Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 143 (2018) 536–543

Procedia Computer Science

www.elsevier.com/locate/procedia

8th International Conference on Advances in Computing and Communication (ICACC-2018)

Techniques and Challenges of Face Recognition: A Critical Review

Shilpi Singh[a],S.V.A.V.Prasad[b]

[a] *Research Scholar, Computer Science Dept . Lingaya's Vidyapeeth,Faridabad,India 121002*
[b] *Professor& Dean, Electronics and Communiation Dept. Lingaya's Vidyapeeth,Faridabad,India 121002*

Abstract

A lot of researches are going on since last two decades for object recognition, shape matching, and pattern recognition in the field of computer vision. Face recognition is one of the important issues in object recognition and computer vision. In our day to day activities, a number of biometric applications are available for recognizing humans such as eye or iris recognition, fingerprint recognition, face recognition. Face is an important part of human being and requires detection for different applications such as security, forensic investigation. It requires proper techniques for face detection and recognition with challenges of different facial expressions, pose variations, occlusion, aging and resolution either in the frame of stationary object or video sequencing images. Authors tried to put the concept of face synthesis, for improving accuracy and recognition rate on different face database like ORL, YALE, AR and LFW. Authors had presented a critical review of various types of face recognition techniques and challenges, to improve efficiency and recognition rate for identifying face images in large database, with comparison of accuracy or recognition rate.

Keywords: Face feature extraction; face detection; synthesis; object recognition; occlusion; recognition rate.

1. Introduction

Face recognition is always an interesting area and one of the challenging tasks in computer vision and image retrieval. It is applicable in variety of domain such as in ATM, healthcare system, driving license system, railway reservation system, surveillance operation and passport authentication. In large database, face image recognition is always a challenging task. There are various biometric features which can be used to identify human such as fingerprint, palm print, hand geometry, iris, face, speech, gaits and signature. But, the major issue was they require

* Corresponding author. Tel.:+91- 129-2598200
*E-mail address:*4.shilpi@gmail.com, prasad.svav@gmail.com

10.1016/j.procs.2018.10.427

active co-operation of person for authentication, whereas face recognition does not require active cooperation of person. Therefore, face recognition is much more convenient as compared to the other biometrics.
Let us first discuss what do you mean by face recognition? One can simply define: Face recognition is the procedure of recognizing an already detected face. It can be known or unknown, in other words, it could be defined as recognizing the person who it is from our enrolled user database? Face recognition has two important tasks: verification and identification. Face verification can be defined as one to one match that correlate a face image against available face image databank whose personality being matched. Face identification is a one to N problem that match a query image of a face against available image in a face database. Third case is also considered when a query face may or may not be in the available databank. In such case, one can compute similarity score and on the basis of highest similarity score one can find out match. Shwetank Arya et al. [30] studied a number of 2D and 3D face recognition techniques and proposed Infrared Spectrum (IRS) to overcome the challenges in face recognition. Face detection and matching is important for face feature extraction and accuracy calculation. Face recognition is still a challenge for recognizing face in motion images, twin's, pose variations, having different accessories like beard, glasses, hair colour, hair partition, make-up, different facial expressions under different illumination condition, light intensity, noise, occlusion and thermal image for face matching and error generation. Jyoti kumar et al. [29] discussed various facial expression recognition (FER) based on geometry and appearance.They had comp ared different feature extraction techniques based on JAFFE dataset. Abdol hossein et al. [9] proposed Gabor-Zernike face feature descriptor and HOG descriptor to extract local stastical feature. They tested result on three different database and retrieved face recognition rate of 98% on ORL database, 97.8% on Yale database and 97.1% on AR database.

2. Types of face recognition

A human being can be identified with the help of different face features, fingerprint, eye/iris, body structure, spot mark and so on. Face is one of the important parts of the body, which plays an important role in recognizing humans. Resolution plays a vital role in face recognition while identifying face in surveillance or CCTV. In face recognition system, first step is to detect a face in an image [6]. Faces decompose into mainly four features like eye, lip, nose and mouth for recognition. Main theme of face detection is to identify whether there are single faces in the image or more in view of stationary picture or video picture. Faces are mainly having dimension in 2D and 3D with different textures and facial expressions [5, 7, 8].

2.1. 2D face recognition

Previously for 2D face recognition following four steps was used:
In face recognition first step was to detect face, second step was face alignment, third step was feature extraction and fourth step was feature matching from database of enrolled users to recognize face. Matrix has been computed on the basis of pixel values at corner of face under different illuminations conditions for 2D face recognition. Normally, face images are represented by a high dimensional vector containing pixel values. Feature matching is done to match the input face in the form of image or video from available database of enrolled images with unique face identity. Various techniques adopted for face detection were based on color, intensity and illumination. It is one of the challenging tasks to recognize who it is? and researcher faces many challenges like facial expression, illumination, poses variations image orientation and occlusion in face recognition. There were some limitations of 2D face recognition. In 2D face recognition system recognition rate and performance is dependent on image capture conditions like head orientation, image quality, lighting conditions, partial occlusion, facial expressions.

2.2. 2D -3D face recognition

Andrea F.Abate et al. proposed a reliable technique for collective 2D visual images and 3D model face recognition based on different parameters such as input size, number of addressed tasks and recognition rate. Comparison of different techniques provides future perspective to the researchers for enabling new techniques in the field of face

recognition [1]. Eigen faces and stereovision techniques used to improve the performance of 2D face recognition system with 3D information known as disparity of face. Face of a person at different position was matched with the help of scan lined-based neural network. Principal component analysis (PCA) for feature extraction and recognition were effectively used for face recognition. 2D- 3D face recognition rate were improved by adding up information in-depth [2]. Face identification process is shown in figure 1.

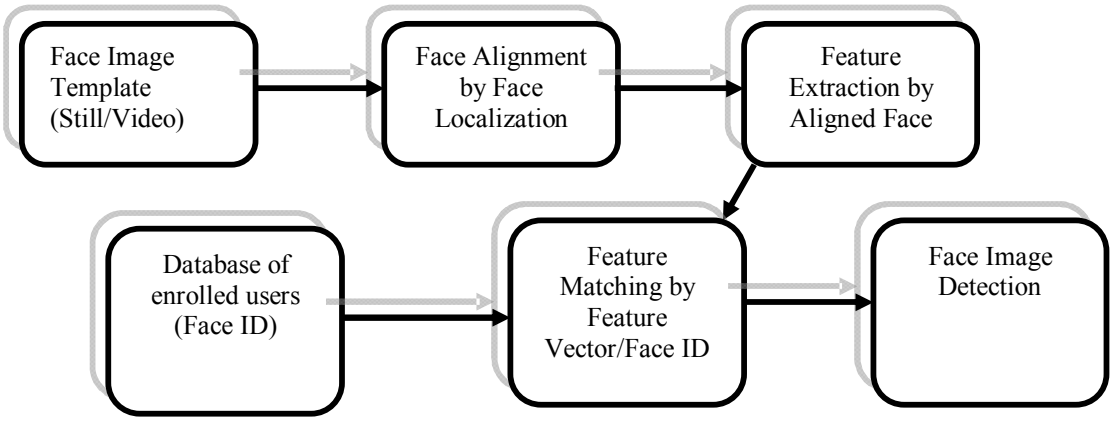

Fig. 1. Face detection process.

2.3. 3D face recognition

Faces are in the form of real image, various textures, different framework which convolute in three dimensions. It seems to be more precise recognition of the face image and minimize the problem of pose variations, occlusion and different illumination condition [30].

Sima Soltanpura et al. [31] proposed a survey for 3D face recognition based on local features. They divided the local descriptor into curves, key points and surface. They had applied image acquisition technology on 3D face database to compare under different conditions. Feature extraction is one of the important modules in face recognition which was considered by authors. They studied about different types of face descriptor and feature extractors for 3D face recognition. They also consider the challenges of face recognition with different face expression and occlusions.

3D image and face feature extraction adopted various techniques and methods for efficient and effective recognition. Normalization between probe and gallery texture is done with the help of bidirectional relighting. Introduction of correlation metrics for finding out similarity scores and concept of pose and light normalized signatures for face verifications applied frequently [5]. Motivation to use 3D face recognition technology is to overcome the drawback of 2D face recognition systems. 3D face images were recognized with the help of different augmentation techniques and tested on various database [6]. It was enhanced with the help of experienced sensors camera capturing better 3D face image which can generate 3D face models [4, 5, 7]. Various techniques are available to recognize a 3D face from a range of viewing angles. One of the benefits of 3D face recognition system is that it is not affected by light intensity. Several methods were introduced to extract the features so that accuracy and recognition rate will be higher [10, 29].

Ge Wen et al. [38] proposed improved face recognition with domain adaptation. In this authors, tried to evaluate face recognition by taking Labeled Faces in the Wild (LFW) dataset as a bench mark. They considered data bias as one of the problem. They had replaced the training data with same distribution because according to them web-collected dataset come from celebrities are quite different from faces of normal people in day to day activities and harder to collect due to privacy concerns. They had applied FaceNet triplet loss function. They achieved accuracy rate of 99.33% with single CNN model without face alignment.

3. Challenges of face recognition

3.1. Aging

Face in the form of various texture entail characteristics value changes over a period of time and reflect as aging, which has a prompt importance in face recognition. Age invariant is also important for visual observation and image retrieval after a long time access. Coupled auto-encoder networks called CAN and non-linear analysis was done for aging and de-aging for the face data set called FGNET, CACD, CACD-VS [14]. Aging factor in face recognition system in different age group for various face set over a period of time calculated for accuracy checking. Aging effect descriptor for various age groups and classification need similarity measure for age discrimination. Various analyses were done globally for the different age group to compute similarity index and finding [15].
Face recognition depends on the features extraction, concerned about the data extraction and basic features properties like wrinkle, marks, spot eyebrow, makeup and so on. An Active Appearance Model (AAM) technique was introduced for reduction of image dimension in face recognition process [16]. Performance of the face feature recognition is extremely important for simulation of sparse-constrained method proposed for face recognition with aging factor to look aging over a span of time period. [17].

3.2. Thermal image

Multi-feature extractions for small and large database need suitable technique for thermal face recognition system. In low resolution Gabor system, thermal image detection needs main attention on the environment based on illumination [18]. Multi-fusion techniques illustrated about Gabor jet descriptor which was used for multi-feature extraction. Fusion algorithms were used for visible thermal infra-red image detection for face recognition system, which requires formation of accuracy and recognition rate. Formation of universal image index quality for thermal image measurement was satisfactory for face recognition. Recognition rate was also checked with UGC-JU for measuring performance [19]. Gabriel Hermosilla et al, [20] stated about thermal spectrum for face recognition in unconstrained environments require local matching method based on the binary pattern, Weber Linear Descriptors and Gabor Jet descriptor. All the face recognition method compared and analyzed for performance evolution. New entropy functions also needed for infra-red image feature extraction and recognition. Feature property extraction for infra-red entropy analysis entail checking of face recognition using different discriminating characteristics on available database for performance evaluation [21].

3.3. IRIS

IRIS is important part of the face, and feature extraction of IRIS plays a vital role in face biometrics analysis. IRIS recognition methods are available and mostly based on the Bio-Hashing techniques. In IRIS Mapping, robustness improved will be checked on the six databases and then results are tabulated for IRIS recognition. It has effectiveness and robustness in the recognized system for better performance [11]. Face and Iris Recognition both are having extraction and recognition for Mobile Engagement system. This application had viability on mobile for response reliability, fusion technology and sample show better accuracy result [12]. Multi-biometrics system accuracy is very important for various features. IRIS corner data loss during the filtering and synthesis of data on bin base framework causes loss of information and again checked with the help of fusion. Experimental results were checked on CASIA-IRIS Framework [13].

3.4. Occlusion

Yu-Feng et al. discussed about single sample face recognition with occlusion, sparsity and robustness. Learning based PCA was used for intra-class variant dictionary and optimization for solving multi-scale sparse coding model. It was a discriminative multi-scale model, promptly used for face recognition with occlusions [23]. Partial occluded face recognition systems for large database were based on generic occlusion and structured sparse dictionary approach. Mutual incoherence regularization and fast algorithm proposed for occlusion with dictionary learning approach, which had lower computational cost for large database representation and performed better as compared to other methods [24]. Mustafa M. Alrjebi et al [22] proposed face recognition against occlusion using two

dimensional multi-colour fusion (2D-MCF) model and SRC. They used fused colour information for effective face recognition against occlusions. They first devised a new local representation for face images and then applied partitioned sparse sensing recognition (P-SRC) for improving accuracy. They applied the result on four different databases for improving the recognition rate. They improved the recognition rate on AR database up to 24.5%, 3.8% recognition rate was improved on Curtin database, up to 25% was improved on FRGC database and 2.86% on Bosphorus database. Face recognition with occlusion in different trained model of 2D-MCF widely used and in that method the previous occlusion fusion details requirement is less and accuracy rate also improved with other method. Two dimension multi colour fusion technique had improved accuracy for face recognition with occlusion.

3.5. Facial expressions

Yulan Guo et al. [32] proposed expression invariant 3D face recognition which was based on feature and matching shape which encompasses local geometric feature, with the help of global similarity between faces. They tested their results on FRGCv2 dataset. They had taken a probe face which was compared against face database using both local feature and 3D cloud registration. They achieved recognition rate of 97.0% and verification rate of 99.01% for different faces either having neutral expressions or having non-neutral expressions. Li Ye et al. [34] proposed an expression insensitive 3D face recognition using multiple subject specific curves. They applied 3D face matching with the iterative closest point algorithm and an expression-irrelevant factor as weight to increase the performance of face matching algorithm. Sparse Representation Classification-SRC and Collaborative Representation Classification –CRC approaches were widely used for facial expression analysis [25]. Facial expression and feature extractions for the six objects joy, sadness, anger, fear, disgust and surprise were needed to extract and classified with the help of NN classifier in 3D Face model [26]. Linearity and faster recognition of facial expression will be achieved with Modified Local Directional Patterns (MLDP) approach. Video based image and face expression with different features were also important for facial expression recognition. Facial expression with generalized discriminant analysis performed on deep belief network had better performance as compared to other available technology [27]. Multimodal model detection is widely adopted for landmark and texture value in facial expression recognition system and analysis of facial expression experiments for better performance [28]. Abdelghafour Abbad et al [35] proposed 3D face recognition based on geometric and local shape descriptors to overcome the challenges of different facial expressions. They had applied four different steps to solve the problem: first step was to model 3D face, second step was feature extraction, third step was to find out geometric information on the 3D surface in terms of curves and fourth step was to find out feature vectors on each scale. They studied and compared their result on GavabDB and Bosphourus datasets and retrieved the recognition rate of 98.9%.

3.6. Poses

Li-Fang Zhou et al. [36] proposed pose robust face recognition with LBP and Huffman coding. They had applied divide and rule technique on face representation and their classification to improve pose variation. Also, they had applied Region Selection Factor (RSF) for face representation of a face image to consider different poses specifically, instead of, generally and applied patch based SRC fusion classification strategy to improve the technique. They studied result on FERET database and LFW database for improving the accuracy. Thibault Napoleon et al. [33] proposed pose invariant 3D face recognition. They proposed an active shape model to detect key features with the help of finite element method. They tried to improve recognition rate by applying LBP technique and applied VanderLugt correlator and Gaussian filter to identify the edges of the image on the basis of local binary patterns for image identification. They studied their result on the PHPID database with 3D reconstructed faces of each person with an azimuth. They proved identification rate of 88.76% with proposed method and compared the result with 2D approach based on VLC database with recognition rate of just 44.97%.
Brahmin Aksasse et al. [37] proposed a new technique to pose invariant face recognition. They tried to improve face recognition rate in the wild animal and proposed a technique for face alignment with the help of single 3D face model in context to FaceGen Modeller. They also introduced a new face descriptor based on Gabor Filters which was combination of Gabor phase and Gabor magnitude in a given framework. It was able to overcome standard presentation in Labeled Faces in the Wild dataset (LFW). They tried to prove accuracy rate of 97.29% on LFW dataset.

3.7. Facial advances

Face recognition becomes more challenging in case when an image differs by surgical variations of faces for increasing beauty. Coarse-to-fine strategy was used to identify landmarks under different poses in 3D face [3]. Half face matching algorithm technique was introduced, based on geometrical structure-based search and modified FLM based search using HK curvature analysis. Robustness and accuracy is important in HK Curvature analysis under different poses [4]. Face transposition patterns used to find out how holistic and distinctive features influenced by 2D and 3D faces detection. 3D stereoscopic effects are more accurate during holistic extraction but not during inverted face feature extraction.
It was noted that in facial inversion of 2D and 3D faces both, recognition rate and performance is almost same and focus on how 3D face recognition influenced by the integration of GPU [7]. External, internal features, facial expressions and face dynamics findings are easier to discriminate in isolated features rather than embedded features [8].Authors tried to figure out different challenges of 2D and 3D face recognition. In table 1, different techniques and applications were compared with different face database for accuracy and recognition rate.

Table 1. Comparison of different face recognition techniques, applications and accuracy rate

S.No.	Techniques	Applications	Face database applied	Accuracy/Recognition rate
1	Histogram Oriented Gradient(HOG)[9]	Global gabor/Zernike descriptor	ORL	98%
			YALE	97.80%
			AR	97.10%
2	Featural Processing[10]	2D/3D Face recognition	Stereoscopic information	Higher in 3D Face
3	Fusion algorithm/RF classifiers[19]	Visible and Thermal Image faces	UGC-JU	99.07%
4	Two dimensional multicolour fusion [22]	2D-MCF Model/Partitioned sparse sensing recognition(P-SRC)	AR	up to 24.5% improved
			CURTIN	up to 3.8% improved
			FRGC	up to 25% improved
			Bosphorus	up to 2.86% improved
5	Modified Local Directional Patterns[27]	General Discriminant Analysis	Deep Belief Network	96.25%
6	Multi-scale strategy based on geometric and local descriptors[36]	3D face recognition	GavabDB and Bosphourus	98.90%
7	LBP technique, shape model [33]	3D face recognition	PHPID database VLC database	88.76% 44.97%.
8	local geometric feature and shape matching[32]	3D face recognition	FRGCv2 dataset	97.00%

9	face descriptor based on Gabor filter [37]	face recognition in wild animal	LFW dataset	97.29%
10	domain adaptation [38]	face recognition in wild animal	LFW dataset	99.33%

4. Conclusions

Face is the most important feature of living body, which plays important role in recognizing human beings. Various techniques across the world are used for face recognition application and research. In this paper, authors tried to extend review of face recognition techniques and its challenges for performance comparison, accuracy and recognition rate on different face database such as ORL, YALE, PHPID, VLC, GAVAbDB, AR, UGC-JU, CURTIN, FRGC, Bosphorous, LFW dataset. Face recognition has increasing applications area such as in the field of security, forensic and requires more accuracy and reliability. Synthesis of various textures is also presented here for face recognition and various challenges were also considered like aging factor, facial features, expressions, pose variations, thermal image, occlusion and illumination. On the basis of review, authors found that, till now maximum accuracy rate of 99.33% achieved for face recognition of wild animal tested on LFW dataset with domain adaptation technique and 99.07% accuracy rate achieved using Fusion algorithm or RF classifiers for human face which was tested on UGC-JU face database. Presented review will be useful for upcoming researchers for selection of appropriate techniques for face recognition.

References

[1] Andrea F. Abate, Michele Nappi, Daniel Riccio, Gabriele Sabatino.(2007) "2D and 3D face recognition: A survey"*Pattern Recognition Letter s* **28(14):** 1885-1906.

[2] Te-Hsiu Sun, Mingchih Chen, Shuchuan Lo, Fang-Chih Tien.(2007) "Face recognition using 2D and disparity eigen face", *Expert Systems with Applications* **33(2):** 265-273.

[3] Michele Nappi, Stefano Ricciardi, Massimo Tistarelli. (2016), "Deceiving faces: When plastic surgery challenges face recognition" *Image and Vision Computing* **54**:71-82.

[4] Yan Liang, Yun Zhang, Xian-Xian Zeng. (2017) "Pose-invariant 3D face recognition using half face" *Signal Processing: Image Communication* **57:** 84-90.

[5] Ioannis A. Kakadiaris, George Toderici, Georgios Evangelopoulos, Georgios Passalis, Theoharis. (2017) "3D-2D face recognition with pose and illumination normalization" *Computer Vision and Image Understanding* **154:**137-151.

[6] Jiang Jing Lv, Xiao Hu Shao, Jia Shui Huang, Xiang Dong Zhou, Xi Zhou.(2017)" Data augmentation for face recognition" Neurocomputing **230**: 184-196.

[7] Vaibhav Jain, Dinesh Patel. (2016) "A GPU based implementation of Robust Face detection System" *Procedia Computer Science***87**:156-163.

[8] Andrew J.Logan, Gael E.Gordon, Gunter Loffler. (2017) "Contributions of individual face features to face discrimination ", *Vision Research***137**: 29-39.

[9] Abdol hossein Fathi, Pendar Alirezazadeh, Fardin Abdali-Mohammadi.(2016) "A new Global-Gabor-Zernike feature descriptor and its application to face recognition" *Journal of Visual Communication and Image Representation* **38**: 65-72.

[10] Z.H.D.Eng, Y.Y.Yick, Y Guo, H.Xu, M.Reiner, T.J.Cham, S.H.A.Chen. (2017) "3D faces are recognized more accurately and faster than 2D faces, but with similar inversion effects" *Vision Research* **138**: 78-85.

[11] Saiyed Umer, Bibhas Chandra Dhara, Bhabatosh Chanda. (2017) "A novel cancelable iris recognition system based on feature learning techniques" *Information Sciences* **406–407**: 102-118.

[12] Maria De Marsico, Chiara Galdi, Michele Nappi, Daniel Riccio. (2014) "FIRME: Face and Iris Recognition for Mobile Engagement" *Image and Vision Computing* **32(12):** 1161-1172.

[13] Di Miao, Man Zhang, Zhenan Sun, Tieniu Tan, Zhaofeng He.(2017) "Bin-based classifier fusion of iris and face biometrics" *Neurocomputing* **224**: 105-118.

[14] Chenfei Xu, QiheLiu, MaoYe (2017) "Age invariant face recognition and retrieval by coupled auto-encoder networks" *Neurocomputing,* **222**: 62-71.

[15] Michał Bereta, Paweł Karczmarek, Witold Pedrycz, Marek Reformat. (2013) "Local descriptors in application to the aging problem in face recognition" *Pattern Recognition* **46(10):**2634-2646.

[16]Sung Eun Choi, Jaeik Jo,Sanghak Lee,Heeseung Choi,Ig-Jae Kim,Jaihie Kim.(2017)"Age face simulation using aging functions on global and local features with residual images"*Expert Systems with Applications* **80**:107-125.

[17] Ji-Xiang Du, Chuan-Min Zhai, Yong-Qing Ye. (2013) "Face aging simulation and recognition based on NMF algorithm with sparseness constraints" *Neurocomputing* **116**: 250-259.
[18] Mingsong Lv, Mingsong Lv, Yangjie Wei, Nan Guan, Wang Yi.(2016) "Multi-feature fusion for thermal face recognition" *Infrared Physics & Technology* **77**: 366-374.
[19] Ayan Seal, Debotosh Bhattacharjee, Mita Nasipuri.(2016) ""Human face recognition using random forest based fusion of à-trous wavelet transform coefficients from thermal and visible images" *AEU-International Journal of Electronics and Communications* **70(8):**1041-1049.
[20] Gabriel Hermosilla, Javier Ruiz-del-Solar, Rodrigo Verschae Mauricio Correa.(2012) "A comparative study of thermal face recognition methods in unconstrained environments*" Pattern Recognition* **45(7):** 2445-2459.
[21] Mamta, Madasu Hanmandlu. (2014) "A new entropy function and a classifier for thermal face recognition" *Engineering Applications of Artificial Intelligence* **36**: 269-286.
[22] Mustafa M.Alrjebi, Nadith Pathirage, Wanquan Liu, Ling Li.(2017) " Face recognition against occlusions via colour fusion using 2D-MCF model and SRC" *Pattern Recognition Letters* **95**: 14-21.
[23] Yu-Feng Yu, Dao-Qing Dai, Chuan-Xian Ren, Ke-Kun Huang. (2017) "Discriminative multi-scale sparse coding for single-sample face recognition with occlusion" *Pattern Recognition* **66**: 302-312.
[24] Weihua Ou, XingeYou, Dacheng Tao, Pengyue Zhang, Yuanyan Tang, Ziqi Zhu. (2014) "Robust face recognition via occlusion dictionary learning" *Pattern Recognition* **47(4)**:1559-1572.
[25] Ali Moeini, Karim Faez, Hossein Moeini, Armon Matthew Safai. (2017) "Facial expression recognition using dual dictionary learning" *Journal of Visual Communication and Image Representation* **45**: 20-33.
[26] Paweł Tarnowski, Marcin Kołodziej, Andrzej Majkowski, Remigiusz J.Rak. (2017) "Emotion recognition using facial expressions", *Procedia Computer Science* **108**: 1175-1184.
[27] Md. Zia Uddin, Mohammed, Mehedi Hassan, Ahmad Almogren, Mansour Zuair, Giancarlo Fortino, Jim Torresen. (2017) "A facial expression recognition system using robust face features from depth videos and deep learning" *Computers & Electrical Engineering* Available online 29 in press.
[28] Wei Zhang, Youmei Zhang, Lin Ma, Jingwei Guan, Shijie Gong.(2015) "Multimodal learning for facial expression recognition" *Pattern Recognition* **48(10):** 3191-3202.
[29] Jyoti Kumar, R.Rajesh, KM.Pooja. (2015) "Facial expression recognition: A survey*" Procedia Computer Science* **58**: 486 – 491.
[30] Shwetank Arya, Neeraj Pratap, Karamjit Bhatia. (2015) "Future of Face Recognition: A Review" *Procedia Computer Science* **58**:578 – 585.
[31] Sima Soltanpour, Boubakeur Boufama, Q.M.Jonathan Wu. (2017) "A survey of local feature methods for 3D face recognition" *Pattern Recognition* **72**: 391-406.
[32] Yulan Guo , Yinjie Lei ,Li Liu , Yan Wang , Mohammed Bennamoun Ferdous Sohel.(2016) ,"EI3D: Expression-invariant 3D face recognition based on feature and shape matching*", Pattern Recognition Letters* **83(3):** 403–412.
[33] Thibault Napoleon, Ayman Alfalou. (2017),"Pose invariant face recognition: 3D model from single photo", *Optics and Lasers in Engineering* **89**: 150-161.
[34] LiYe, WangYing, HuiLiu, Jing Hao.(2018), Wen,"Expression-insensitive 3D face recognition by the fusion of multiple subject-specific curves," *Neurocomputing* **275**: 1295-1307.
[35] Abdelghafour Abbad ,Khalid Abbad ,Hamid Tairi.(2017) ,"3D face recognition: Multi-scale strategy based on geometric and local descriptors*," Computers & Electrical Engineering*,Available online.
[36] Li-Fang Zhou ,Yue-WeiDu, Wei-Sheng Li, Jian-XunMi, XiaoLuan.(2018), "Pose-robust face recognition with Huffman-LBP enhanced by Divide-and-Rule strategy *", Pattern Recognition* **78**: 43-55.
[37] Brahim Aksasse, Hamid Ouanan, Mohammed Ouanan. (2017), "Novel approach to pose invariant face recognition "*Procedia Computer Science* **110**: 434-439.
[38] Ge Wen, Huaguan Chen, Deng Cai, Xiaofei He. (2018),"Improving face recognition with domain adaptation", Neurocomputing **287**: 45-51.