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Comparison and Review of Face Recognition Methods Based on Gabor and Boosting Algorithms

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ABSTRACT

The face plays an essential role in identifying people and showing their emotions in society. The human ability to recognize faces is remarkable. But face recognition is a fundamental problem in many computer programs. Due to the inherent complexities of the face and the many changes in its features, different algorithms for face recognition have been introduced in the last 20 years. Face recognition methods that are based on the structure of the face are unsupervised methods that produce good results compared to the linear changes that occur in the image. In this article, the Gabor algorithm, which is the origin of face recognition algorithms, has been described. Over the past decade, most of the research in the area of pattern classification has emphasized the use of the Gabor filter bank for extracting features. Because the Gabor algorithm has shortcomings, researchers have introduced a new method that is a combination of Gabor and PCA. After the introduction of the Gabor method, more complete and accurate algorithms have been introduced, such as Boosting algorithms, which we have briefly explained in this article. Also, here are the results of the comparison made by the researchers between Boosting and Gabor algorithms .The results show that Boosting-based algorithms have performed better compared to Gabor-based algorithms.

1. Introduction

The problem of face recognition is one of the famous problems in the field of computer vision. Face recognition is a system method in which people are identified exclusively by their facial features [1]. Face detection is the cornerstone for all face analysis algorithms, including face alignment, face modeling, face relief, face recognition, face verification, head pose tracking, gender, age detection, and more [2]. In general, the applications of face recognition systems include gender classification, document control, access control, human-computer interaction system, attendance system, photography of some digital cameras, and extraction of facial features such as nose, eyes, mouth, and skin color [3]. Computers can clearly understand faces and then begin to truly understand people's thoughts and intentions. Research in this field has been carried out for more than 30 years, as a result of which face recognition techniques have been in a good state and have made good progress. In recent years, many commercial applications of face recognition have become more widespread, such as identifying criminals, security systems, video and image processing. Face recognition methods are generally divided into three categories (a) methods based on knowledge and fixed characteristics, (b) methods based on appearance (c) methods based on pattern matching [4].

In the method, based on knowledge and fixed features, the location of facial features such as eyes, nose, mouth, and skin color is determined, and it is recognized by geometric relationships between these facial features [5]. In appearance-based methods, the face recognition issue is considered a two-class pattern recognition issue, which is based on statistical learning. The learned features are in the form of distribution models or discriminant functions that are subsequently used for face recognition. Appearance-based methods have received considerable attention in recent years and have been proven to be more successful and robust than feature-based methods [6]. In pattern matching methods, a standard face pattern (often the whole face) is manually predetermined or parameterized by a function. When the image is tested, correlation values with standard patterns are calculated independently for the contours of the face, eyes, nose, and mouth. The presence of a face is determined based on correlation values. This approach has the advantage of the simplicity of implementation. However, because it cannot effectively handle changes in scale, pose, and shape, it is not sufficient for face recognition. Multi-scale, multi-resolution templates, sub-template, and transformable templates were subsequently presented to achieve robustness against scale and shape changes [7]. Many algorithms have been proposed for face recognition, including the Gabor algorithm, PCA, BFO-GA, boosting algorithm, SVM algorithm, firefly algorithms and etc. [8]. In this article, we will first explain the Gabor algorithm, then the combination method of Gabor and BFO will be explained. Then the boosting algorithm and the methods based on it, including Adaboost, Float Boosting, and SVM algorithm, are explained. Finally, a comparison was made between the methods based on the Gabor algorithm and the boosting method, and the results of them are given here.

2. An Overview of the Presented Methods

2.1. Gabor and PCA Algorithms

The Gabor wavelet, also known as the Gabor filter, was introduced by Dennis Gabor in 1946 as a tool for signal processing in noisy systems. Gabor filters were introduced by Dennis Gabor for one-dimensional signals, but later, Dogman extended them to two-dimensional filters. The Gabor wavelet method is a method that uses local features for face recognition [9]. Multi-directional face image information can be extracted by Gabor wavelets. The features extracted by Gabor filters are called Gabor features, and these features exist in local areas with multiple scales [10]. Because Gabor filters create redundancy and this affects face recognition, an algorithm was introduced in which, instead of using Gabor filters alone, a combination of Gabor filters calculated using PCA (Principal Component Analysis) is used. These filters are called original Gabor filters, and they help to remove redundancy and succeed in face recognition. This method is a fast method in face recognition and requires a small training set. Human faces are matched with the features extracted by this method Fig. 1 [11].

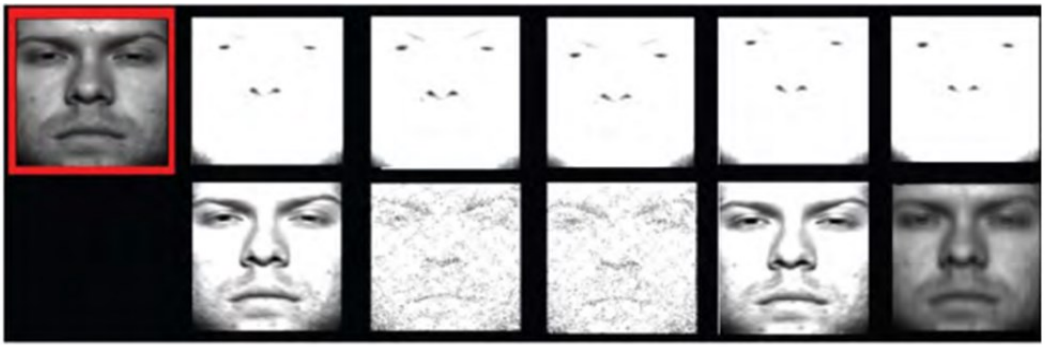

Fig. 1. 2D Gabor representation of a human face

Different methods can be used to calculate the principal component. Li et al. and Zou et al. have used eigenvalues related to the covariance matrix of the data. If we consider the input data X as follows:

$$X = [X1, X2, \dots, Xn] \tag{1}$$

where n is the number of data samples, and Xi is a data sample with dimensions D. First, the average of the samples, i.e., $\bar{X}$, is subtracted from each of the data samples (relation 2).

$$\hat{X} = [X_1 - \bar{X}, X_2 - \bar{X}, \dots \dots X_n - \bar{X}] \tag{2}$$

Then the covariance matrix $\sum \hat{X}$ is calculated from the following equation:

$$\sum \hat{X} = \frac{1}{n} \hat{X} \hat{X}^T \tag{3}$$

The main axes are now obtained by calculating the eigenvectors $\phi_{\hat{X}}$ of the covariance matrix equation (4).

$$\sum \hat{X} \, \phi_{\hat{X}} = \phi_{\hat{X}} \tag{4}$$

That

$$\Lambda_{\hat{X}} = \begin{bmatrix} \lambda_1 & 0 \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots 0 & \lambda_n \end{bmatrix} \tag{5}$$

Where $\Lambda_{\hat{X}}$ is the diagonal matrix of eigenvalues corresponding to eigenvectors $\phi_{\hat{X}}$. The corresponding eigenvectors with the highest eigenvalues represent the original vectors with the highest data variance, in other words, the primary principal components. The i is sample data, i.e., X_i, can be transferred to the PCA space using Equation (6).

$$y_i = \phi_{\hat{X}}^{-1}(X_i - \bar{X}) = \phi_{\hat{X}}^{T}(X_i - \bar{X}) \tag{6}$$

It should be noted that a diagonal matrix, for example $\phi_{\hat{X}}$ has the property $\phi_{\hat{X}}^{-1} = \phi_{\hat{X}}^{T}$. The data in the PCA space can be returned to its original space using the relation (7).

$$X_i = y_i \phi_{\hat{X}} + \bar{X} \tag{7}$$

If only a subset of eigenvectors in $\phi_{\hat{X}}$ is selected, the result will be obtained by depicting the data space in a subspace of the PCA space. This can be very useful for reducing redundancy in data, i.e., removing all eigenvectors that are equal to zero [12, 13].

2.2. BFO-Gabor Algorithms

Dora et al. have used this method for face recognition. In their work, they used two facial image databases, ORL and UMIST, to investigate the effectiveness of the proposed BFO-Gabor method approach. The ORL dataset contained 400 different face samples, and the UMIST dataset contained 1012 different faces. These filters were used to separate the extracted features and then use the probabilistic reasoning model for classification. The performance of the proposed method has been confirmed using the ORL database. It can be seen from the results (Table 1) that their proposed method works better than the Gabor filter method, evolutionary Gabor filter optimization (EGFO), and congestion optimization [14-16].

Table 1. The error rate for face classification

Face database	**Methods**				
	GF method (3×5) (%)	GF method (5×8) (%)	EGFO method (%)	PSO-Gabor method (%)	BFO-Gabor method (%)
ORL	9.5	8.5	4.5	3	2
UMIST	10.91	8.45	2.11	1.99	1.44

2.3. Methods based on Boosting Algorithm

In 2001, Viola and Jones introduced the first real-time full-face face detection system. The proposed system included three types. Their proposed system included three types of cultivation. First, instead of using pixel information, they proposed the use of a new image representation called an Integral image and a set of simple Haar-like features that can be calculated at any location and scale using the integral image in constant time. Second, they used a modified version of the boosting learning algorithm called AdaBoost, both for feature selection and classification design. Then, to increase the speed of calculations, they presented a cascade structure of categories that quickly rejects the background areas of the image in the initial layers of the cascade and performs further calculations on the face candidate areas.

Their final detection consisted of 38 layers and 6060 features. Non-face training dataset, 10,000 images are used in the first layer, and between 5,000 and 6,000 images are used for the next layers. The best performance of the system on the CMU+MIT test set with 422 false detections is 94.1%. Processing a 384×288-pixel image on a 700 MHz Pentium 3 processor was reported to be around 67 milliseconds, which was 15 times faster than other methods presented before them under similar conditions. Their method is the first system in a new family of face detection methods called Boosting-based methods [17]. Since the successful work of Viola and Jones, the attention of most researchers has been focused on boosting-based approaches. These methods showed very good results in both accuracy and speed and thus became very suitable for real-time applications [18, 19].

2.4. Alternative Boosting Algorithm

Ma and Ding proposed a method based on the Adaboost algorithm, which has two major differences from the Adaboost used in the Viola and Jones system. First, each test sample is weighted differently based on its misclassification cost. Second, the weights of positive and negative samples are updated separately in each iteration. They claimed that with these two changes, each layer of the cascade focuses more on face samples and achieves a higher and more robust detection rate with a relatively low number of false detections. Therefore, the final detection can achieve a high detection rate. The training dataset included 11580 faces and 11000 non-faces in the size of 20×20 pixels. The final detector consists of 20 layers and 3000 features.

The performance of the system on the CMU+MIT test set with 10 false detections is reported to be 90.1%, which is 7% better than the Viola and Jones system [20]. After them, Linhart et al. compared three algorithms named Discrete Adaboost, Real and Gentle. They trained three cascading detectors of 20 layers, each using five basic Haar-like features and a weak stump classifier. The training dataset included 5000 faces and 3000 non-faces in the size of 20×20 pixels. The efficiency of three detectors based on Discrete behavior, Real and Gentle, on the CMU+MIT test set with 130 images and 510 full-face faces, with 10 false detections, is reported as 79.5%, 75.4%, and 82.7%, respectively. It shows that the performance of Gentle is slightly better than the other two methods [21].

2.5. Float Boosting Algorithm

Li et al. also proposed a new boosting algorithm called FloatBoosting to solve the monotony problem in the forward sequential search procedure of AdaBoost. After each iteration, FloatBoost removes the least important weak cluster, which leads to a higher error rate for the final cluster. Compared to sequential Boost, FloatBoost requires fewer weak classes to achieve the same error rate. The cost of such an improvement is the learning time, which takes about five times longer [22]. Dhivakar et al. have presented a method that consists of two main components for face recognition and recognition of recognized faces. In the identification stage, skin color segmentation with a threshold color model is used in combination with the Adaboost algorithm, which is fast and accurate in recognizing faces. Also, a series of morphological operators are used to improve face recognition performance. The detection part consists of three steps: Gabor feature extraction, dimensionality reduction, and feature selection using the PCA algorithm and KNN-based (K-Nearest Neighbors) classification. This system is able to recognize scales, poses, and skin colors in different lighting conditions. The set of images that were given to the system for face recognition included 250 images. Fig. 2 and Fig. 3 show the input image and the detected image by this method, respectively [23].

Fig. 2. input image

Fig. 3. detected image

2.6. SVM algorithm

SVM algorithm (Support Vector Machine) is one of the algorithms in the field of data classification. A set of points in the n-dimensional data space is called a support vector, which shows the boundaries of the categories and performs their classification and demarcation, and by moving one of these two items, it may change [24]. The SVM algorithm performs the best classification and separation between the data by the criterion of placing the support vectors.

The structure of the SVM training algorithm is based on an inner multiplication kernel between a support vector such as Xi and the X vector obtained from the input space. The smallest subset of training data extracted by the above algorithm is called the Support Vector. Depending on how this inner multiplication kernel is generated, different learning machines with corresponding non-linear decision planes may be obtained. The purpose of this algorithm is to find the best border among the data, and it considers the largest possible distance from all categories and is not sensitive to other data points. The SVM algorithm is one of the newest facial recognition techniques that has been widely used in recent years in various applications such as face recognition, object recognition, handwriting and digit recognition, speech and speaker recognition, and image and information retrieval [25].

Filali et al. have presented a comparison between four algorithms, Haar-AdaBoost, GF-SVM, LBP-AdaBoost, and GFNN, for face recognition. These techniques are different according to the way of data extraction and learning algorithms. The Haar-AdaBoost and LBP-AdaBoost methods are based on the boosting algorithm, which is used to both select and learn a robust classifier with cascade classification. At the same time, the two methods, GF-SVM and GFNN, use the Gabor filter to extract data. The detection time of the methods is different from each other. In fact, the methods based on the boosting algorithm are faster than the other two algorithms. But in terms of tracking rate and false detection rate, the Haar-AdaBoost method works better. For the four methods, during each round of training, a new weak learner is added to the ensemble, and a weight vector is adjusted to focus on examples that were not classified in previous rounds. The result is a classifier that has higher accuracy than poorly trained classifiers. The example of the test image is shown in Fig. 4, and the method of detection by the different methods presented in this article is shown in Fig. 5 [26].

Fig. 4. Sample image including 56 faces

Fig. 5. Recognition by different methods

3. Conclusion

In this article, the Gabor algorithm, which is the origin of face recognition methods, was explained, and the researchers developed face recognition methods inspired by this algorithm in the following years. Among Gabor-based methods, the BFO-GA algorithm performed better and had a lower error rate in face recognition. Algorithms based on the boosting method have higher operating speed and better detection accuracy compared to Gabor. In this article, the SVM algorithm, which is one of the newest and most widely used face recognition techniques, was investigated. In the comparison between four algorithms, including Haar-AdaBoost, GF-SVM, LBP-AdaBoost, and GFNN algorithms, the methods based on the boosting algorithm performed faster than the other two algorithms. And among them, the Haar-AdaBoost method has performed better compared to other methods.

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References

[1] D. Bhattacharyya, R. Ranjan, F. Alisherov, and M. Choi, "Biometric authentication: A review," *International Journal of u-and e-Service, Science and Technology*, vol. 2, no. 3, pp. 13-28, 2009, https://www.earticle.net/Article/A148496.

[2] H. M. I. Pousinho, V. M. F. Mendes, and J. P. S. Catalão, "A hybrid PSO–ANFIS approach for short-term wind power prediction in Portugal," *Energy Conversion and Management*, vol. 52, no. 1, pp. 397-402, 2011, https://doi.org/10.1016/j.enconman.2010.07.015

[3] M. Abdullah, M. Wazzan, and S. Bo-Saeed, "Optimizing face recognition using PCA," *arXiv preprint*, arXiv:1206.1515, 2012, https://doi.org/10.48550/arXiv.1206.1515.

[4] M.-H. Yang, D. J. Kriegman, and N. Ahuja, "Detecting faces in images: A survey," *IEEE Transactions on pattern analysis and machine intelligence*, vol. 24, no. 1, pp. 34-58, 2002, https://doi.org/10.1109/34.982883.

[5] D. Triantafyllidou and A. Tefas, "A fast deep convolutional neural network for face detection in big visual data," *INNS conference on big data*, pp. 61-70, 2016, https://doi.org/10.1007/978-3-319-47898-2_7.

[6] E. Osuna, R. Freund, and F. Girosit, "Training support vector machines: an application to face detection," *Proceedings of IEEE computer society conference on computer vision and pattern recognition*, pp. 130-136, 1997, https://doi.org/10.1109/CVPR.1997.609310.

[7] E. Hjelmås and B. K. Low, "Face detection: A survey," *Computer vision and image understanding*, vol. 83, no. 3, pp. 236-274, 2001, https://doi.org/10.1006/cviu.2001.0921.

[8] A. Yousefiankalareh, T. Kamyab, A. M. Ghahfarokhi, F. Beheshtinejad, H. Mirzanejad, and S. Seddighi, "Utilizing Multi-Agent Systems Approach in Firefly Algorithm," *2021 International Conference of Modern Trends in Information and Communication Technology Industry (MTICTI)*, 2021, https://doi.org/10.1109/MTICTI53925.2021.9664757.

[9] H. Cho, R. Roberts, B. Jung, O. Choi, and S. Moon, "An efficient hybrid face recognition algorithm using PCA and GABOR wavelets," *International Journal of Advanced Robotic Systems*, vol. 11, no. 4, p. 59, 2014, https://doi.org/10.5772/58473.

[10] D. Dubey and 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, pp. 103-112, 2016, https://doi.org/10.14257/ijsip.2016.9.9.10.

[11] G. C. Feng, P. C. Yuen, and D. Q. Dai, "Human face recognition using PCA on wavelet subband," *Journal of electronic imaging*, vol. 9, no. 2, pp. 226-233, 2000, https://doi.org/10.1117/1.482742.

[12] A. K. Jain and S. Z. Li, *Handbook of face recognition*, Springer London, 2011, https://doi.org/10.1007/978-0-85729-932-1.

[13] C.-r. Zou, N. Sun, Z.-h. Ji, and L. Zhao, "2DCCA: a novel method for small sample size face recognition," *2007 IEEE Workshop on Applications of Computer Vision (WACV'07)*, 2007, https://doi.org/10.1109/WACV.2007.1.

[14] L. Dora, S. Agrawal, R. Panda, and A. Abraham, "A novel optimal Gabor algorithm for face classification," *Soft Computing for Problem Solving*, pp. 821-832, 2019, https://doi.org/10.1007/978-981-13-1595-4_65.

[15] D.-G. Zhang, S. Liu, X.-H. Liu, T. Zhang, and Y.-Y. Cui, "Novel dynamic source routing protocol (DSR) based on genetic algorithm-bacterial foraging optimization (GA-BFO)," *International Journal of Communication Systems*, vol. 31, no. 18, p. e3824, 2018, https://doi.org/10.1002/dac.3824.

[16] S. Dasgupta, S. Das, A. Abraham, and A. Biswas, "Adaptive computational chemotaxis in bacterial foraging optimization: an analysis," *IEEE Transactions on Evolutionary Computation*, vol. 13, no. 4, pp. 919-941, 2009, https://doi.org/10.1109/TEVC.2009.2021982.

[17] P. Viola and M. Jones, "Rapid object detection using a boosted cascade of simple features," *Proceedings of the 2001 IEEE computer society conference on computer vision and pattern recognition, CVPR 2001*, 2001, https://doi.org/10.1109/CVPR.2001.990517.

[18] J. Lu, K. N. Plataniotis, A. N. Venetsanopoulos, and S. Z. Li, "Ensemble-based discriminant learning with boosting for face recognition," IEEE transactions on neural networks, vol. 17, no. 1, pp. 166-178, 2006, https://doi.org/10.1109/TNN.2005.860853.

[19] S. Zafeiriou, C. Zhang, and Z. Zhang, "A survey on face detection in the wild: past, present and future," *Computer Vision and Image Understanding*, vol. 138, pp. 1-24, 2015, https://doi.org/10.1016/j.cviu.2015.03.015.

[20] Y. Ma and X. Ding, "Robust real-time face detection based on cost-sensitive AdaBoost method," *2003 International Conference on Multimedia and Expo, ICME'03, Proceedings (Cat. No. 03TH8698)*. 2003, https://doi.org/10.1109/ICME.2003.1221654.

[21] R. Lienhart, A. Kuranov, and V. Pisarevsky, "*Empirical analysis of detection cascades of boosted classifiers for rapid object detection*," *Joint pattern recognition symposium*, 2003, https://doi.org/10.1007/978-3-540-45243-0_39.

[22] S. Z. Li and Zhenqiu Zhang, "Floatboost learning and statistical face detection," *IEEE Transactions on pattern analysis and machine intelligence*, vol. 26, no. 9, pp. 1112-1123, 2004, https://doi.org/10.1109/TPAMI.2004.68.

[23] B. Dhivakar, C. Sridevi, S. Selvakumar, and P. Guhan, "Face detection and recognition using skin color," *2015 3rd International Conference on Signal Processing, Communication and Networking (ICSCN)*, 2015, https://doi.org/10.1109/ICSCN.2015.7219848.

[24] A. Yousefiankalareh, T. Kamyab, F. Shahabi, E. Salajegheh, H. Mirzanejad, and M. M. Masouleh, "Face recognition based on sparse coding using support vector machine classifier," *2021 International Conference on Intelligent Technology, System and Service for Internet of Everything (ITSS-IoE)*, 2021, https://doi.org/10.1109/ITSS-IoE53029.2021.9615322.

[25] V. N. Vapnik, *The nature of statistical learning theory*, Springer science & business media, 2020, https://doi.org/10.1007/978-1-4757-3264-1.

[26] H. Filali, J. Riffi, A. M. Mahraz, and H. Tairi, "Multiple face detection based on machine learning," *2018 International Conference on Intelligent Systems and Computer Vision (ISCV)*, 2018, https://doi.org/10.1109/ISACV.2018.8354058.