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PERFORMANCE ENHANCEMENT OF DEEP LEARNING BASED FACE DETECTION SYSTEM

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Abstract

Most people in the globe wore the masks due to the Covid -19 pandemic, which makes it difficult to recognize the faces. Due to the mask covering the face, according to the NIST 2020 report the state of arts methods have a 20% to 50% error rate, while recognizing the face. A large number of scholars have lately claimed to address this problem using a variety of methodologies, including CNN. In certain cases, researchers used traits from both the occluded (mask-covered) and non-occluded areas of the face in order to identify individuals. Due to the high error rate, these two traits or situations are unable to recognize the face well. The Principal Component Analysis (PCA) and other methods can be used to overcome these issues

KEYWORDS:-Face recognition, Principal Component Analysis (PCA) and Convolutional Neural Network (CNN)

I. INTRODUCTION

One way facial recognition systems function to verify the identity of its users is by comparing facial features in an image with those in a database. This is done by identifying and measuring the unique characteristics of each person's face in the photo or video that is provided [1]. Phase verification, face identification, and clustering are the three primary components of face recognition [2]. There are a variety of uses for each of these components, such as face verification in an identity authorisation system or an identifying system for criminals [3]. Face recognition, on the other hand, can be useful in video surveillance systems that can identify many people in a single image [4]. In Fig. 1 it shows the images before the pandemic and after the pandemic. Due to the pandemic, mask covers 50 to 80 percent of their faces [5]. So by using the traditional facial recognition algorithms error rates have grown from 22 to 50 percent [6]. As a result face recognition applications are hampered by this high mistake rate and require a reliable approach for mask face identification that can match the benchmark method's accuracy [7]. Masked face recognition has been attempted by numerous academics recently; however their methods have shown to be ineffective due to a lack of robustness. There are two approaches to masked face recognition:

1. Method based on reconstruction
2. Discard approach.

(a) (b)

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Fig 1: Public gathering pictures (a) Image before pandemic, (b) Image After pandemic

METHOD BASED ON RECONSTRUCTION

In this approach, researchers primarily recreate the occluded section of the face in order to recognise it. The author of [8] employed a facial symmetry approach to rebuild facial information in order to detect a person's facial features. First and foremost, the data set containing face photographs taken from various angles has been constructed in there research. When it comes to recognizing a face, the first step is to identify the landmarks of the face and determine which portion of the input face image is missing. Then, using the same landmark information, the same face can be found in the database and both images can be combined to reconstruct the facial image. Due to the fact that the landmark of the masked face cannot be recognised easily. The author of [9] demonstrated that 3D face recognition may be accomplished by the use of a 2D picture to recreate a 3D face. This approach is effective for face recognition despite the fact that it requires just a little amount of training data for each subject (person). A 3D model for each class is generated using the landmark of the 2D face picture, which is used as a starting point by this approach. The landmarks in an input test picture have been recognised, and a 3D face has been produced and compared to the dataset to determine the state of the face. Some of the researchers were capable of detecting more than 50% of the landmarks in an input image.

DISCARD APPROACH

Author discards occluded parts of the face and utilises only non-occluded parts by applying cropping filter to remove non-upgraded face portion they split bulk is picture in 100 blocks and pick first 50 blocks as non-occluded facial part. They then employed a CNN model to categorise the photos, which is not optimal for face mask identification because there techniques cannot extract the characteristics hidden by the mask. In case of the injuries to the faces, masks of various sizes and shapes make it difficult to recognize the faces. It includes both the occluded and non-occluded parts of a person's face. A mask learning strategy was recently published in the study [10] that first constructed a mass directory using PDSN which compares two similar photos of the same person, in which one image has an occluded part and the other is the normal. In the next round of testing, an unknown picture is fed into the CNN, where it is processed via several convolutional layers until reaching the fully connected layer. Occluded parts will be included in this feature map. Using the mask directory, they can then delete the feature maps for the masked area. As a result, they are endowed with the characteristics of the face that has been partially hidden from view. Since masked faces and other occluded facial pictures such as those with sunglasses, bread, and the like cannot be recognised using this technique, the author of the research [11] set out to enhance face recognition accuracy for all types of occluded facial images. Facenet was used for feature extraction [12], followed by MTCNN for facial area recognition and cropping, and then Support Vector Machine (SVM) for picture classification. As you can see, the dataset they employed is made up of both occluded and non-occluded photos. Images with masks will have identical features during feature extraction, and a mask

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will cover 50% to 70% of a face. This approach has low identification accuracy since it requires 50-70 % of the same traits on two distinct people's faces.

Non-masked and masked face recognition using principal component analysis (PCA) have recently been reported by certain studies [13]. Their approach was able to identify 68 to 73 % of masked faces. The PCA approach was used to discover the main components of a masked face picture, but it was unable to choose the optimal Eigen faces because of the occluded part of the face. As a result, the identification rate dropped.

It is found in many literature reviews, that researchers employed 3D face recognition algorithms to rebuild the occluded part of a face. In the case where they built a 3D face model, and in order to recognise a face, the input test image must have a minimal number of characteristics and landmarks [14]. Scientists have also attempted to recognise faces by using only the non-occluded portions of a face, but this has also failed due to the absence of characteristics from the occluded portions of the faces [15]. In addition, some researchers attempted to recognise masked faces without removing the mask using deep learning and other methods, but they were unsuccessful. This was due to the mask being present in all face images, which caused the system to achieve a minimum 50 percent similarity across all faces [16].

An image-based reconstruction technique is proposed in the research [17], which may be used to partially rebuild the occluded portion of an image of a masked face. The mask region has been manually removed from the image. PCA is used as a reconstructive approach, while facenet is used for face recognition and identification of facial features. The most important contribution of this article is the procedure of face rebuilding. A face that has been occluded may be rebuilt in this study by evaluating the non-occluded component of the face, as demonstrated in this article.

The rest of the paper is laid out as follows. Section II covers the system architecture; Sections III and IV provide the methodology, problem statement and objectives. Section V covers the conclusion.

II. SYSTEM ARCHITECTURE

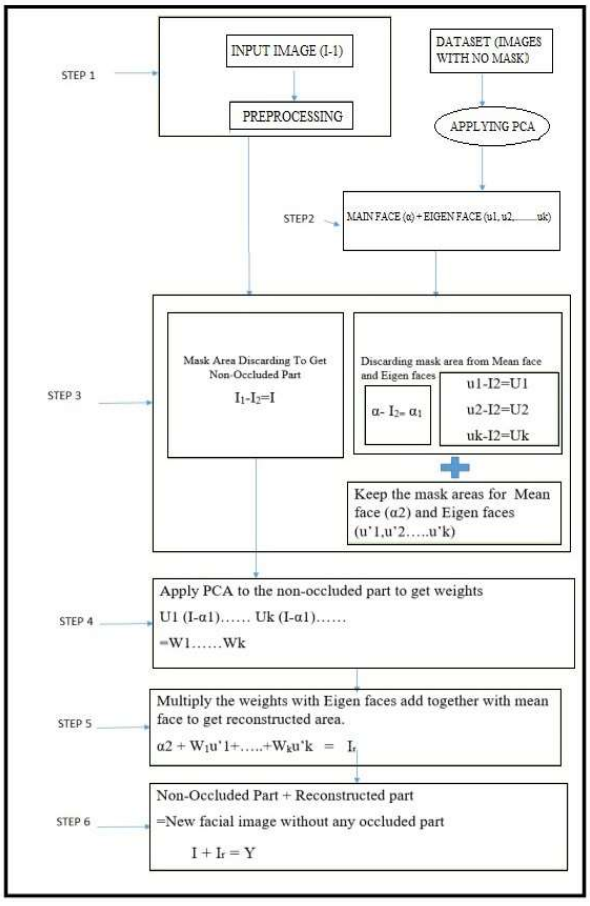

Fig. 2 System Architecture.

The system architecture is divided into two parts.

1. Face Reconstruction
2. Face Recognition
3. ***The first part (face reconstruction)***

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The reconstruction phase is mentioned in six steps below.

Step 1: The dataset contains the pictures of each subject (person). The images in the dataset and the input images had the same face area and size.

In step 1, i.e., "I1," the input test image is accepted from the user and then pre-processed. A PCA analysis was done.

Step 2: In this step, the mean face image (α) and Eigen faces u1, u2,... u_k were calculated, where u_k is the k^{th} Eigen face.

Step 3: The mask region was removed from the input test picture in order to obtain the non-occluded portion of the image, i.e., the mask region is shown as "I2," and "I1" represents a portion of the input picture that is not obscured by the mask. Then the identical area had also been discarded from the mean face as well as from the Eigen faces and was saved in a new directory, with α2 representing the area rejected from the mean face and u'1, u'2, u'3, u'k representing the area that was discarded from the Eigen faces.

Step 4: At the end of the third phase, the mean face ' α1' is subtracted from the input "I" and multiplied by the Eigen faces "U1, U2,... Uk." Weights are generated by multiplying on each Eigen face. These weights are real numbers and differ based on the picture "I" that is used as an input.

Step 5: To reconstruct the occluded part I_r of the face, the weights (w1, w2,... wk) were multiplied with the discarded Eigen faces (u'1... u'k) and summed together with the discarded mean face image (α2).

Step 6: The reconstructed parts Ir and I are summed to generate a facial image Y with no occlusion area.

B: The Second Half (Face Recognition)

Many researches have used different approaches for face detection. Such as by using neural networks, the features of the images in the dataset have retrieved and the characteristics of each image has represented as a vector representation in their approach [18, 26]. The vector representation can be projected onto a unit hyper sphere, which was the next step. Embedding is the term used to describe this dense vector representation of a class. It was coincident with the persons embedding of the new input test image "Y" when the vector representation of the new input test image "Y" is projected into the unit hyper sphere.
The face-recognition model has been trained with the help of the training data. As shown in "Fig. 3".

Fig. 3 Mean face from the training dataset. [25]

III. METHODOLOGY

Methodologies help us differentiate the occluded and the non-occluded part of the face.
There are four methodologies and they are as follows

1. Detect and reject areas with masking tape.
2. Principal Component Analysis.

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3. Reconstruction of the obstructive portion.
4. Identification of individuals

1. Detect and reject areas with masking tape

A pairwise differential Siamese network is a strategy that is useful when the mask and the target are of different size and form. In our instance, there is just one possible form, which is a face mask, which allows us to discard the occluded portion of the face. The mask area has been picked and discarded. No particular plan or method has been used to keep the whole system from getting too complicated.

Here are some good principles about face detection:

1. helps find missing people.
2. improves image organization.

Face detection is a new technology that could change the way we live in the future. But like any new idea, putting this new system into place in society comes with some consequences and risks.

Here are some cons about face detection:

1. It imposes on personal freedom.
2. misuse, causing fraud and other crimes.

2. **Principal Component Analysis**.

PCA is a well-established and well-known approach for calculating the most important Eigen vectors and Eigen values in a given set of data. To exhibit the non-occluded part of the face, PCA is applied to it, resulting in the generation of Eigen vectors and Eigen values that are most ideal for illustrating the non-occluded region of the face. In order to figure out the main parts of the part that wasn't covered, they took the area of the face mask out of both the normalised picture (mean face) and the original picture.

Eigen faces in order to get the principal components of the non-occluded part.

Here are some good prons about Principal Component Analysis:

1. It improves the performance of the algorithm.
2. Reduces Overfitting.
3. It improves visualisation.

Here are some cons about principal component analysis:

1. Independent variables become less interpretable.
2. Data standardisation is a must before PCA.

3. **reconstruction of the obstructive portion**

Many of the researchers have recreated the occluded portion of the face using the primary components that they obtained in the previous stage of the process. The primary components of an image can be expressed by combining the normalised image with the principal components. A dataset including several photos of each person is required for face recognition. From this dataset, the normalised image, or the mean multiplied, has been obtained for each individual. In the previous step, they obtained the Eigen faces and Eigen values to represent the input image's non-occluded part, and then they multiplied the Eigen values with the corresponding Eigen faces and added them together with the normalised image (mean face); however, they did this for the masked area, and as a result, they only got the reconstructed form of the masked area. Finally, they have added the

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reconstructed form of the masked area to the normalised image (mean face).

Reconstruction of the face in "Fig. 4" has demonstrated the Eigen face calculated from the training dataset. After that, the Eigen face principal components and their corresponding Eigen face weights were calculated using the non-occluded portion of an input test picture. This was done by multiplying the weights with their Eigen vectors, and then adding the mean face to the rebuilt picture. "Fig. 5" displays both the original test image and the rebuilt version.

Here are some good points. reconstruction of the obstructive portion.

1. The concept uses video redundancy to improve still picture systems.

Here are some good cons. reconstruction of the obstructive portion.

1. Image similarity issues multiply

Identification of individuals

Many of the researchers have identified the individuals using different methods. such as a convolutional neural network, Facenet, etc. Some of the methods have few limitations for identifying the individuals.

Here are some good reasons for identifying the individuals:

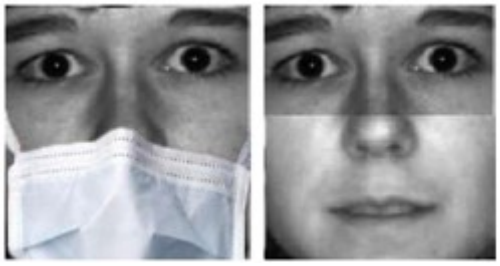
1. It identifies the image of the group of people.
2. It recognised the image when it was a little bit blurry.

Some of the cons of identifying the individuals are

1. It is difficult to recognise the images from a certain distance.

provides less accuracy when the image is not aligned properly.

Fig 4.Eigen faces. These are only some of the Eigen faces [25].



(a) (b)

Fig 5. (a) Input test image and (b) reconstructed image [25]

The methodologies of the different studies are mentioned in the given Table 1".

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Reference No.	Author	Method Used	Advantages	Limitations
[1,29,25,39]	Susanta Malakar et.al Shubham Gupta et.al Warinthorn Naultim et.al Zijian Zhang et.al	Principal Component Analysis (PCA)	Occluded part accuracy is up to 15% Partial face recognition	Cannot Construct the Occluded part accurately. Needs to better recognize the partial face with more accuracy or faces with Occlusion. More security can be added such as retina. Recognition rate can be improved.
[2,4,511,12,14,19,20,24]	Muhammad Ihtisham Amin et.al, Jinu Lilly Joseph et.al, Paras Jain et.al,Meijin Lin et.al,Yelanati Ayyappa et.al, Renjith Thomas	Convolutional Neural Network (CNN)	Achieved an accuracy of 97.67% in masked face recognition. Face recognition accuracy of 67.18%. Identify seven different emotions of face. Automatic analysis of Facial expressions.	Complex architectures make the real-time Implementation time consuming. Application deployed on the android device only. More number of emotions to be recognized. There is no chance of capturing the image if it in motion.
[3,13]	Nitendra Mishra et.al	Local Binary Pattern(LBP), Gabor filter	Images can be captured easily.	Diminishing the preparing time for video preparing. Detection and recognizing to above 90%.
[6,22]	R. Satheesh Kumar et.al	Deep Learning	Faces can be identified if	Difficult to identify the face in the crowded place such as
		Methods, Deep Perceptual Mapping	people wear or doesn't wear a mask	Seminar Hall etc.
[7,23]	Ali Elmahmudi et.al Zheng chen et.al	Deep Learning Methods, VGG – Face Model	Faces can be recognized easily. Students expression and behaviour recognition	Needs more consistency in selecting facial features for recognition. Difficult to recognize the students expression when ever there are student movements has occured.
[8,15,]	Chandra prabha K et.al, Kolipaka preethi et.al	Neural Network ,LBHP(Local Binary Histogram Pattern) Algorithm	Images can be capture when they are static. Recognizes the images and marked their attendance automatically	The performance of face recognition security framework is improved. To update attendance of multiple people.
[9,26,27]	Mohammad Abuzneid et.al	BPNN(Back Propagation Neural Network)	It will lead to a robust face recognition system.	Converge faster and more accurate.
[10,19]	Meijin Lin et.al Radha Guha et.al	Support Vector Machine, Local Binary Pattern, Histogram of Oriented Gradient	Has better recognition accuracy for small sample space	It may overcome the over-fitting problem. Needs more accuracy in automatic face recognition.

Table 1-Comparison of Previous Methodologies.

New and enhanced face reconstruction technologies are included in the suggested method. In comparison to the standard approach for masked face photos, the new method has significantly improved face recognition results. By analysing the non-occluded portion of a face, the occluded portion of a facial picture can be rebuilt. The suggested technique cannot correctly rebuild the afflicted section, and all photos in the data set must be centred and only comprise the facial area of the face. In future work, we hope to enhance the rebuilt result.

1. conclusions

After investigating various research articles, we found that the state-of-the-art methods are not suitable to recognise maskable faces effectively and that deep learning is more effective to enhance face detection accuracy. In this article, we have proposed a deep learning-based methodology to achieve the same.

REFERENCES

[1] Susanta Malakar et.al Masked Face Recognition Using Principal Component Analysis and Deep learning 18th International Conference on Electrical Engineering 2021 DOI:10.1109/ecti-con51831.2021.9454857 978-1-6654-0382-5/20/$31.00

[2] Muhammad Ihtisham Amin , Muhammad Adeel Hafeez , Rana Touseef , and Qasim Awais Person Identification with Masked Face and Thumb Images under Pandemic of COVID-19 7th International Conference on Control, Instrumentation and Automation (ICCIA)|DOI: 10.1109/ICCIA52082.2021.94035772021|978-1-6654-0350-4/20/$31.00 ©2021 IEEE

[3] Nitendra Mishra, Aruna Bhatt Feature Extraction Techniques in Facial Expression Recognition 5th International Conference on Intelligent Computing and Control Systems (ICICCS) 2021 DOI: 10.1109/ICICCS51141.2021.9432192 | 978-1-6654-1272-8/21/$31.00 ©2021 IEEE.

[4] Jinu Lilly Joseph, Santhosh P. Mathew Facial Expression Recognition for the Blind Using
Deep Learning 4th International Conference on Computing, Power and Communication Technologies (GUCON)|DOI: 10.1109/GUCON50781.2021.9574035 | 978 978-1-7281-9951-1/21/$31.00 ©2021 IEEE

[5] Paras Jain, M Murali, and Amaan Ali Face Emotion Detection Using Deep Learning Fifth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC) DOI: 10.1109/I-SMAC52330.2021.9641053".978-1-6654-2642-8/21/$31.00 ©2021 IEEE.

[6] Andres Espinel, Noel Perez, Daniel Riofrio Diego Benitez and Ricardo Flores Moyano Face Gesture Recognition Using Deep-Learning Models IEEE Colombian Conference on Applications of Computational Intelligence (ColCACI) | DOI: 10.1109/ColCACI52978.2021.9469528.| 978-1-6654-3534-5/20/$31.00 ©2021 IEEE .

[7] R. Satheesh Kumar, Anagha Rajendran, Amrutha.V, Gopika.T. Raghu Deep Learning Model for Face Mask Based Attendance System in the Era of the Covid-19 Pandemic 7th International Conference on Advanced Computing and Communication Systems (ICACCS).|DOI:10.1109/ICACCS51430.2021.9441735. 978-1-6654-0521-8/20/$31.00 ©2021 IEEE.

[8] Ali Elmahmudi, Hassan Ugail Experiments on Deep Face Recognition using Partial Faces Sixth International Conference on Inventive Computation Technologies [ICICT 2021] DOI 10.1109/CW.2018.00071 | 978-1-5386-7315-7/18/$31.00 ©2018 IEEE Part Number: CFP21F70-ART; ISBN: 978-1-7281-8501-9.

[9] Chandra prabha K, Prabha Selavaraj, Vijaya Kumar Burugari, Kanmani P Image extraction for vehicle theft detection using Neural Network International Conference on Computer Communication and Informatics (ICCCI -2021), Jan. 27 – 29, 2021, Coimbatore, INDIA DOI: 10.1109/ICCCI50826.2021.9457023.| 978-1-7281-5875-4/20/$31.00 ©2021 IEEE.

[10] Abuzneid, Mohannad; Mahmood, Ausif . Improving Human Face Recognition using Deep Learning based Image Registration and MultiClassifier Approaches [IEEE 2018 IEEE/ACS 15th International Conference on Computer Systems and Applications (AICCSA) 1–2. DOI:10.1109/AICCSA.2018.8612896 | 978-1-5386-9120-5/18/$31.00 ©2018 IEEE.

[11] Meijin Lin;Zihan Zhang;Weijia Zheng A Small Sample Face Recognition Method Based on Deep Learning. 2020 IEEE 20th International Conference on Communication Technology (ICCT), DOI:10.1109/icct50939.2020.9295707.

[12] Yalanati Ayyappa, P.Neelakanteswara, P.Neelakanteswara, Yamini Tondeti, CMAK Zeelan Basha Automatic Face Mask Recognition System With FCM AND BPNN 5th International Conference on Computing Methodologies and Communication (ICCMC 2021) DOI 10.1109//ICCMC51019.2021.9418243 ©2021 IEEE |978-1-6654-0360-3/20/$31.00 ©2021 IEEE.

[13]Harikrishnan Sudarsan, Arya Sudarshan,Sadashiv Aravind,S,Remya Ajai A (2019).Vision-Face Recognition Attendance Monitoring System for Surveillance using Deep Learning Technology and Computer Vision IEEE 2019 International Conference on Vision Towards Emerging Trends in Communication and Networking (ViTECoN) - Vellore, India (2019.3.30-2019.3.31)], 1–5. DOI:10.1109/ViTECoN.2019.8899418 | 978-1-5386-9353-7/19/$31.00 ©2019 IEEE.

[14] Xiujie Qu, Tianbo Wei, Cheng Peng, Peng Du A Fast Face Recognition System Based On Deep Learning 2018 11th International Symposium on Computational Intelligence and Design (ISCID) DOI 10.1109/ISCID.2018.00072 | 2473-3547/18/$31.00 ©2018 IEEE.

[15] Kolipaka Preethi,Swathy Vodithala; (2021). Automated Smart Attendance System Using Face Recognition 2021 5th International Conference on Intelligent Computing and Control Systems (ICICCS),DOI:10.1109/ICICCS51141.2021.9432140 | 978-1-6654-1272-8/21/$31.00 ©2021 IEEE.

[16] Shubham Gupta, Divanshu Jain, Milind Thomas Themalil, Electronic Voting Mechanism using Microcontroller ATmega328P with Face Recognition . 2021 5th International Conference on Computing Methodologies and Communication (ICCMC), – .DOI:10.1109/iccmc51019.2021.9418372 | | 978-1-6654-0360- 3/20/$31.00 ©2021 IEEE.

[17] Asep Hadian Sudrajat Ganidisastra;Yoanes Bandung. An Incremental Training on Deep Learning Face Recognition for M-Learning Online Exam Proctoring . 2021 IEEE Asia Pacific Conference on Wireless and Mobile (APWiMob). DOI:10.1109/APWiMob51111.2021.9435232 | | 978-1-7281-9475-2/21/$31.00 ©2021

[18] Radha Guha . A Report on Automatic Face Recognition: Traditional to Modern Deep Learning Techniques 2021 6th International Conference for Convergence in Technology (I2CT),– .DOI:10.1109/i2ct51068.2021.9418068 | 978-1-7281-8876-8/21/$31.00 ©2021 IEEE

Suresh Gyan Vihar University Journal of Engineering & Technology
(An International Bi-Annual Journal), Volume 8, Issue 2, 2022, pp 32-40
ISSN: 2395-0196

[19] Vallabhaneni Sri Harsha Sai; Image classification for user feedback using Deep Learning Techniques . 5th International Conference on Computing Methodologies and Communication (ICCMC) –. DOI: 10.1109/ICCMC51019.2021.9418419.| 978-1-6654-0360-3/20/$31.00 ©2021 IEEE.

[20] Dane Brown Mobile Attendance based on Face Detection and Recognition using OpenVINO . 2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS),– DOI:10.1109/icais50930.2021.9395836 | 978-1-7281-9537-7/20/$31.00 ©2021 IEEE.

[21] Cho, MyeongAh; Kim, Taeoh; Kim, Ig-Jae; Lee, Kyungjae; Lee, Sangyoun. Relational Deep Feature Learning for Heterogeneous Face Recognition. IEEE Transactions on Information Forensics and Security, 16(), 376–388. DOI:10.1109/TIFS.2020.3013186.

[22] Harshada Badave, Madhav Kuber; Head Pose Estimation Based Robust Multicamera Face Recognition . 2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS) – DOI:10.1109/icais50930.2021.9395954 | 978-1-7281-9537-7/20/$31.00 ©2021 IEEE.

[23] Chethana H.T,Trisiladevi C. Nagavi . A Heterogeneous Face Recognition Approach for Matching Composite Sketch with Age Variation Digital Images. 2021 Sixth International Conference on Wireless Communications, Signal Processing and Networking(WiSPNET). DOI:10.1109/wispnet51692.2021.9419436 | 978-1-6654-4086-8/21/$31.00 ©2021 IEEE

[24]https://www.nist.gov/system/files/documents/2021/05/12/2020%20Annual%20Report%20for%20website.pdf

[25]https://ieeexplore.ieee.org/document/9454857.

[26]https://www.independent.co.uk/news/uk/crime/super-recognisers-used-by-the-police-to-identify-criminals-and-spot-offenders-in-crowds-10324186.html

[27]https://www.businessinsider.in/science/news/vaccinated-us-health-experts-are-wearing-masks-indoors-as-the-delta-variant-spreads/articleshow/84069322.cms