(Optimizing Haar-Cascade Performance for Face Detection Using Median Filter)

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ملخص:

تُركز عملية تمييز الوجوه على توفير المزيد من الأمان باستخدام المميزات البيولوجية وزيادة مستوى الأمان والخصوصية. وفي هذا البحث، اقترحنا طريقة لتحسين خوارزمية خواص هار المستطيلة Haar-like cascade والمدرجة ضمن مكتبة -OpenCV Open Computer Vision والتي تم تطويرها من قبل شركة Intel. حيث أظهرت النتائج تحسنا واضحا في دقة خوارزمية -Haar Cascade للكشف عن الوجوه.

الكلمات المفتاحية: تمييز الوجوه، Haar Cascade، OpenCV، المميزات البيولوجية.

Abstract:

Face detection concentrates on providing more security by using biological features and increasing security and privacy levels. In this paper, we proposed an approach to optimize the Haar-cascade algorithm developed from the OpenCV Computer vision library which was developed by Intel Company. The results revealed a clear enhancement and thereby improved the level of accuracy for the detected faces using Haar-Cascade.

Keywords: Face Detection, Haar cascade, OpenCV2.

Introduction:

Image processing is a system that processes image-based input and produces image-based output. The purpose of the system is to enhance the quality of the image based on the user's intention. Specifically, it aims to improve the quality of the image. Human faces are dynamic objects with varied shapes and colors, which can pose more problems compared to other image objects[1].

Detecting human faces plays a crucial role in human-machine interaction and computer vision-based applications. The human face provides unique and non-replicable identity information. However, due to various factors such as different lighting conditions, expressions, backgrounds, and other uncertainties, detecting human faces remains challenging in real-world applications[2].

The rapid change in technical services requires more security and privacy. During the last decade, biometric technology has become the most important security method for providing individuals with more reliable services and preventing their sensitive data from being stolen. Face detection is one of the most used techniques because it helps the end-user verify their credentials and use their faces as a two-factor authentication feature (TFA) for more security.

The Haar cascade algorithm is used to achieve high performance and fast processing speed in face detection because it has the advantage of a high detection rate for human faces based on the training set used to reduce the error ratio and make it more accurate[1].

Literature Review:

Yi-Qing Wang used the viola-jones algorithm for face detection. In this algorithm, Haar-like features, or a scalar product between an image and a few Haar-like templates are used. This approach was applied to 2000 images which are divided into 1000 images in the training set, and 1000 images in the testing set. These images are taken from National Oceanic and Atmospheric Administration (NOAA) and European Southern Observatory[3]. The Adaboost algorithm is used to classify the features and achieve a high performance.

In this study, Ashu Camar et al. gave a thorough introduction to face detection and covered a wide range of face detection techniques, their methods for extracting features, and the mechanisms involved in matching and classifying them. In addition, the researchers conducted many scientific discussions that would aid in the creation of new face-detection techniques. They also talked about the benefits and drawbacks of various databases used in face detection[4].

Liying Lang and Weiwei Gu applied three algorithms on three various databases to face detection. The AdaBoost algorithm, the Principal Component Analysis (PCA) algorithm, and the automatically generated cascade classifier (AM-CC) algorithm. Using these algorithms in this study not only achieves high results but also face detection velocity by more than one time and adds too much improvement to the illumination. By applying these algorithms to the Carnegie Mellon University (CMU) database, the following results were obtained: the Adaboost algorithm achieved 83.2%, the PCA algorithm achieved 80.4% and the AM-CC algorithm achieved 91.6%. while applying these algorithms on the IMM database obtained the following results:the Adaboost algorithm achieved 85.6%, the PCA algorithm achieved 81.3% and the AM-CC algorithm achieved 93.2%. Finally applying these algorithms to the ORL database achieved the following results: the Adaboost algorithm achieved 87.9%, the PCA algorithm achieved 84.5% and the AM-CC algorithm achieved 96.5%[5].

The researchers in this study utilized an algorithm that relies on skin color. The algorithm involves creating a graphical model of skin color using multiple pixels, then segmenting the skin color into images by iteratively projecting the histogram to obtain a binary image of skin color. After that, further enhancement of the segmentation result is performed. The results showed that faces can be detected with different sizes, rotations, and expressions under various illumination conditions quickly and accurately[6].

The study used a method to analyze colored images of faces under different lighting and complex backgrounds. The lighting was controlled, and missing colors were compensated for. The method also created maps and boundaries of the mouth and eyes to verify each candidate's face. It showed high accuracy across various facial variations in color, orientation, expression, and 3D pose in multiple images. This method was tested on the FERET face database and CMU database and demonstrated good performance[7].

To achieve high performance in face detection, researchers, VIOLA and JONES, used several techniques that are capable of processing images extremely rapidly. The function of these technologies can be summarized in three main points: Firstly, a new representation of images that called the “Integral Image” which allows computing the features from images extremely rapidly. Secondly using the Adaboost classifier to choose a small number of visual features from a big number of possible features. Thirdly, quickly discard the background areas of the image. The most important feature of the technology used here is the speed of time in face detection which is faster approximately 15 times than any previous approach as well as achieving a higher accuracy[8].

The researchers studied several techniques used in face detection, identifying the merits and demerits of each method and comparing them with each other. These techniques are: firstly, Feature Base Face Detection which is distinguished as more accurate and has low execution time but its demerit is high learning time. Secondly, Geometric Base Face Detection, a distinguished Effective approach that is easy to implement but its demerits are low accuracy and more false alarms. Thirdly, Haar Like Feature Base Face Detection which is distinguished by improved feature extraction part and fewer false alarms but its demerits are high execution time and complex to implement. After study and comparison, the researchers found that the best technique among the techniques used is: Haar Like Feature Base Face Detection[9].

In order to improve the accuracy of the face detection system, researchers utilized various techniques to achieve the highest percentage of face detection in the shortest amount of time. The study involved the use of hardware devices, such as a webcam and an Arduino board with a microcontroller, serving as input and output devices. Face detection techniques were applied using the MATLAB platform to develop a real-time application, such as a security system. The development of a real-time application, like a security system, was one of the most important goals of this study[10].

The methodology used by Turk and Pentland aimed to detect them by comparing facial characteristics with those of known individuals. This approach uses 2D face recognition, based on the principle that faces are usually upright and can be identified and described from a small set of 2D views. The images are displayed on a feature space (face space) that best encodes the difference between facial images. This approach provides the ability to recognize new faces in a more accurate and unsupervised manner[11].

Zafaruddin and Fadewar introduced the PCA algorithm for face recognition, which is implemented using a neural network system. The methodology consists of three main steps. First, the head is processed by rotating and normalizing it. The second step involves identifying important aspects of identification through PCA components. In the third step, the corresponding eigenfaces are calculated using the initial set of face images. The study involved creating a database of faces using neural networks, with a separate network built for each person. This approach was tested on the ORL database[12].

Methodology:

The Model of the Proposed Approach:

We plan to enhance the performance of the Haar Cascade algorithm from Open Computer vision (OpenCV2). The process will start with converting the input image from RGB to BGR to help clarify the edges. The next step concentrates on sharpening the image using kernel (array of values) to emphasize edges and helps the Haar-like cascade algorithm with a median filter to achieve much more reliable results based on the extracted features and reduce the outcome error ratio. Figure (1) describes the steps of this study for enhancing the Haar Cascade algorithm by preprocessing the input image.

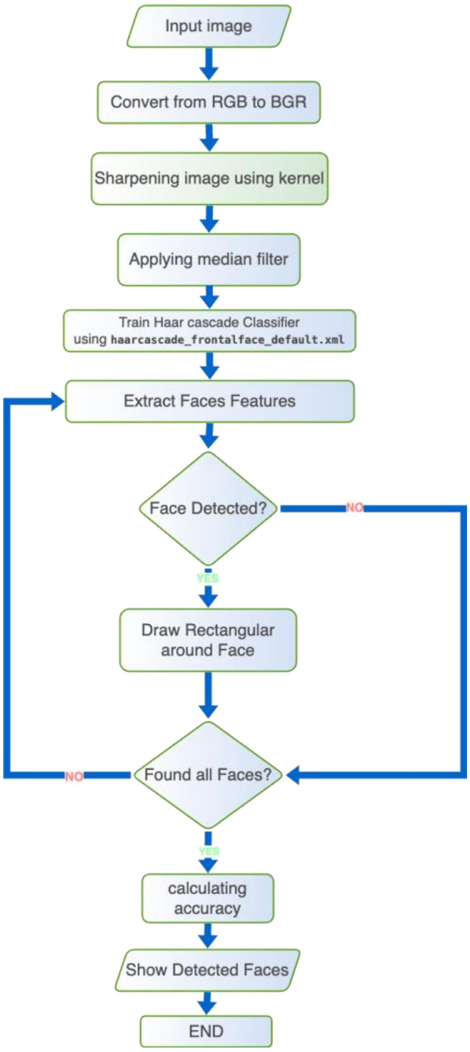

Figure (1) shows the flowchart of the proposed model

Sharpness using Kernels

In image processing, a kernel is a small 2D matrix with a set of values, which is used to transform the input image. these values are specified based on the applied operation, such as blurring, sharpening, edge detection, etc as shown in Figure (2). This process involves multiplication and addition and it is called convolution.

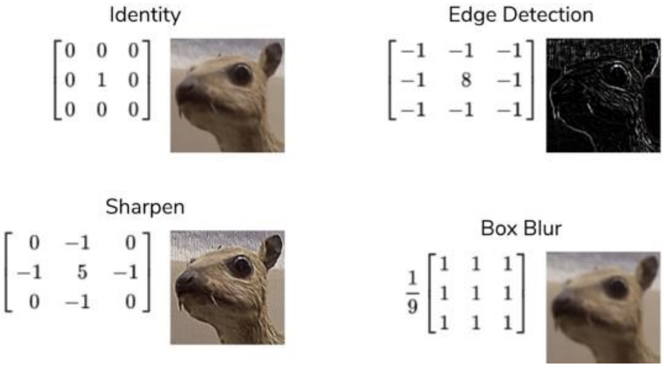

Figure (2): describes the Kernal matrix Values (Convolutional Features)

Median filter.

Median filtering is a technique used to process non-linear signals to remove noise. It has been used in time series analysis and image processing. Proposed by Tukey in 1971, the average filtering process involves moving a window over the points of the image (or sequence), replacing the value in the center of the window with the average of the original values inside the window. This results in a smoother and clearer image (sequence) than the original[13].

Although the classical smoothing procedure, which involves using a low-frequency linear filter, is the most suitable method for removing or reducing noise, median filtering is even better as it preserves sharp edges, unlike classical smoothing which blurs these edges. Additionally, median filtering is very effective in reducing spiky noise[13].

One-Dimensional Median Filters

The middle number in size for n odd numbers is the median of n numbers x 1..... x. We define n as the average of the two middle values. We denote the median by Median (x 1 ..... x,).

For example: Median (0, 3, 4, 0, 7) = 3.

A median filter of size n on a sequence $\{x_i$, iÎz$\}$ is for n odd defined through:

y_i = Median x_i ΔMedian $_n$ (x_{i_v}, ..., x_i ,.....,x_i+v), iÎZ. (1)

Where v = (n-1)/2 and z represents the set of all natural numbers. Other terminology includes moving medians and running medians. It is easy to see that this median filter preserves edges, whereas the corresponding moving average filter[13].

z_i=(x_{i_v}+ ... + x_i+ ... + x_i+v)/n, iÎz. (2)

changes an edge into a ramp with width n.

Two-Dimensional Median Filters.

Digital pictures will be represented by sets of numbers on a square lattice $\{x_{ij}\}$ where (i, j) runs over Z^2 or some subset of Z^2[13].

A two-dimensional median filter with filter window A on a picture $\{x_{ij}, (i,j) \hat{I} Z^2\}$ is defined through:

$$Y_{ij} = \text{Median}_A\, x_{ij}\ \Delta\ \text{Median}\ [x_i + {}_{r,\,j}+_s;\ (r, s)\ \hat{I}A]\ (i, j)\ \hat{I}\ Z^2 \qquad (3)$$

Results and Discussions

The experiment involves using OpenCV, also known as the Open Computer Vision Library, developed by Intel. This library provides a training set for the Haar cascade algorithm, which is utilized to train the proposed model. The next step involves testing the trained algorithm using two image sets, each rich in features and details. The first image contains 8 complete faces without any cuts, while the second image consists of 27 full faces to add more complexity to the test. The proposed model involves preprocessing steps in the algorithm, including sharpening the image and applying a median filter to enhance the accuracy of the face detection process. First, we tested the algorithm without optimizing the image on Image (1), as shown in Figure (1), resulting in an accuracy of 80.00%.

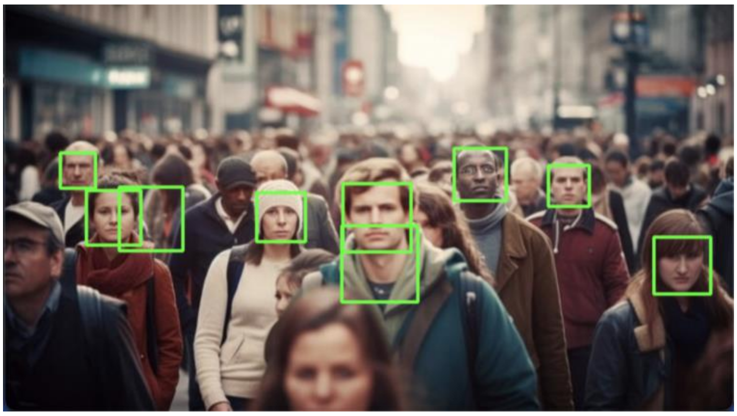

Figure (3): The first testing image.

The accuracy of the outcomes was calculated using Binary Classification. It depends on four major values as illustrated in Figure (5) and as shown in the following equation:

$$\text{Accuracy}=\frac{TP+TN}{TP+TN+FP+FN} \qquad (4)$$

- True Positive (TP) means correctly predicting human faces.

- False Positive (FP) means incorrectly predicting non-faces as faces.

- False Negative (FN) means missing human faces.

- True Negative (TN) means correctly predicting non-faces.

the output for the first image is:

- True Positives (TP): 8
- False Positives (FP): 1
- True Negatives (TN): 0
- False Negatives (FN): 1
- Accuracy: 80.00%

The result of 1 false positive and 1 false negative indicates that the algorithm needs more customization to improve the outcomes. Specifically, the lack of true negatives (TN = 0) proves that the model failed to identify negative cases that impact the overall performance.

Therefore, we optimized the image to prevent any falsely detected faces, and the accuracy increased to 100% as shown in Figure (2).

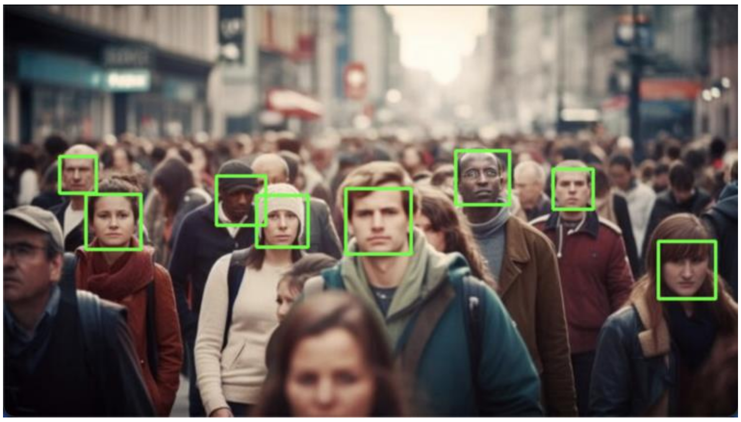

Figure (4) shows the result of the face detection test for the enhanced image.

the result was as follows:

- True Positives (TP): 8
- False Positives (FP): 0
- True Negatives (TN): 2
- False Negatives (FN): 0
- Accuracy: 100.00%

The elimination of false positives and false negatives, along with the correct identification of 2 true negatives, significantly improved the model's performance. This suggests that the optimization process effectively addressed the issues observed in the original configuration, leading to a more reliable and precise model.

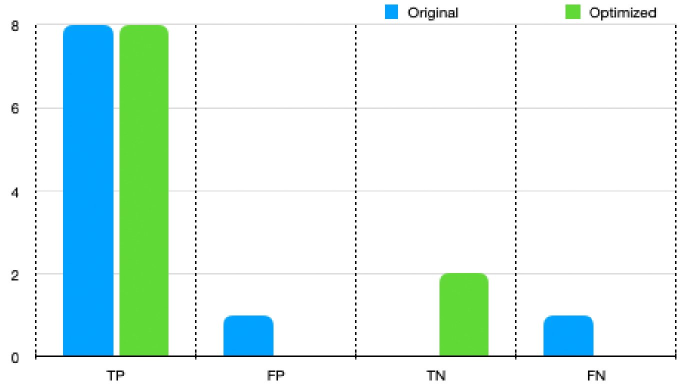

Figure (5) illustrates the four parameters of the accuracy for the first testing image.

The second experiment was applied to image (2) with more details and spots that can be detected as a human face to make it more complicated and harder to detect as shown in Figure (4).

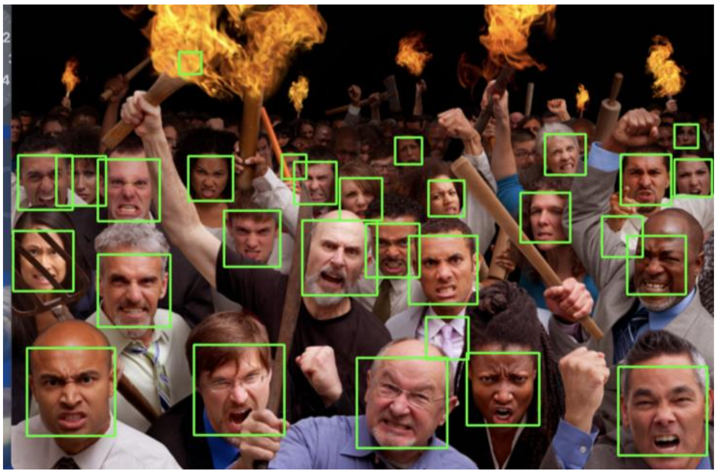

Figure (6) shows the result of the face detection test without optimization process.

the result for the original image 2:

- True Positives (TP): 27
- False Positives (FP): 2
- True Negatives (TN): 2
- False Negatives (FN): 1
- Accuracy: 90.62%

As for Image 2, the original configuration already demonstrated a high accuracy of 90.62%. However, 2 false positives and 1 false negative indicate a misclassification problem even though the model correctly identified both positive and negative cases.

The optimized configuration of Image 2 shows a clear improvement in accuracy, reaching 96.55%. Eliminating false positives, while having the same true and false negatives values, indicates the improved detection process in positive case identification. However, there is some reduction in true negatives. Despite this, the overall accuracy improved based on the optimization process.

- True Positives (TP): 27
- False Positives (FP): 0
- True Negatives (TN): 1
- False Negatives (FN): 1
- Accuracy: 96.55%

Figure (7) shows the result of face detection for the optimized image.

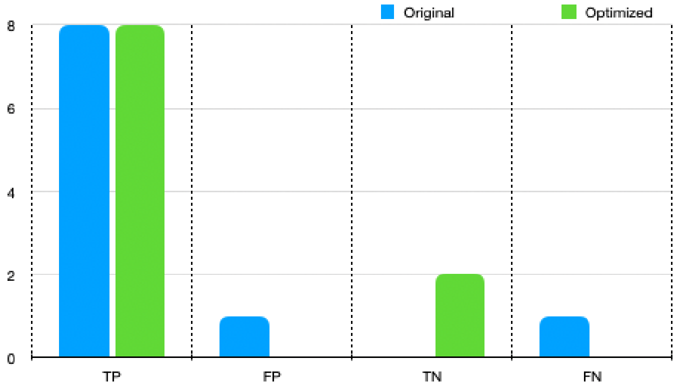

Figure (8) illustrates the four parameters of the accuracy for the second testing image .

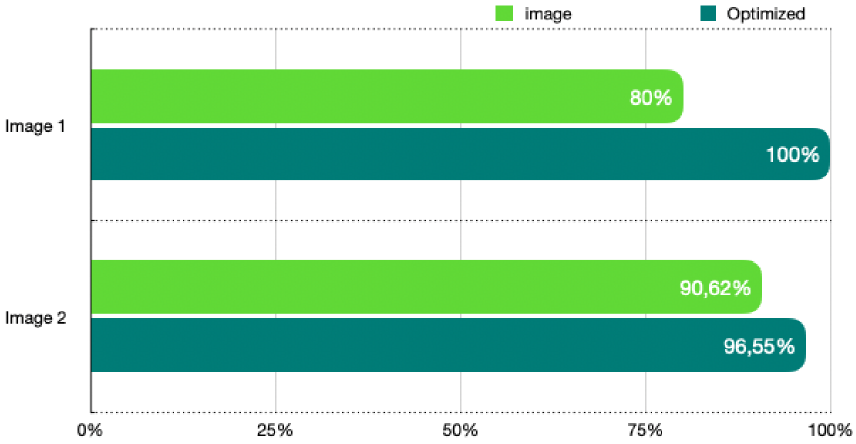

Figure (9) shows the final results for the proposed model.

Conclusion

Finally, the results indicate that the optimization process significantly improved the model's performance for both Image 1 and Image 2. Image 1 showed a significant demonstration from 80.00% to 100.00%, highlighting the success in addressing initial misclassifications, while the second image test achieved a higher accuracy of 96.55%. These results highlighted the advantages of this model evaluation and achieved optimal performance in image classification for face detection task.

References

[1] D. T. P. Hapsari, C. G. Berliana, P. Winda, and M. A. Soeleman, "Face detection using haar cascade in difference illumination," in *2018 International Seminar on Application for Technology of Information and Communication*, IEEE, 2018, pp. 555–559. Accessed: Jul. 30, 2024. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/8549752/

[2] L. Cuimei, Q. Zhiliang, J. Nan, and W. Jianhua, "Human face detection algorithm via Haar cascade classifier combined with three additional classifiers," in *2017 13th IEEE international conference on electronic measurement & instruments (ICEMI)*, IEEE, 2017, pp. 483–487. Accessed: Jul. 31, 2024. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/8265863/

[3] Y.-Q. Wang, "An analysis of the Viola-Jones face detection algorithm," *Image Processing On Line*, vol. 4, pp. 128–148, 2014.

[4] A. Kumar, A. Kaur, and M. Kumar, "Face detection techniques: a review," *Artif Intell Rev*, vol. 52, no. 2, pp. 927–948, Aug. 2019, doi: 10.1007/s10462-018-9650-2.

[5] L. Lang and W. Gu, "Study of face detection algorithm for real-time face detection system," in *2009 Second International Symposium on Electronic Commerce and Security*, IEEE, 2009, pp. 129–132. Accessed: Jul. 31, 2024. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/5209668/

[6] Q. Liu and G. Peng, "A robust skin color based face detection algorithm," in *2010 2nd International Asia Conference on Informatics in Control, Automation and Robotics (CAR 2010)*, IEEE, 2010, pp. 525–528. Accessed: Jul. 31, 2024. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/5456614/

[7] R.-L. Hsu, M. Abdel-Mottaleb, and A. K. Jain, "Face detection in color images," *IEEE transactions on pattern analysis and machine intelligence*, vol. 24, no. 5, pp. 696–706, 2002.

[8] P. Viola and M. J. Jones, "Robust Real-Time Face Detection," *International Journal of Computer Vision*, vol. 57, no. 2, pp. 137–154, May 2004, doi: 10.1023/B:VISI.0000013087.49260.fb.

[9] M. Chauhan and M. Sakle, "Study & analysis of different face detection techniques,"

International Journal of Computer Science and Information Technologies, vol. 5, no. 2, pp. 1615–1618, 2014.

[10] M. Ayi, A. K. Ganti, M. Adimulam, and B. Karthik, “Interfacing of MATLAB with Arduino for face detection and tracking algorithm using serial communication,” in *2017 International Conference on Inventive Computing and Informatics (ICICI)*, IEEE, 2017, pp. 944–948. Accessed: Jul. 31, 2024. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/8365276/

[11] M. A. Turk and A. P. Pentland, “Face recognition using eigenfaces,” in *Proceedings. 1991 IEEE computer society conference on computer vision and pattern recognition*, IEEE Computer Society, 1991, pp. 586–587. Accessed: Jul. 31, 2024. [Online]. Available: https://www.cin.ufpe.br/~rps/Artigos/Face%20Recognition%20Using%20Eigenfaces.pdf

[12] G. Md. Zafaruddin and H. S. Fadewar, “Face Recognition Using Eigenfaces,” in *Computing, Communication and Signal Processing*, vol. 810, B. Iyer, S. L. Nalbalwar, and N. P. Pathak, Eds., in Advances in Intelligent Systems and Computing, vol. 810. , Singapore: Springer Singapore, 2019, pp. 855–864. doi: 10.1007/978-981-13-1513-8_87.

[13] B. I. Justusson, “Median Filtering: Statistical Properties,” in *Two-Dimensional Digital Signal Prcessing II*, vol. 43, in Topics in Applied Physics, vol. 43. , Berlin/Heidelberg: Springer-Verlag, 1981, pp. 161–196. doi: 10.1007/BFb0057597.

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