Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 806-816
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

Double Classification Face Detection Algorithm Based On Successive Mean Quantization Transform

Shuyao Tian[1,2], Zhen Zhao[1*], Tao Hou[3], Liancheng Zhang[2,1]
[1] College of Electronics and Control Engineering, North China Institute of Aerospace Engineering, Langfang, China
[2] Hebei Electric Vehicle Charging Technology Innovation Center, China
[3] Beijing Aerospace Xinli Technology Co., Ltd, Beijing, China
*Corresponding Author.

Abstract:

Face detection refers to the determination of whether there are faces in the target image. If so, the location and number of faces should be determined. In the face detection process, there may be adverse effects such as different postures, changeable expressions, uneven shopping, obstructions and so on, which will reduce the accuracy of face detection. Therefore, this paper proposes a double classification face detection algorithm based on Successive Mean Quantization Transform (SMQT), which uses SMQT to extract face features, and then uses SNOW classifier and SVM classifier to locate the face region twice, so as to accurately identify the face position. After the usage, the accuracy and robustness of detection is effectively improved; the false detection rate is reduced; the operation speed of the algorithm is improved, and the robustness and accuracy of the algorithm is greatly improved.

Keywords*: Human face detection technology, Successive mean quantization, SNOW classifier, SVM classifier.*

I. INTRODUCTION

Face detection [1-3] is to judge whether there is a face in the target image. If there is, use a rectangular box to identify the specific location of the face. In recent years, face detection is widely used in various fields such as video surveillance, man-machine exchange, face database, computer vision and so on [4-7]. Zhu[8] proposed a face recognition algorithm by face block approximate symmetry preprocessing to solve the problems of low accuracy and poor stability caused by local occlusion in unrestricted scenes. According to the location of face feature points and Src algorithm for face recognition, the recognition rate is effectively improved. The face recognition algorithm based on orthogonal sparse constrained nonnegative tensor decomposition proposed by Song Shan et al. [9] can add orthogonal sparse constraints to the traditional nonnegative tensor decomposition, reduce the correlation between base images and obtain sparse coding. The improved algorithm achieves good recognition effect. Zou Peng[10] proposed an occluded face recognition algorithm based on feature reorganization and optimization training, which uses the weight feature of information entropy to optimize the information of pool layer, and proposed an improved PSO algorithm to optimize the error back propagation stage of convolution network, which

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 806-816
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

significantly improves the training convergence speed and recognition speed of classifier. Wang Hongxing [11] proposed a face recognition algorithm based on LBP and elm. By improving LBP algorithm, the influence of noise points is reduced. Experiments show that the face recognition rate can be effectively improved by the algorithm.

In reference [12], in order to solve the problem of low accuracy, conventional PCA and SVM face recognition algorithms, an improved k-cv: k-fold cross validation algorithm is proposed to optimize SVM parameters, The recognition accuracy of this algorithm in yale face database is 9.08% higher than that of conventional PCA and SVM combined algorithm. Reference [13] proposed the concept of face detection by SNOW classifier and YCbCr skin color model. This method is suitable for face detection under complex conditions, is not limited by facial expression, and is also suitable for multi face detection. However, the face recognition rate is not high under the interference of attitude change or occlusion. Therefore, on the basis of combining the advantages of SNOW and SVM classifier, this paper proposes a dual face classification and detection algorithm. In terms of feature extraction, SMQT is selected to extract face local features. SMQT [14] is an effective feature extraction method. Under the influence of illumination, rotation, occlusion, complex background and other factors, SMQT can obtain the structural features of the landmark area at a low computational cost, while increasing the accuracy of detection. The algorithm in this paper uses SMQT to extract the face features of candidate areas, and then realizes the recognition of face and non-face areas through the double classification algorithm of SNOW classifier [15] and SVM classifier [16], so as to accurately locate the face position. Experiments show that this algorithm can achieve good detection effect.

II. BASIC PRINCIPLE OF FACE DETECTION ALGORITHM

2.1 Description of SMQT feature extraction algorithm

The goal of SMQT is to extract features that are not sensitive to illumination and sensor variability , and the method can automatically decompose the image structure to obtain structural features, and use this feature to extract features that are not sensitive to illumination, so as to reduce the impact on illumination factors in feature extraction. The SMQT extraction algorithm is introduced in detail below.

Let the pixel value sequence of the face candidate region be defined as $D(x)$(x is a pixel of the candidate region), SMQT input parameter L, and output $M(x)$ after the transformation of SMQT. The transformation is expressed as follows:

$$D(x)\xrightarrow{SMQT_L}M(x) \tag{1}$$

$SMQT_L$: $D(x)\rightarrow M(x)$, $M(x)$ is the transformed pixel value sequence, and $SMQT_L$ function can be explained by a binary tree. The vertex is the mean quantization unit MQU (mean quantization unit). Each MQU requires three calculation steps: calculating the mean, quantizing and decomposing into two sequences.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 806-816
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

(1) Calculated mean:

If the pixel value of the candidate selection is $V(x)$ and the average pixel value is $\bar{V}(x)$, it can be expressed as:

$$\bar{V}(x)=\frac{1}{|D|}\sum_{x\in D}V(x) \tag{2}$$

Quantification:

$$\xi\left(V(x),\bar{V}(x)\right)=\begin{cases}1, V(x)>\bar{V}(x)\\ 0, else\end{cases} \tag{3}$$

Quantize the candidate pixel points with the calculated mean value, and use $\otimes$ to represent the connection, then define:

$$u(x)=\underset{y\in D}{\otimes}\xi\left(V(x),\bar{V}(x)\right) \tag{4}$$

Where: $u(x)$ is the MQU output of the mean quantization set.

Decompose input 1 into two parts:

$$D_0(x)=\left\{x\middle|V(x)\le\bar{V}(x),\forall x\in D\right\} \tag{5}$$

$$D_1(x)=\left\{x\middle|V(x)>\bar{V}(x),\forall x\in D\right\} \tag{6}$$

In this way, you can get an MQU, where $\mathrm{D}_0(x)$ is the left fork tree and $\mathrm{D}_1(x)$ is the right fork tree, as shown in Fig 1.

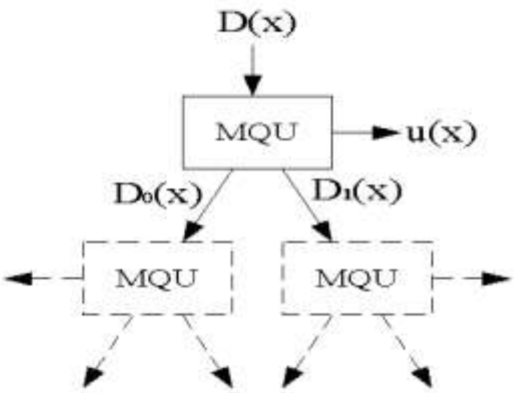


Fig 1: MQU computing unit

The output $u(x)$ of MQU can be taken as the structure of $D(x)$, which is neither a value, nor the similarity coefficient of linear transformation. Because the input error and gain are constantly adjusted, each MQU unit is independent. MQU is not sensitive to illumination, so the features extracted by SMQT are not sensitive to illumination.

MQU is the main operation unit of SMQT structure. The first level transformation of SMQT only depends on one MQU unit, and its output result is $u(x)$. Then the nth (n = 1, 2,..., 2^{l-1}) unit of the L (L = 1, 2,..., 2^{l-1},1represents the current branch of the binary tree) level transformation defines $u_{(l,n)}$ to identify the level of the binary tree, so the final pixel sequence $M(x)$ is the weighted sum of the MQU output at the bottom of the binary tree, $M(x)$ is the final SMQT feature extraction, and the output of SMQT is

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 806-816
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

$$M(x) = x \left| V(x) = \sum_{L=1}^{L} \sum_{n=1}^{2^{L-1}} V\left(u_{(l,n)}\right) \cdot 2^{L-1}, \forall x \in M, \forall u_{(l,n)} \in U_{(l,n)} \right. \quad (7)$$

2.2 SNOW classifier and training analysis

SNOW classifier is a sparse network linear unit training structure. Its basic idea is to train linear sparse network through predefined sample features, and train face network and non-face network to realize classification. In the training process of SNOW classifier, the samples are also divided into two categories: positive samples and negative samples, in other words, face samples and non-face samples. Face samples are positive samples, while the others are negative.

(l) Define decision threshold γ, rising parameter α and falling parameter β, where $\alpha > 1$, $0 < \beta < 1$。. Suppose $\omega_t = \{i_1, i_2, \ldots, i_m\}$ is the feature set of the face sample of the target node T on the network, and set ω_i' as the weight of the eighth feature of the network node t. When $\sum_{x \in w} w_i' > \gamma$ (w is a scanned image block of 32×32 size), the training process ends. Otherwise, adjust the weight ω_i' of the network node according to step (2).

(2) If the input is a face image sample, when $\sum_{x \in w} w_i' \le \gamma$, $w_i' = \alpha w_i', \forall i \in w$;If the input is a non-face image sample, when $\sum_{x \in w} w_i' > \gamma$时, $w_i' = \beta w_i'$, $\forall i \in w$.

Here, $\gamma = 200$, $\alpha = 1.005$, $\beta = 0.995$.

In the process of face detection, the classifier may have the phenomenon of repeated detection. This algorithm uses the geometric position and classification scoring method to reduce the repetition rate. Each classifier detects separately from other classifiers. If the repetition rate of a certain region is higher than a fixed threshold, it is considered that a certain number of classifiers can detect the region, At the same time, different classifiers are used to detect the region. Those with high classification results are retained, others are removed, and duplicate results will not be obtained.

2.3 SVM

The central idea of SVM is to detect the best classification hyperplane of two kinds of samples in the original space. When the linearity is inseparable, the addition of the relaxation variable is made for analysis, and the SVM is actually a linear classifier with maximum interval. Its purpose is to find an N-1-dimensional hyperplane in any space to maximize the interval between the two types of data points separated by the hyperplane. The hyperplane with the maximum interval is called support vector machine.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 806-816
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

III. KERNEL FUNCTION

Support vector machine has many characteristics, one of which is the processing of data dimension promotion, mainly through kernel functions to achieve the purpose of dimension promotion. Because different kernel functions will map different feature spaces, and the indicators of different feature spaces cannot be compared, Vapink once proposed to minimize the cross-validation error rate on how to select kernel functions, Radius interval bound, support vector number and other evaluation criteria. At present, there are mostly three types of kernel functions studied below:

Multiple kernel function

$$K(x, x_i) = [(x \cdot x_i) + 1]^q \quad (8)$$

Where q stands for the order of polynomials, and the result is a polynomial classifier of order Q.

(2) RBF(Radial basis function)

$$K(x, x_i) = \exp\{-\frac{|x - x_i|^2}{\sigma^2}\} \quad (9)$$

(3)S-shaped kernel function

$$K(x, x_i) = \tanh[v(x \cdot x_i) + c] \quad (10)$$

At this time, the SVM algorithm includes a hidden layer multilayer perceptron network. Unlike the traditional perceptron network, which is determined by people with experience. In addition, the algorithm does not have the problem of local minima that perplex the neural network.

Among the above commonly used kernel functions, the most commonly used are the first and the second. In addition to the three functions mentioned above, there are still some other kernel functions such as exponential radial basis kernel function and wavelet kernel function, which are relatively less used. In fact, there are all kinds of sample sets to be trained, and the kernel functions have their own advantages and disadvantages. B. Bacsens and s. viaene used LS-SVM classifier and UCI database to compare linear kernel function, polynomial kernel function and radial basis function. From the experimental results, different kernel functions have their own pros and cons for different databases, and radial basis function has slightly excellent performance on most databases.

3 1 Double face classification algorithms based on SMQT

The algorithm first uses the SMQT method to calculate the features of the corresponding blocks, then after the SNOW, the face and non-face have been preliminarily divided, and finally uses the SVM method to classify the preliminarily divided faces again. The overall operation speed of the algorithm is significantly improved, and the introduction of support vector machine classifier greatly reduces the false detection rate, which meets the practical application requirements of the system. Finally, the system block diagram is shown in Fig 2.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 806-816
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

Fig 2 Analysis of face detection results of SMQT + SNOW + SVM algorithm

3.2 Double classifier and training analysis

(1) Face / non face training sample selection

Generally, the training samples are from FERET face database and some images collected on the network (including face and non-face). Firstly, SMQT + SNOW face detection system is used to automatically detect all face training samples, and all the detection results are automatically saved into images one by one. Then these images are manually screened, and the nonface images and the collected non-human face samples are combined into a nonface data set. The face images detected by SMQT + SNOW system and other collected face photos are combined into a human face data set. The generation process of face / non face training sample set is shown in Fig 3.

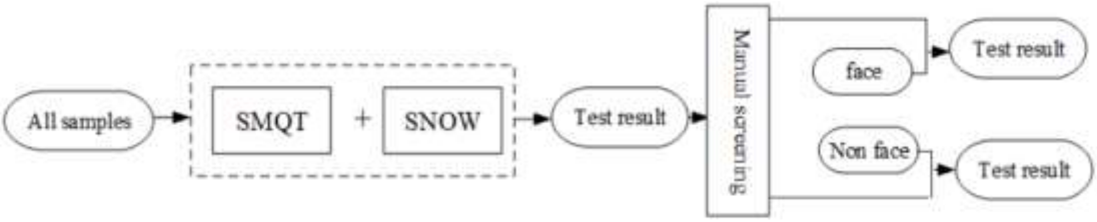


Fig 3 production flow chart of face / non face training sample set

(2) Training process and algorithm

Training process: before sending the selected face / non face training samples to support vector machine for training, image preprocessing and feature extraction are required. The preprocessing operation normalizes the sample size to 19×19 size. Feature extraction directly reads the pixels of the normalized training sample, and the training box is shown in Fig. 4.

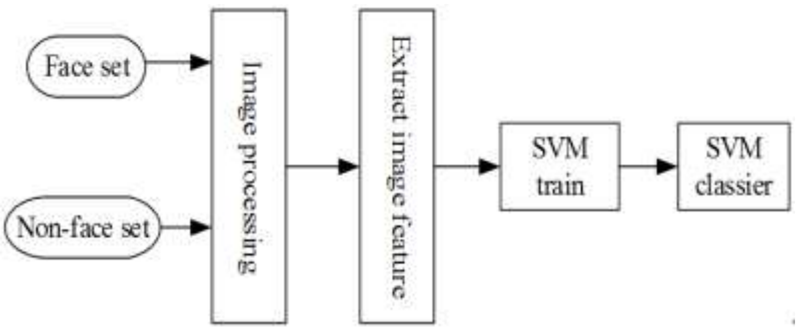


Fig 4 training flow chart of SVM classifier

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 806-816
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

Training algorithm: a total of 20 image directories need to be read circularly in the training process, which are defined as directory 1, directory 2,..., directory n$(1 \le n \le 20)$. Directory 1 contains 800 images selected from the face set and 1300 images selected from the non-face set. These 2100 images form an initial training set. The remaining face set / non-human face set training samples are equally divided into 19 copies and put into directory 2, directory 3... Directory 20 respectively. Set SVM classifier to operate 20 image directories one by one, and record it as one traversal, and the traversal times are represented by K (k = 0).

IV. ANALYSIS OF EXPERIMENTAL RESULTS AND COMPARISON OF ALGORITHMS

The improved algorithm SMQT + SNOW + SVM decreased the false detection rate and improves the detection efficiency. Here, 264 image face samples are collected by using the MATLAB platform. The image faces can be recognized basically, with different illumination and complex background. SMQT + SNOW and the algorithm in this paper (SMQT + SNOW + SVM) are taken for detection. The evaluation criteria include correct detection rate and false detection rate, The detection time, including the correct and false detection rate of face image, is calculated as follows:

Correct detection rate: it can correctly reflect the effectiveness of detecting real faces. The definition formula is:

$$\text{Correct detection rate}=\frac{\text{Number of correctly detected faces}}{\text{Number of all faces}}*100\% \tag{11}$$

False detection rate: the probability of detecting the non-face area in the image set as a face. This probability can reflect the detection probability of non-face by different algorithm systems, which has a certain relationship with the size of the image itself, background complexity and deflection angle. Its definition is as follows:

$$\text{Error detection rate}=\frac{\text{Number of false detected faces}}{\text{Number of all processing windows}}*100\% \tag{12}$$

Sample processing and experimental results FERET face database is selected for verification. After extracting features by SMQT, face detection can be realized by SNOW classifier.

Firstly, the detection results of the image set after SMQT + SNOW are compared with the algorithm. The comparison results are shown in Table I. The detection results of the detection accuracy and false detection rate after SMQT + SNOW and SMQT + SNOW + SVM algorithms are shown in Table 2 and table 3 respectively.

TABLE I. Comparison of detection time between SMQT + SNOW and the algorithm in this paper

Test images	A	b	c	d	e
（W*H）SMQT+SNOW	800*600	600*480	500*384	480*258	384*256
	37.1	24.3	21.9	17.8	13.8
The algorithm in this paper	72.7	56.8	48.5	44.8	30.8

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 806-816
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

TABLE II. Comparison of detection results between SMQT + SNOW and the algorithm in this paper

Test image mode	Correct detection rate	Error detection rate	Correct detection rate	Error detection rate
	SMQT+SNOW		SMQT+SNOW+SVM	
Face images	91.5%	5.31%	97.2%	2.86%
Non-face images	97.9%	1.43%	100%	0

By comparing the detection results after SMQT + SNOW with this paper, it can be seen from table 1 that the detection time for images of different sizes is different. The larger the size, the longer the detection time. Compared with this paper, the detection time of SMQT + SNOW algorithm is shorter, indicating that the detection performance of SMQT + SNOW algorithm verified in this paper is better.

The following aspects can be seen from table 2 and table 3:

The face detection algorithm SMQT + SNOW + SVM with support vector machine has higher correct detection rate than SMQT + SNOW algorithm.

2. In non-face images, the false detection rate of SMQT + SNOW + SVM face detection algorithm is 0, that is, the image trained by SVM can remove the window of false detection as face in SMQT + SNOW algorithm, so as to reduce the false detection rate;

3. It can also be seen from the two tables that the sum of correct detection rate and false detection rate of face image is not equal to 100%, which is mainly because there is still a small proportion of missed detection rate, that is, not all faces are detected. This problem needs to be further studied. In this paper, the main solution is to improve the false detection rate and shorten the detection time based on SMQT + SNOW algorithm.

The following will verify the detection effect of SMQT + SNOW algorithm under different factors such as face number, face deflection angle, uneven light, occlusion, complex background and so on.

For different expressions including a single face image, the detection results under different degrees of illumination and different deflection angles are shown in Fig 5.

(a)Test result of SMQT+SNOW

(b)Test result of SMQT+SNOW+SVM

Fig 5 detection results of individual faces with different expressions.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 806-816
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

As can be seen from the above Fig, when using the SNOW classifier to detect humans, the first and second human images are not recognized. This is because the two faces have the characteristics of too dark light and too large expression, so they can not accurately find the position of the face. This algorithm adds SVM classifier after the SNOW classifier to deal with different expressions and different angles of the face, can be effectively detected.

The detection results of multiple faces are shown in Fig 6.

(a)Test result of SMQT+SNOW (b)Test result of SMQT+SNOW+SVM

Fig.6 detection results of multiple face images from different angles

It can be seen from the above Fig that in multiple face detection, the single classification algorithm cannot completely detect faces with dark skin color and occlusion. The overall recognition rate is low. This algorithm combines the advantages of the two classifiers. It can effectively detect the faces with occlusion on the side and the faces with unobvious back features, especially for the objects with dark skin color.

When there is strong light around the face and complex background, the face detection results are shown in Fig 7:

(a)Test result of SMQT+SNOW

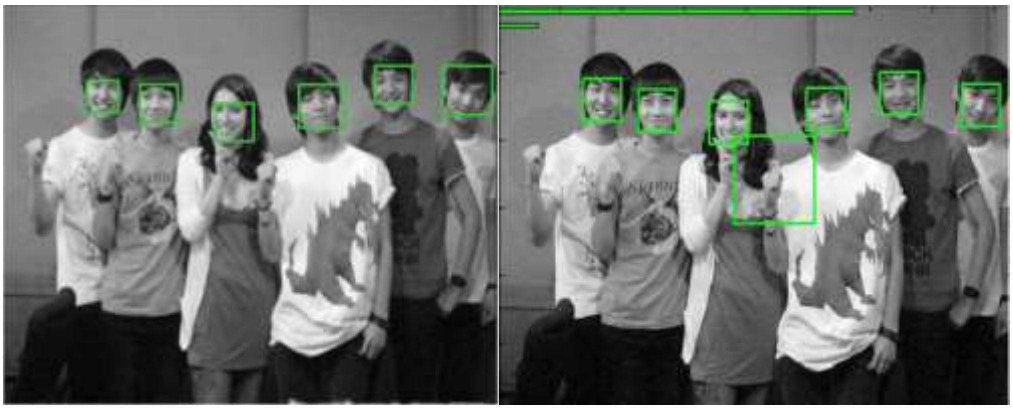
Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 806-816
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

(b)Test result of SMQT+SNOW+SVM

Fig. 7 face detection results with strong illumination

As can be seen from Fig 9, the accuracy of the detection results of the face detection algorithm based on SMQT + SNOW has decreased due to the excessive density of the face, the influence of strong illumination, the size of the face and the mutual occlusion, resulting in false detection and missed detection, which shows that the detection rate of the SMQT + SNOW algorithm is not high when the face occlusion area is too large under strong illumination. In the same environment, only two faces are not accurately recognized, and the others can be detected. It is proved that the algorithm can still have good detection results under strong light.

Fig. 8 shows the results of face detection in a complex background.



(a) Test result of SMQT+SNOW (b)Test result of SMQT+SNOW+SVM

Fig 8 Face detection under complex background

From the detection results of all the above images, it can be concluded that when there is a complex background, SMQT + SNOW algorithm has a certain false detection rate, and this algorithm can well recognize the face position and avoid false detection.

V. CONCLUSION

This paper mainly studies the face detection method based on SMQT + SNOW + SVM, and verifies the accuracy and robustness of SMQT algorithm in illumination, occlusion and complex background detection. It solves the problem that the traditional SMQT + snow face detection algorithm has a high false detection rate in strong light and complex background. Due to the introduction of support vector machine, the false detection rate is reduced and the real-time operation requirements of the system are met.

ACKNOWLEDGEMENTS

This study was funded by the Doctoral Foundation Project of North China Institute of Aerospace Engineering: Research on Hyperspectral reconstruction technology based on compressed sensing (BKY-2022-05).

REFERENCES

[1]. E.Hjelmas, B. K. Low, Face detection: A survey, Computer vision and image understanding, vol.83, no.3, 2001, pp: 236-274.

[2]. H. A. Rowley, S.Baluja, T.Kanade, Neural network-based face detection, IEEE Transactions on pattern analysis and machine intelligence, vol.20, no.1, 1998, pp: 23-38.

[3]. R.Ranjan, A.Bansal, J.Zheng, et al, A fast and accurate system for face detection, identification, and verification, IEEE Transactions on Biometrics, Behavior, and Identity Science, vol.1, no.2, 2019, pp: 82-96.

[4]. K.Zhang, Z.Zhang, Z.Li, et al, Joint face detection and alignment using multitask cascaded convolutional networks, IEEE Signal Processing Letters, vol.23, no.10, 2016, pp: 1499-1503.

[5]. S.Yang, P.Luo, C. C. Loy, et al, Faceness-net: Face detection through deep facial part responses, IEEE transactions on pattern analysis and machine intelligence, vol.40, no.8, 2017, pp: 1845-1859.

[6]. R.Qi, R. S. Jia, Q. C. Mao, et al, Face detection method based on cascaded convolutional networks, IEEE Access, vol.7, 2019, pp: 110740-110748.

[7]. S.Wu, M.Kan, S.Shan, et al, Hierarchical attention for part-aware face detection, International Journal of Computer Vision, vol.127, no.6, 2019, pp: 560-578.

[8]. Y.Zhu, L.Li, J.Zhang, Face recognition algorithm based on face block approximate symmetry preprocessing, Software guide, vol.20, no.4, 2021, pp: 75-80.

[9]. S.Song, Y.Feng, C. G. Xu, Face recognition algorithm based on orthogonal sparse constrained nonnegative tensor decomposition, Journal of operations research, vol.25, no.2, 2021, pp: 55-66.

[10]. P.Zou, Z.Yang, K.Li, Occluded face recognition algorithm based on feature reorganization and optimization training, Journal of Dalian Jiaotong University, vol.42, no.3, 2021, pp: 116-120.

[11]. H. X. Wang, Y. Y. Hu, C. Deng, Research and implementation of face recognition algorithm based on LBP and elm, Journal of Henan University of Technology (NATURAL SCIENCE EDITION), vol.40, no.5, 2021, pp: 139-145.

[12]. Z. M. Lin, PCA and SVM face recognition algorithm based on k-cv optimization, Journal of Jilin University (Information Science Edition), vol.38, no.4, 2020, pp: 491-496.

[13]. Y. Y. Yuan, X. W. Hui, Face detection based on YCbCr skin color model and SNOW classifier, Computer system application, vol.19, no.1, 2010, pp: 157-160.

[14]. V. Jain, D. Patel. A GPU based implementation of robust face detection system, Procedia Computer Science, vol.87, 2021, pp: 156-163.

[15]. P. R. Krishna, P.Ahammad, R.Sethuraman, Hybrid Prediction Models for Rainfall Forecasting, Annals of the Romanian Society for Cell Biology, 2021,pp: 40-46.

[16]. R.Ankita, C. U. Kumari, M. J. Mehdi, et al, Lung cancer image-feature extraction and classification using GLCM and SVM classifier, Int. J. Innov. Technol. Explor. Eng, vol.8, no.11, 2019, pp: 2211-2215.