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Automatic Human Face Recognition from Still Group Images Based on Image Processing Techniques.

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Abstract

The most fundamental and crucial technique in face recognition is face matching. Although many different algorithms have been used in various types of research in the field of human face detection, the problem of face detection and recognition persists because it is difficult to achieve reliable face matching under a variety of shooting conditions such as lighting changes, face position differences, or viewing angle differences. In this research, two-dimensional Normalized cross-correlation NCC was used to match the image of suspects with the captured image. The designed recognition algorithm was implemented to recognize a target face in an image of several faces (a Group image). Several different cases were tested. In group image #1, when the target image existed, a high normalized cross-correlation (NCC) value of 0.9307 was significantly higher than the NCC values of all other images in the group. In group image #2, when the target image does not exist, a maximum normalized cross-correlation (NCC) value of 0.5638 is lower than the value obtained when the target image was included in the group image. Ultimately, a test was conducted to determine if the target image was present in the group image. The results indicated that the max NCC value was below 0.6, indicating no target image was identified. The designed recognition algorithm has proven successful in all cases.

Keywords: Face Recognition, Face identification, Group Images, Normalized Cross-Correlation.

التعرف التلقائي على الوجه البشري من الصور الجماعية الثابتة بناءً على تقنيات المعالجة الصورية

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الخلاصة

التقنية الأساسية والأكثر أهمية في التعرف على الوجوه هي مطابقة الوجه. على الرغم من استخدام العديد من الخوارزميات المختلفة في أنواع مختلفة من الأبحاث في مجال اكتشاف الوجه البشري، إلا أن مشكلة اكتشاف الوجه والتعرف عليه لا تزال قائمة لأنه من الصعب تحقيق مطابقة موثوقة للوجه في ظل مجموعة متنوعة من

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ظروف التصوير مثل تغيرات الإضاءة وموضع الوجه. الاختلافات، أو اختلافات زاوية المشاهدة. في هذا البحث، تم استخدام الارتباط المتبادل الطبيعي ثنائي الأبعاد NCC لمطابقة صورة المشتبه بهم مع الصورة الملتقطة. يتم تنفيذ خوارزمية التعرف المصممة لدينا للتعرف على الوجه المستهدف في صورة مكونة من عدة وجوه (يشار إليها باسم صورة المجموعة). تم اختبار عدة حالات مختلفة. في صورة المجموعة رقم 1، عندما تكون الصورة المستهدفة موجودة، تبلغ قيمة الارتباط المتبادل المقاس العظمى 0.9307، والتي كانت أعلى بكثير من قيم الارتباط المتبادل المقاس لجميع الصور الأخرى في المجموعة. في صورة المجموعة رقم 2، عندما لا تكون الصورة المستهدفة موجودة، تبلغ قيمة الارتباط المتبادل المقاس القصوى 0.5638، وهي أقل من القيمة التي تم الحصول عليها عند تضمين الصورة المستهدفة في صورة المجموعة. وفي النهاية، تم إجراء اختبار لتحديد ما إذا كانت الصورة المستهدفة موجودة في صورة المجموعة. أشارت النتائج إلى أن القيمة القصوى للارتباط المتبادل المقاس كانت أقل من 0.6، مما يشير إلى عدم تحديد أي صورة مستهدفة. لقد أثبتت خوارزمية التعرف المصممة نجاحها في جميع الحالات.

1. Introduction

Image processing techniques play a role in several important areas and have become necessary in many research and technical fields. In image processing, the focus is on appropriate digital encoding of images and finding ways to process this digital data so that these images or the information carried by the images are usable by the machine, which could be a computer, a robot, or other machines. Digital image processing is of great importance in image perception, that is, when trying, for example, to make a computer or robot understand the image or its meaning. It is also essential in pattern or shape recognition [1]. Facial recognition is a means of identifying or confirming an individual using his or her face. Facial recognition systems can identify people in photos or clips [2]. It is a category of biometric-based security [3]. It is a fast and effective verification system that is faster and more convenient than other biometric techniques, such as fingerprints or retina scans. The facial identification system uses fewer contact points than passwords or PINs. It is compatible with multi-factor validation to provide an additional security verification step [4,5]. Machines use computer vision to identify people, places, and objects in images with accuracy that reaches or exceeds human levels faster and more efficiently [6]. Law enforcement regularly uses facial recognition [7,8]. Human facial recognition systems use unique mathematics patterns to store biometric data. Hence, it is one of biometric technology's most secure and effective identification methods.

Facial data can be anonymized and kept private to reduce the risk of unauthorized access. Accurate User Identification technology distinguishes real users from their facial images. This prevents an attempt to circumvent the system using an active user's photo from succeeding [9,10,11]. Media companies use facial recognition to test audience reaction to movie trailers, characters in TV premiere episodes, and the best placement for TV promos [12]. Facial verification algorithms that match people to clear reference images, such as a driver's license, have scored high degrees of accuracy. However, this degree of accuracy can only be achieved when there is consistency in location and lighting, clear facial features that are not obstructed by any obstacles, and control of colors, background, camera quality, and image resolution [13,14,15]. Several challenges stand in the way of creating effective facial recognition systems, including the lack of a vast database that includes images of all people on the face of the Earth, in addition to the fact that massive databases may cause a decrease in the accuracy of the results in some cases, in addition to the lack of computers capable of quickly extracting data from databases containing billions of images. However, these obstacles can not limit the effectiveness of facial recognition technologies forever, as they will be dealt with over time [16]. These factors can impede the algorithms' generalization and adaptation to various

scenarios and conditions. The constrained pixel count in small facial images poses challenges in extracting facial attributes, resulting in diminished precision of face recognition systems [17].
Moreover, small facial images frequently need help with issues such as inadequate resolution and poor image quality, further complicating the recognition process. The task of facial recognition conveys broad challenging issues, such as accuracy and reliability [18], Bias and Discrimination [19], Privacy Concerns [20], Ethical Considerations, and Environmental Constraints [21]. This research project aims to recognize only the frontal facial human images to decide about (known or unknown face). Recognize the facial images by analyzing the still images conveyed by a single human face; these images are taken in front view with nearly uneven illumination conditions. Localization of only the face from the original input facial image to obtain "the Region of Interest "(ROI), which is utilized to get the best features. Test dataset samples may suffer from occlusion in the eyes and eyebrows due to hair.

In this research, two-dimensional Normalized cross-correlation NCC was used to match the image of suspects with the captured image. The designed recognition algorithm was implemented to recognize a target face in an image of several faces (a Group image)

2. Materials and Methodology

2.1. Normalized Cross-Correlation (NCC):

Correlation-based recognition is one of the most basic ways of identifying facial images [22]. Assuming that the unknown input image and all group images were aligned, the topic will be allocated to the class that maximizes the normalized correlation between the input and gallery images. It can be used as a face detector by sliding the cropped group image as a narrow window over the test image and computing the maximum normalized correlation (MNC). This approach works effectively when the faces in the test and train photos are the same size, and the head attitude, lighting, and facial emotions are the same [23]. The computation of the Normalized Cross-Correlation (NCC) coefficient was used in correlation-based algorithms for face detection. The initial step in using these strategies is recognizing unstable facial features, such as the face, eyes, nose, or mouth. There are several difficulties in using equation (1) for template matching [24].

The NCC tackles cross-correlation difficulties by normalizing the image and feature vectors to unit length and provides a cosine-like correlation coefficient. As a result, the Cross-Correlation (CC) matching was improved using the NCC matching [25]. The equation of NCC is defined as:

$$NCC = \gamma_{(u,y)} = \frac{\sum_{x,y}[f(x,y)-\overline{f_{u,v}}][t(x-u,y-v)-\bar{t}]}{\left[\sum_{x,y}[f(x,y)-\overline{f_{u,v}}]^2 \sum_{x,y}[t(x-u,y-v)-\bar{t}]^2\right]^{1/2}} \quad (1)$$

Where; "*(x,y)*" is the original image, "$\bar{f}$" represents the mean image intensity in the region under the template "*t*"; "$f_{u,y}$" is the mean of "*f(x,y)*" in the region under the template. $\bar{t}$ represents the mean of image intensity in the template.

The coefficient of cross-correlation $\gamma(u, v)$ will range from $^-1$ to $^+1$. A value of $\gamma(u, v) = 1$ implies that "*t*" has the same shape as the picture *f(x, y),* whereas a value of $\gamma(u, v) = -1$ indicates that "*t*" have the same shape but opposite signs $\gamma(u, v) = 0$ indicates that they are entirely uncorrelated. When this normalization was applied to real discrete images, one will find that a correlation coefficient NCC >0.6 indicates a pretty good match.

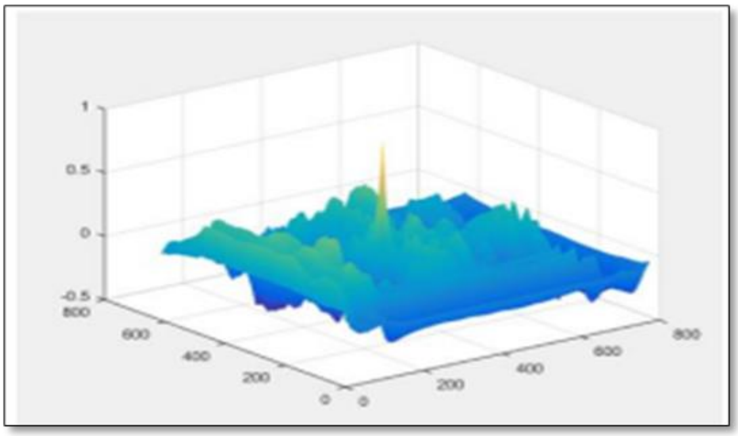

Figure 1: The plot of NCC [26]

2.2 Automatic Face Recognition Method

Automated identification and recognition of single-person images through a group of people is the primary goal of current research. Among the problems associated with this work is the distance captured for each image. In the process of automatic recognition of an image of an individual human face among several faces in a group image, three methods were proposed to implement it, including face detection based on the method of changing the template, face detection based on skin color segmentation, and face detection based on the method of changing a template for images containing noise. The sections below illustrate those proposed methods for automatically identifying a person's face from among several faces in a group image. The identification process involves matching biometric templates (a Target image) against an extensive database (a Group image).

Target Image **Group Image**

Figure 2: An example of implementing an identification process to identify an individual in a database of previously collected samples. Face Identification /Recognition (1: N matching)

Template matching is an advanced method employed in machine learning to identify patterns. It is imperative to differentiate an individual sample from a database of previously collected samples. The verification method compares photographs of an individual captured in various poses. The implementation showcased a one-to-one matching procedure, Figure 3.

Figure 3: Example of implementing a verification process for a specific person Face Authentication/Verification (1:1 matching)

The performance of this proposed recognition method will be tested as a face Identification /Recognition (1: N matching).

2.3 Face Identification Based on Variant Template Method

Face detection is the initial phase of a face identification system and is usually the first step; it is an essential part of automatic face recognition. The current method verifies the automated face recognition system's proposed face positions using the Cross-Correlation matching with the average face. This automated proposed face detection technique was shown to be quite effective. The Variant template method (VTM) efficiently limited the search space, and the best face placement was discovered through correlation with the average face. The following algorithm (1) clarifies the steps for face identification based on VTM, which has to match a target face image to the faces in a group image. The steps involve a collection of images that serve as a target image and group image, which necessitates intricate processing throughout the entirety of the program, including face detection, creating a cut rectangle geometric shape from the read image, and so on. The single-face image was cropped into a rectangular shape, and the normalized cross-correlation (NCC) and maximum NCC were computed.

Algorithm 1 ***Face recognition based on automatic method***
Input: *Group image (**I_G**), image contains N of people.* *Single image (**I_S**), image containing face of one person within (**I_G**).* *Output: the matched area of single face in group image.*
Steps: ***Step1***: *read (**I_S**),.* ***Step2***: *used the function "vision.CascadeObjectDetector" to detect a face from (**I_S**) by Viola – Jones face detector.* ***Step 3***: *used the function "insertObjectAnnotation" to cut rectangle geometric shape from (**I_S**) that contains the single face.* ***Step 4***: *Cropping rectangular shape of the single face image (**I_{Ss}**).* ***Step5***: *read (**I_G**),.* ***Step6***: *used the function "vision.CascadeObjectDetector" to detect the faces from (**I_G**) by Viola – Jones face detector.* ***Step7***: *used the function "insertObjectAnnotation" to cut rectangle geometric shapes from (**I_G**) that contains the faces.* ***Step 8:*** *Cropping rectangular shapes of each face image (**I_{Gi}**), where i=1, 2, 3…, N.* ***Step 9***: *resize (**I_{Ss}**) to size (**I_{Gi}**).* ***Step10***: *computes the normalized cross-correlation (N_Corr_i) of (**I_{Ss}**) and (**I_{Gi}**).* ***Step11***: *find the peak in (N_Corr_i):* *[maxCorrValue(i), maxIndex(i)] = max(abs(N_Corr_i(:)))* ***Step12***: *find and Display the matched area.* *Mx=max(maxCorrValue(:))* *Im=find(maxCorrValue(:)==Mx)* ***Step13***: *end algorithm.*

3. Experimental Results and performance analysis

In the current research, image identification was performed on two images: the target image is a part of the group image, and the target image is not the group image.

I. The program was tested on the "**Target**" image as part of the "**Group**" **Image**" (i.e., extracted from the group image). Several instances of recognition were conducted and showcased, all of which used this particular identification method. Consider this instance, a collective depiction of a few actresses, Figure 4.

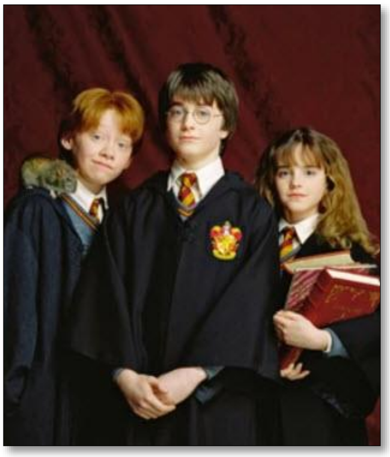

Figure 4: An image represents the Group image #1.

Figure 5: The target image is inside a set of group images. Figure 6 displays the identified faces in the target and group images. Figure 7 displays the cropped faces of the target and group images.

Figure 5: A target image extracted from the group image.

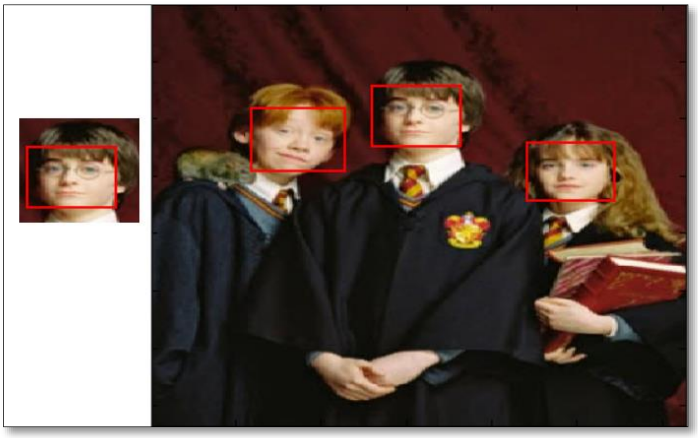

Figure 6: Detected faces in target and group images.

Figure 7: Cropped faces from target and group images.

To determine the maximum NCC, commonly employed in quantifying the information similarity between the target and the faces of a group. The correlation coefficient of the time series data can vary between $^{-}1.0$ and $^{+}1.0$. Figure 8 illustrates the maximum values of NCC between the "Target" cropped face and the faces extracted from the "Group" image.

Target Image	**Cropped image**		
 Target Image	 Face #1	 Face #2	 Face #3
NCC	0.8632	0.9307	0.8053

Figure 8: The Max NCC values computed between the "Target" cropped face and the faces extracted from the "Group" image.

Figure 8 demonstrates that the target face has the highest value (Max NCC) of 0.9307 compared to all other faces. This indicates that it is the desired target, and that a successful match has occurred. Consequently, the outcome of the cross-correlation will display a frame that contains the identified face and has a size equivalent to the cropped target face image, Figure 9.

Figure 9: The result of the final identification process

II. Furthermore, the Target-face image is distinct from the Group of faces image, as depicted in Figure 10. The facial recognition outcomes for the Target and Group images are displayed in Figure 11.

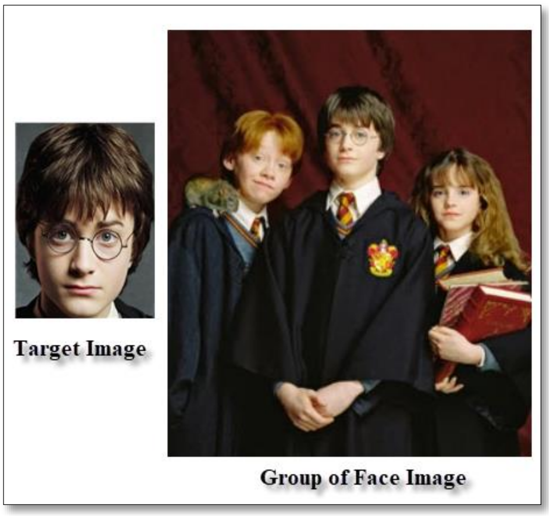

Figure 10: Target and Group images for the second identification test

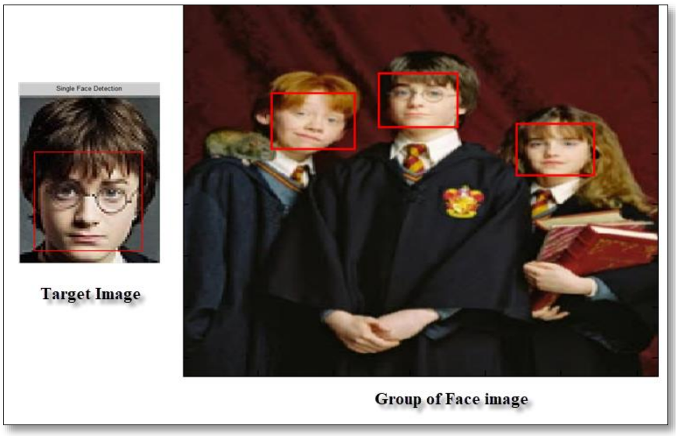

Figure 11: The detected faces of the Target and Group images.

Figure 12 displays the cropped faces of both the Target and Group images. Figure 13 shows the highest correlation values, specifically the maximum normalized cross-correlation (Max NCC), between the cropped Target face and the faces of the Group images.

Figure 12: The cropped faces of the Target and Group images.

Target Image	**Cropped image**		
			
NCC	0.5994	0.6180	0.5983

Figure 13: The performance of NCC between the cropped faces of the Target and Group face images.

Figure 13 demonstrates that the target face has the highest value (Max NCC) of 0.6180 compared to all other faces. This indicates that it is the desired target and a successful match has occurred even though the image is not in the group image. The final identification result of the processes is shown in Figure 14.

Figure 14: The final result of identifying a target face not part of the group image.

For further analysis, the portability of the identification software system was developed by testing it on another collection of images from Target and Group, Figure 15. Figure 16 depicts the performance of the face-detection method for both Target and Group images. Figure 18 showcases the cropped versions of all the faces recognized in Figure 17.

Target image **Group image** #2.

Figure 15: Another test Target and Group image #2.

Target Faces image **The group detected face image** #2.

Figure 16: Detected faces of Target and Group images.

Cropped of target Face #1 Face #2 Face #3 Face #4 Face #5

Figure 17: Extracted faces of cropped Target and Group images.

The maximum cross-correlation values (i.e., Max. NCC) between the cropped faces of Figure 17 are shown in Figure 18.

Cropped Images					
	0.5366	0.5809	0.8071	0.5992	0.4839

Figure 18: Maximum NCC values between the cropped Target and Group faces.

Accordingly, the final identification result is shown in Figure 19.

Figure 19: The final step of the identification process.

Based on the outcomes of the preceding tests, it was concluded that the target image was detected in the group image. The following scenario will apply if the target image is absent in the group image. All preceding steps in algorithm 1 will be executed. Figure 20 depicts images of the testing target and group. Figure 21 displays the identified faces from Figure 20.

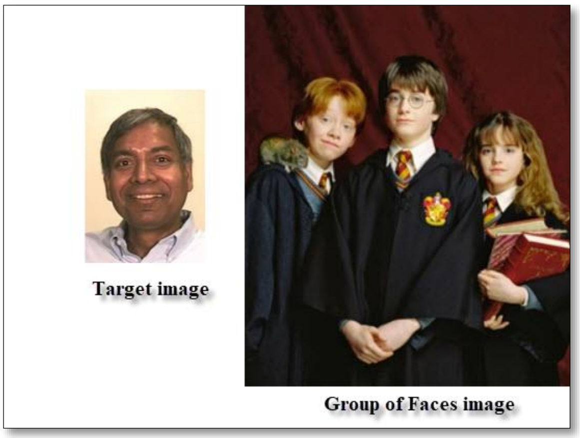

Figure 20: Testing "Target" and "Group" images.

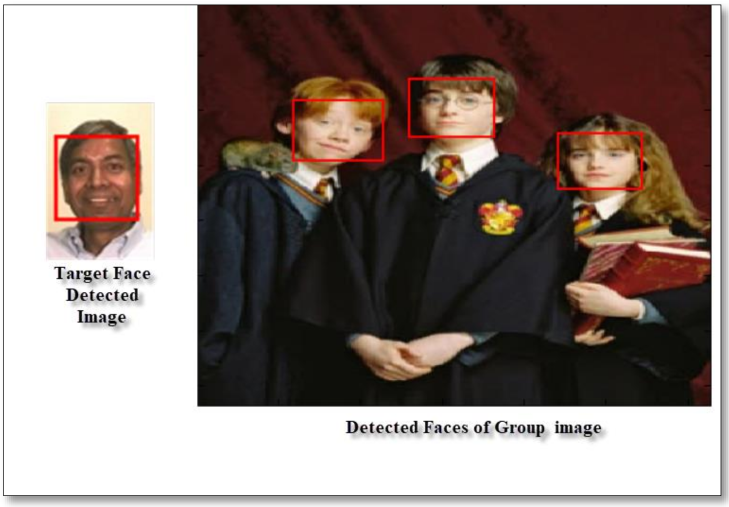

Figure 21: The detected faces in Target and Group images.

The maximum correlation (i.e., Max NCC) values between the cropped faces of the Target and Group images are shown in Figure 22.

Target Image	Cropped image		
			
NCC	0.5380	0.5482	0.54657

Figure 22: Maximum Normalized-Cross-Correlation values obtained by matching the cropped faces of the Target and Group images.

All of the maximum normalized cross-correlation (NCC) values found are below 0.6, indicating that none of the faces in the Group are representative of the Target face. If a target face from the image of the group above matches the faces of the group above, it is expected that the same result will occur, Figure 23.

Target Image	Cropped Image				
					
NCC	0.5337	0.4995	0.5505	0.5420	0.5638

Figure 23: Similarly, as in the previous test, none of the **Group** faces can identify the **Target** face.

4. The Accuracy Rate

The accuracy rate of the face detection and recognition method was tested on the testing dataset. The most common way for determining detection and recognition accuracy rates based on a dataset was to divide the dataset into membership classes. In the beginning, a training dataset was utilized to train the process. Then, this rule was tested on the testing dataset, and the output-resulting values were compared with the previously known classifications. The accuracy of detection and recognition was calculated depending on equations (2 and 3) below.

$$\text{Detection Efficiency} = \frac{\text{No.of Faces Detected}}{\text{No.of faces in an image}} \times 100\% \tag{2}$$

$$\text{Identification Efficiency} = \frac{\text{No.of Faces identification}}{\text{No.of faces Detected.}} \times 100\% \tag{3}$$

The accuracy rates of the face detection and recognition process are evaluated on two tested datasets. Two examples of the tested (single-person) images and the training (group persons) images were selected from (the FRGC) dataset. The statistical data results are tabled in Table (1).

Table 1: The statistical results of the accuracy of detection and recognition

Input Image	No. of faces in an image	No. of Faces Detected	No. of Faces Identification
Group Image #1	3	3	3
Group Image#2	5	5	4

To determine the accuracy rate of the face detection and verification process in this recognition approach, equations (2 and 3) should be utilized. Therefore, the efficiency of detection and verification will be;

$$\text{Detection Efficiency} = \frac{3}{3} \times 100 = 100\% \tag{4}$$

$$\text{Identification Efficiency} = \frac{4}{5} \times 100 \approx 80\% \tag{5}$$

5. Conclusion:

The current research focuses on automating the identification and recognition of a single face image (target image) within a group of people (image group). The proposed recognition algorithm, based on VTM, was considered an algorithm that identifies a specific face within an image containing multiple faces. The introduced algorithm has demonstrated its efficacy in various tested cases. The algorithm demonstrates robustness and effectiveness in facial recognition. The detection efficiency in group image#1 is 100%, and the identification efficiency in group image #2 is 80%.

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