be defined as a process which use pre-defined rules to determine a face based on human knowledge. It is a rule based method which involves capturing the knowledge of face and converting into set of rules. It is simple to guess some easy rules. For example, a face usually has two symmetric eyes, and the eye area is darker than the cheeks. Facial features could be the distance between eyes or the color intensity difference between the eye area and the lower zone. A major disadvantage with these methods is the difficulty in building an appropriate set of rules. If the rules are general then they are false positive. Furthermore, if the rules were too detailed then there false negatives. The solution to overcome these problems is to make hierarchical knowledge-based methods. These are efficient with simple inputs. These rule-based methods uses human knowledge of what makes a typical human face and captures relationships between facial features. They are designed mainly for face localization. Limitation of this is, if a person is wearing glasses, it is almost impossible to find the face. There are algorithms that detect face-like textures or the skin color in which it is important to select the best color model to detect faces.

B. **Feature based methods**: Also known as Feature invariant approaches, these methods aim to find structural features that exist even when the pose, viewpoint, or lighting conditions differ and uses these to locate faces. It approaches to find face structure features that are robust to pose and lighting variations like mouth, cheek, eyes, ears, nose, chin, lips etc. Distance between eyes, ears or location of eyes and nose, length of nose is used as to determine the face. Also potential faces are normalized to a fixed size, position and orientation. Then, the face area or region in an image is verified using a back propagation neural network. These are designed mainly for face localization.

C. **Template Matching Methods**: It uses pre-stored face templates to judge if an image is a face. This method compares input image with stored template of faces or features. It defines a face as a function. Each features can be defined independently. These methods are mainly used for both face localization and detection and are easy to implement but incomplete for face detection and do not give good results for variations in scale, shape and pose.

D. **Appearance based methods**: The appearance based methods as the name suggest uses a set of training images for learning of the models or templates. It shows superior performance over others. In general, they rely on techniques from statistical analysis and machine learning to find the relevant characteristics of face and non- face images. The learned characteristics are in the form of distribution models or discriminant functions that are consequently used for face detection [2]. Algorithms used in this methods are PCA (Eigenface), Distribution based methods, Neural Networks, Support Vector Machines (SVM), Hidden Markov model etc.

The Categorization of Methods for Face Detection in a Single Image is mentioned in below table.

Table-1 Face Detection Approach and Representative Works

Approach	Representative Works
Knowledge Based	Multiresolution rule based method [20].
Feature invariant	
Facial Features	Grouping of Edges[21]
Textures	Space Gray-Level Dependence Matrix (SGLD) of face pattern[22]
Skin Color	Mixture of Gaussian[23]
Multiple Features	Integration of skin color, size, shape[24]
Template Matching	
Predefined Face	Shape Template[25]
Deformable Templates	Active Shape Model[26]
Appearance Based Model	
Eigenface	Eigenvector Decomposition and Clustering[6]
Distribution Based	Gaussian Distribution and Multilayer Perceptron[27]
Neural Network	Ensemble of Neural Networks and arbitration schemes[28]
SVM	SVM with polynomial kernel[29]
Naïve Bayes Classifier	Joint statistics of local appearance and position[30]
Hidden Markov Model	High order statistics with HMM[31]
Information - Theoretical	Kullback relative information[32]

2.2 CLASSIFICATION BASED ON APPROACH TO DETECT THE FACE

Recognition of face can be performed both in still image and in video based. In this study, we are performing face recognition in still image. Face recognition for still images can be classified in 3 main approaches as mentioned below:

Holistic based Approach:

In this approach, the whole face region is taken into consideration as input data into face detection system. This method has proved to be an excellent technique for recognizing face in terms of recognition rate.

Types of holistic method are

a. Principal Component Analysis (PCA)
b. Single Value Decomposition (SVD)
c. Artificial Neural Network (ANN)

Feature based Approach:

In this approach, local features on face such as eyes, nose, ears, lips, nose length, cheek, chin their position, location, length etc. are taken into consideration and are used as input data for structural classifier. Hidden Markov Model method belongs to this category.

Hybrid based Approach:

This originates as a combination of both holistic and feature based approach. This idea comes from how human vision system perceives both local feature and whole face. Modular Eigenfaces, hybrid local feature, shape normalized, component based methods are examples of hybrid approach.

2.3 DETAILED STUDY OF METHODS AND ALGORITHMS USED IN FACE RECOGNITION

In this section, a detailed study on various human face recognition methodologies developed is provided.

Figure 2. Types of Face Recognition Methods

Appearance Based Methods:

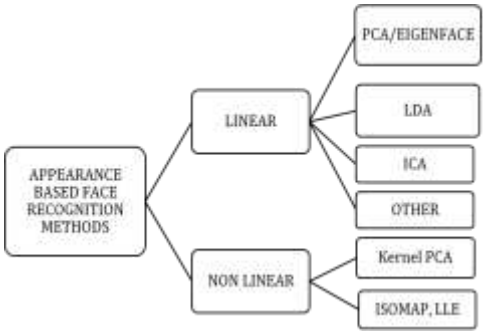

Figure 3. Types of Appearance based Face Recognition

a. Eigenface Based Method

This uses Principal Component Analysis (PCA) scheme. A detailed description of PCA can be found in [1][2][4][6]. Principal Component Analysis (PCA) is a powerful technique for extracting a structure from potentially high-dimensional data sets, which corresponds to extracting the eigenvectors that are associated with the largest eigenvalues from the input distribution. This eigenvector analysis has already been widely used in face processing.

Step 1: Prepare the data
The faces constituting the training set (Γ_i) should be prepared for processing.

Step 2: Subtract the mean
Average matrix Ψ has to be calculated, then subtracted from the original faces (Γ_i) and the result stored in the Variable Φ_i:

$$\Psi - \frac{1}{M}\sum_{n=1}^{M}\Gamma_n \qquad (i)$$

$$\phi_i \quad \Gamma \quad \Psi \qquad (ii)$$

Step 3: Calculate the covariance matrix. In step three, the covariance matrix C is calculated according to

$$C = \frac{1}{M}\sum_{n-1}^{M}\Phi_n \Phi_n^T \qquad (iii)$$

Step 4: Calculate the eigenvectors and eigenvalues of the co-variance matrix. The eigenvectors (Eigenfaces) and the corresponding eigenvalues should be calculated. The Eigen-faces must be normalized so that they are unit vectors, i.e. length 1. The description of the exact algorithm for determination of eigenvalues and eigenvectors is eliminating, as it belongs to the standard arsenal of most math programming libraries.

Step 5: Select the Principal Components
From M eigenvectors (Eigenfaces) U_i, only M^0 should be chosen, which have the highest eigenvalues. The higher

the eigenvalue, the more characteristic features of a face does the particular eigenvector describe. Eigenfaces with low eigenvalues can be omitted, as they explain only a small part of characteristic features of the faces. After M^0 Eigenfaces U_i are determined, the" training" phase of the algorithm is finished.

b. Distribution based Methods – LDA Algorithm [8]

Linear Discriminant Analysis (LDA) is also called as Fisher's Discriminant Analysis or Fisherface Analysis and is another dimensionality reduction technique. It is an example of class specific method. In LDA, the goal is to find an efficient way to represent the face vector space. LDA finds the vectors in the underlying space that best discriminate among classes. LDA maximizes between class scattering matrix measure while minimizes the within class scatter matrix measure, which make it more steady for classification [8]. Lih-Heng Chan [9] proposed a framework of facial biometric was designed based on two subspace methods i.e., Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA). First, PCA is used for dimension reduction, where original face images are projected into lower-dimensional face representations. Second, LDA was proposed to provide a solution of better discriminant. Both PCA and LDA features were presented to Euclidean distance measurement which is conveniently used as a benchmark. LDA-based methods outperform PCA for both face identification and verification. Fisher faces are one the most successfully widely used method for face recognition. It is based on appearance method. In 1930 Fisher developed linear/fisher discriminant analysis for face recognition which shows successful result in this process.
Linear Discriminant Analysis (LDA) tries to differentiate between classes rather than trying to present the data. Therefore, LDA cares about getting feature vectors for Class Discrimination. We define two below scatter matrices

$$S_w = \sum_{j=1}^{R}\sum_{i=1}^{M_j}(x_i^j - \mu_j)(x_i^j - \mu_j)^T$$

$$S_b = \sum_{j=1}^{R}(\mu_j - \mu)(\mu_j - \mu)^T$$

The first is called the within-class scatter matrix while the second is called the between-class scatter matrix. j denotes the class while i denotes the image number. μ_j is the mean of class j while μ is the mean of all classes. M_j is the number of images in class j and R is the number of classes. The algorithm aims at maximizing the between-class matrix while minimizing the within-class matrix. The limitation of LDA is that, within the class scatter matrix is always single, after all the number of pixels in images is larger than the number of images so it can boost detection of error rate if there is a variation in pose and lighting condition within same images. To overcome this problem algorithms like the fisher face technique uses the advantage of within-class information so it minimizes the variation within class, so the problem with variations in the same images such as lighting variations can be overcome [9][10].

c. Independent Component Analysis (ICA)

ICA [10] is considered as a generalization of PCA. PCA considers image elements as random variables with minimized 2nd order statistics. ICA proposed by [11, 12] minimizes both second-order and higher order dependencies in the input data and tries to get the basis of which the projected data is statistically independent. Also here PCA is used to reduce dimensionality prior to performing ICA. Two different approaches or architectures are taken by the ICA for face recognition which are mentioned as:

1. ICA Architecture 1: In this approach according to [11] images are considered as random variables and pixels as trials. So here we care about independence of images or functions of images. It tries to find a set of statistically independent basis images.

2. ICA Architecture 2: In this pixels are considered as random variables and images as trials. So in this, we care about independence of pixels or functions of pixels. In other words ICA architecture 2 uses ICA to get a representation in which the coefficients used for coding images are statistically independent.

d. Local Binary Patterns (LBP)

Local Binary Patterns (LBP) was first presented by Ojala et al. in [13] to use in texture description. The basic method, labels each pixel with decimal values called LBPs or LBP codes, to describe the local structure around of pixel. As illustrated in Figure 1, value of the center pixel is subtracted from the 8 neighbor pixels' values, if the result is negative the binary value is 0, otherwise 1. The calculation starts from the pixel at the top left corner of the 8-neighborhood and continues in clockwise direction. After calculating with all neighbors, an eight digit binary value is produced. When this binary value is converted to decimal, the LBP code of the pixel is generated, and placed to the coordinates of pixel in matrix [14].

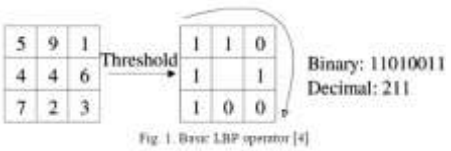

Figure 4. Basic LBP Operator Display

There is a drawback of LBP which uses 8-neighborhood (3x3) that cannot cover large-scale structures. To take into account texture of different size structures, the method is generalized. In [15] Ojala et al. revised the method to be flexible for any radius and any number of sampling points and named the new method as Extended LBP(ELBP). The histograms of LBP are used for face recognition since LBP histograms contain information about the distribution of local micro patterns.

Figure 5 below shows different examples of ELBP operator. 'P' represents the number of neighbors and 'R' represents the radius of a circle on which neighbors are located. Because the face image is too big for LBP calculation, dividing the image into small regions is proposed in [16]. Some parts of face (like eyes, mouth) contain more information for face recognition.

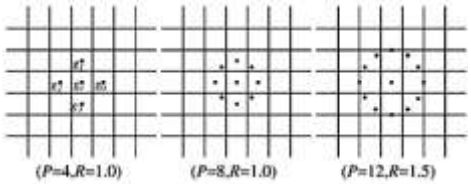

Figure 5. ELBP Operator Examples

Yang et al. proposes to train and allocate different weights for face parts, by their information covering and then concatenating them end to end to build up global description of face. This helps to collect local pattern information with spatial details of the whole image. To decide if two face images are belong to same person, the images histograms are compared. Chi square statistic similarity measure is used for comparison of histograms. It can be defined as follows:

$$X_w^2(S,M) = \sum_{i,j} w_j \frac{(S_{i,j} - M_{i,j})^2}{(S_{i,j} - M_{i,j})}$$

where $i = 0, 1,..., n-1$, $j = 0,1,...,m-1$, w_j is the weight for region j, S is target face image histogram and M is the query face image histogram [16].

e. Support Vector Machine (SVM)

While most methods for training a classifier (e.g. Bayesian, neural networks, and RBF) are based on minimizing the training error, i.e. empirical risk, SVMs operates on another induction principle, called structural risk minimization, which aims to minimize an upper bound on the expected generalization error. An SVM classifier is a linear classifier where the separating hyperplane is chosen to minimize the expected classification error of the unseen test patterns. This optimal hyperplane is defined by a weighted combination of a small subset of the training vectors, called support vectors hence named Support Vector Machine [17]. Given a set of points belonging to two classes, a Support Vector Machine (SVM) finds the hyper plane that separates the largest possible fraction of points of the same class on the same side, while maximizing the distance from either class to the hyper plane. PCA is first used to extract features of face images and then discrimination functions between each pair of images are learned by SVMs. SVMs as defined in [17] can be considered as a new paradigm to train neural networks or radial basis function (RBF) classifiers or polynomial function.

f. Sparse Networks of Winnows (SNoW)

Yang et al. proposed a method that uses SNoW learning architecture [18] to detect faces with different features and expressions, in different poses and under different lightning conditions. SNoW is a sparse network of linear functions that uses Winnow update rule [18]. It is mainly tailored for learning in domains in which potential number of features taking part in decisions is very large, but may be not known in priori.

g. Neural Networks Based

Neural networks based have been applied successfully in many pattern recognition problems, such as optical character recognition, object recognition, and autonomous robot driving. Neural network architectures proposed as face recognition is considered as a two class pattern recognition. The advantage of using neural networks for face recognition is the feasibility of training a system to capture the complex class conditional density of face patterns. The drawback of neural network architecture is that they has to be extensively tuned to get exceptional performance.

Table -2: Types of Neural Network Architectures

S. No	Name
1	Hierarchical Neural Network
2	Auto associative Neural Networks
3.	Probabilistic decision based Neural Network
4.	Multilayer Neural Network

h. Naïve Bayes Classifier

This appearance based approach was developed by Schneiderman and Kanade as Naïve Bayes classifier to estimate the joint probability of local appearance and position of face patterns (subregions of the face) at multiple resolutions. Since some local patterns of an object are more unique than others; like intensity patterns around eyes are much more distinctive than the pattern found around the cheeks. Naïve Bayes classifier provides better estimation of the conditional density functions of the subregions and also gives a functional form of the posterior probability to capture the joint statistics of local appearance and position on the object.

i. Hidden Markov Model

The underlying assumption of the Hidden Markov Model (HMM) is that patterns can be characterized as a parametric random process and that the parameters of this process can be estimated in a precise, well defined manner. In developing an HMM for a pattern recognition problem, a number of hidden states need to be decided first to form a model. Then, one can train HMM to learn the transitional probability between states from the examples where each example is represented as a sequence of observations. The goal of training an HMM is to maximize the probability of observing

the training data by adjusting the parameters in an HMM model with the standard Viterbi segmentation method and Baum-Welch algorithms. After the HMM has been trained, the output probability of an observation determines the class to which it belongs [19]. HMM-based methods usually treat a face pattern as a sequence of observation vectors where each vector is a strip of pixels. HMMs have been applied to both face recognition and localization [19].

j. Information – Theoretical Approach

The spatial property of the face pattern can be modeled through different aspects. The contextual constraint, among others, is a powerful one and has often been applied to texture segmentation. The contextual constraints in a face pattern are usually specified by a small neighborhood of pixels. Markov Random Field (MRF) theory provides a convenient and consistent way to model context dependent entities such as image pixels and correlated features. The face and nonface distributions can be estimated using histograms. A probability function p(x) for event that template is a face and probability function q(x) for event that template is a nonface id defined. Training database is decided with faces of individuals. From the training sets, the most informative pixels (MIP) are selected to maximize the kullback relative information between p(x) and q(x) (i.e. to give the maximum class separation). MIP is then used to obtain linear features for classification and representation. Distance from face space (DFFS) is calculated. If the DFFS to the face subspace is lower than the distance to the nonface subspace, a face is assumed to exist within the window which is passed over input image [19].

3. APPLICATIONS OF FACE RECOGNITION SYSTEM

- **Security and Surveillance**:-Access control of buildings, airports/seaports, computer or network security; CCTV Surveillance to look for suspects/criminals.
- **General Identity Verification:-**Driving License, Electoral registrations, National Ids (UID AADHAR cards in India), Passports, Employee IDs, Bank Account ID etc.
- **Criminal justice systems**: - Mug-shot or booking systems, post-event analysis, forensics.
- **Access Control**: - Face verification, matching a face against a single enrolled exemplar.
- **Image database investigations**:-Searching image databases of licensed drivers benefit recipients, missing children, immigrants and police bookings.
- **Video Indexing in Multimedia environments with adaptive human computer interfaces**

4. LIMITATIONS OF FACE RECOGNITION ALGORITHMS

There are various challenges and limitations which are associated with face detection and face recognition algorithms affects the performance or result of the method are mentioned below:

1. Facial Aging occurred due to hormonal and biological changes.
2. Pose Invariance which is the result of camera- face pose due to which facial features (eyes, nose) gets occluded.
3. Image Orientation occurs as the face images vary for different rotations about the camera's optical axis and imaging conditions like lighting, camera characteristics (sensor, flash, lenses) affect the appearance of face.
4. Occlusion might be limitation as in an image of group of people, some persons face may get partially or fully occluded due to other people or object.
5. Presence or absence of structural components: Facial features like beards, moustache, glasses, sunglasses, and nose ring etc. which cause great deal of variability in shape, size, color or texture of face.

5. CONCLUSION

This paper attempts to provide a comprehensive study and tried to survey all the important and influential algorithms in simple and understandable manner on a significant number of papers to cover the recent development in face recognition field. Present study exposes that face recognition algorithm can be enhanced using hybrid methods for better performance. The list of references to provide more detailed understanding of the approaches described is enlisted. When appropriate, we have reported on the relative performance of methods, and are also cognizant that there is a lack of uniformity in how methods are evaluated and, so, it is imprudent to explicitly declare which methods indeed have the lowest error rates. Also categorization of algorithms have been done and pros and cons have been provided. We apologize to researchers whose important contributions may have been overlooked.

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REFERENCES

[1] B.S.Khade et al, "Face Recognition Techniques: A Survey" International Journal of Computer Science and Mobile Computing, Vol.5 Issue.11, November- 2016, pg. 65-72.

[2] M.-H. Yang, D. J. Kriegman, and N. Ahuja. Detecting faces in images: A survey. IEEE Trans. on PAMI, 24(1):34–58, 2002. 1, 11, 12, 13

[3] A Survey of Recent Advances in Face Detection: Cha Zhang and Zheng you Zhang June 2010 Technical Report MSR-TR-2010-66.

[4] Comparative Study on Face Recognition Using HGPP, PCA, LDA, ICA and SVM", Global Journal of Computer Science and Technology Graphics & Vision Volume 12 Issue 15 Version 1.0 Year 2012 Type: Double Blind Peer

Reviewed International Research Journal Publisher: Global Journals Inc. (USA) Online ISSN: 0975-4172 & Print ISSN: 0975-4350 By Hardik Kadiya , Merchant Engineering College.

[5] "Towards a Practical Face Recognition System: Robust Alignment and Illumination by Sparse Representation" Andrew Wagner, Student Member, IEEE, John Wright, Member, IEEE, Arvind Ganesh, Student Member, IEEE, Zihan Zhou, Student Member, IEEE, Hossein Mobahi, and Yi Ma, Senior Member, IEEE.

[6] Turk, Matthew A and Pentland, Alex P. *Face recognition using eigenfaces*. Computer Vision and Pattern Recognition, 1991. Proceedings {CVPR'91.}, {IEEE} Computer Society Conference on 1991.

[7] Deepika Dubey and Dr.G.S.Tomar, "Deep perusal of human face Recognition Algorithms from Facial Snapshots, International Journal of Signal Processing, Image Processing and Pattern Recognition ",Vol-9,No-9,(2016),pp.103-112

[8] An Efficient LDA Algorithm for Face Recognition Jie Yang, Hua Yu, William Kunz School of Computer Science Interactive Systems Laboratories Carnegie Mellon University Pittsburgh, PA 15213.

[9] Lih-Heng Chan, Sh-Hussain Salleh and Chee-Ming Ting. "Face Biometrics Based on Principal Component Analysis and Linear Discriminant Analysis." J. Computer Sci., 6 (7): 693-699, 2010.

[10] M. Sharkas, M. Abou Elenien "Eigenfaces vs. Fisherfaces vs. ICA for Face Recognition; A Comparative Study", ICSP 2008 Proceedings, 978-1-4244-2179-4/08/ ©2008 IEEE.

[11] M.S. Bartlett, J.R. Movellan, and T.J. Sejnowski, Face recognition by independent component analysis, IEEE Trans Neural Networks 13 (2002), 1450–1464.

[12] B. Draper, K. Baek, M.S. Bartlett, and J.R. Beveridge, Recognizing faces with PCA and ICA, Computer Vis Image Understand (Special Issue on Face Recognition) 91 (2003).

[13] T. Ojala, M.Pietikäinen and D. Harwood (1994), "Performance evaluation of texture measures with classification based on Kullback discrimination of distributions", Proceedings of the 12th IAPR International Conference on Pattern Recognition (ICPR 1994), vol. 1, pp. 582 – 585

[14] D. Huang, C. Shan, M. Ardabilian, Y. Wang and L. Chen "Local binary patterns and its application to facial image analysis: A survey", IEEE Transactions on Systems, Man, and Cybernetics, Part C, vol. 41, pp.765 -781 2011.

[15] T. Ojala, M. Pietikäinen, and T. Maenpaa, "Multiresolution grayscale and rotation invariant texture classification with local binary patterns," IEEE Transaction on Pattern Analysis and Machine Intelligence., vol. 24, no. 7, pp. 971–987, Jul. 2002.

[16] H. Yang and Y. Wang, "A LBP-based face recognition method with Hamming distance constraint," in Proc. Int. Conf. Image Graph., Aug., 2007, pp. 645–649.

[17] M.-H. Yang, D. J. Kriegman, and N. Ahuja. Detecting faces in images: A survey. IEEE Trans. on PAMI, 24(1):13, 2002. pp. 13

[18] A. Carleson, C. Cumby, J. Rosen, and D. Roth, "The SNoW Learning Architecture", Technical Report UIUCDCS-R-99-2101, Univ. of Illinois at Urbana-Champaign Computer Science Dept., 1999.

[19] M.-H. Yang, D. J. Kriegman, and N. Ahuja. Detecting faces in images: A survey. IEEE Trans. on PAMI, 24(1):34–58, 2002. pp 14-15.

[20] G. Yang and T. S. Huang, "Human Face Detection in Complex Background," Pattern Recognition, vol. 27, no. 1, pp. 53-63, 1994.

[21] T.K. Leung, M.C. Burl, and P. Perona, "Finding Faces in Cluttered Scenes Using Random Labeled Graph Matching," Proc. Fifth IEEE Int'l Conf. Computer Vision, pp. 637-644, 1995.

[22] Y. Dai and Y. Nakano, "Face-Texture Model Based on SGLD and Its Application in Face Detection in a Color Scene," Pattern Recognition, vol. 29, no. 6, pp. 1007-1017, 1996.

[23] S. McKenna, S. Gong, and Y. Raja, "Modelling Facial Colour and Identity with Gaussian Mixtures," Pattern Recognition, vol. 31, no. 12, pp. 1883-1892, 1998.

[24] R. Kjeldsen and J. Kender, "Finding Skin in Color Images," Proc. Second Int'l Conf. Automatic Face and Gesture Recognition, pp. 312- 317, 1996.

[25] I. Craw, D. Tock, and A. Bennett, "Finding Face Features," Proc. Second European Conf. Computer Vision, pp. 92-96, 1992.

[26] A. Lanitis, C.J. Taylor, and T.F. Cootes, "An Automatic Face Identification System Using Flexible Appearance Models," Image and Vision Computing, vol. 13, no. 5, pp. 393-401, 1995.

[27] K.-K. Sung and T. Poggio, "Example-Based Learning for View Based Human Face Detection," IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 20, no. 1, pp. 39-51, Jan. 1998.

[28] H. Rowley, S. Baluja, and T. Kanade, "Neural Network-Based Face Detection," IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 20, no. 1, pp. 23-38, Jan. 1998.

[29] E. Osuna, R. Freund, and F. Girosi, "Training Support Vector Machines: An Application to Face Detection," Proc. IEEE Conf. Computer Vision and Pattern Recognition, pp. 130-136, 1997.

[30] H. Schneiderman and T. Kanade, "Probabilistic Modeling of Local Appearance and Spatial Relationships for Object Recognition," Proc. IEEE Conf. Computer Vision and Pattern Recognition, pp. 45-51, 1998.

[31] A. Rajagopalan, K. Kumar, J. Karlekar, R. Manivasakan, M. Patil, U. Desai, P. Poonacha, and S. Chaudhuri, "Finding Faces in Photographs," Proc. Sixth IEEE Int'l Conf. Computer Vision, pp. 640- 645, 1998.

[32] M.S. Lew, "Information Theoretic View-Based and Modular Face Detection," Proc. Second Int'l Conf. Automatic Face and Gesture Recognition, pp. 198-203, 1996.