Occlusion Invariant 3D Face Recognition with UMB – DB and BOSPHORUS Databases

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ABSTRACT
Face is having unique identity amongst all other biometric traits. Face recognition is performed using 2D and 3D facial data. 3D face recognition has many advantages over 2D Face recognition. This paper represents the 3D Face recognition challenges while processing the data captured using 3D face scanners. The performance of state-of-art, Face recognition system is affected due to pose, illumination variations and highly concerned issue of occlusion. The occlusion and its effects on 3D face recognition, along with occlusion invariant techniques are being surveyed. Moreover, various publically available 3D face databases like UMB-Db and Bosphorus that address the various occlusion issues are also reviewed.

General Terms
Image processing, Machine Learning, Security.

Keywords
3D Face Recognition, Occlusion, 3D face database, Expression, UMB-DB, Bosphorus.

1. INTRODUCTION
In biometric systems, human beings are easily recognized by distinctive features of face which is a unique property, like physiological and behavioral characteristics. In biometric recognition, the human face is mostly preferred because of several advantages like its contactless acquisition and moreover it is well accepted amongst the users [13]. It is being widely used in many applications such as public records, authentication, security and safety. Without attention of users it can be easily acquired. This make it the most reliable and preferred technique amongst all other biometric modalities.

This paper is organized as follows: in Section 2, a brief overview of face recognition is presented. 2D face recognition and 3D face recognition is presented. Section 3 describes the advantage of 3D face recognition over 2D face recognition and also depicts various short comings of face recognition systems like occlusion, ageing effect, illumination, changes in pose. Section 4 summarizes occlusion and its causes due to external objects and internal objects. In section 5, the overview of 3D face databases which addresses occlusion challenges are presented. Section 6 presents the different approaches of occlusion invariant 3D face recognition.

2. FACE RECOGNITION
For face recognition, the acquisition, registration and feature matching can be based on acquired 3D or 2D data [13]. 3D Face Recognition has many advantages over 2D Face Recognition due to enhancement in dimensionality, using the parameters like shape and texture channels parallel. The texture channels include the 2D image information. Information about face in 3D analysis is registered with shape parameters like surface normal. Shape of the face or the probe is mostly affected by the variations like illumination [1], [22].

3. SHORTCOMINGS OF 3D FACE RECOGNITION
3D Face Recognition is widely preferred among all techniques of recognition. 3D face recognition have higher rate of accuracy than 2D face recognition. It is very robust to obstacles and variations coming across face detection while processing and acquiring face data like variations in pose, illumination factor, expression, ageing i.e. over time, the face will go through various changes. For example, from childhood to age hood also known as time dimension which can be due to age or intentionally made changes [1], [22].

It is also affected by occlusions and makeup variations. Recent research in 3D face recognition has shown that shape of face also plays important role while identifying one's identity. It is immune to spoofing and deception. At the same time, the data of shape helps to eliminate the effects of illumination and pose from the texture of 3d Face. If shape and texture of face processing done together then this could lead to high performance [1].

Another problem coming while processing the face is internal factors. As discussed, ageing is one more issue that changes the facial shape and appearance due to speech and expressions. Since humans take help of mouth and vocal track to produce speech. Due to movements in facial muscles will create new expressions like neutral, smiling, angry, happy, worried etc. Like Human vision, the automated system should recognize and process the face without taking in considerations of all hurdles. The concerned complication while recognizing the face is occlusion. Occlusions make problematic scenarios in identifying the original image of face. Handling of occlusion variations is still a challenging task [1].

4. OCCLUSION
The real world applications are forced to work in controlled scenarios (issues) which are nothing but presentation of other problematic issues [12]. In particular, subjects or persons providing information of face may have a non neutral facial expression and the face can be occluded due to hair, hands, phone , scarf , glasses , goggles , and other type of accessories [12], [22]. It can hide some part or whole part of face [8]. Maximum available approaches with 3D face recognition, does not deal with such kind of issues. The reason behind this is the lack of publically available databases, featuring a large number of acquisitions taken in presence of 3D facial

information which can be affected due to internal and external objects [1] ,[22]. This can lead to missing information. Thus, there are two types of occlusions as follows:

1. Occlusion due to Internal Objects
2. Occlusion due to External Objects

4.1 Occlusion Due to Internal Objects

During acquisition changes in pose can lead to self occlusions where a part of facial surface hinders acquisition of another region. Thus presence of these occlusions causes missing of information of facial surface [15].

4.2 Occlusion Due to External Objects

External objects are like hand, hair, scarf, eyeglasses, goggles and other objects [15]. Partial occlusion is a challenging problem and has found its implications in many areas of image processing as shown in Figure 1. The Real life examples of occlusion in face are like

1. Iris Recognition: The Eyelashes occlude the iris.
2. Identification via Ear: The part of face occluded by Earrings.
3. Medical (Biomedical): Arteries may be occluded due to high cholesterol level.
4. Hair, hands, Goggles.

Emerging and developed technologies also lead to short comings like misuse of the developments for hacking and forgery. Intruders misbehave which subsequently in order to deceive the security system, the affects the performance of recognition system. In accordance with face recognition the spoofing and deception can degrade the quality of system leading to rise in failure rates of the realistic systems [8]. People may change their looks to trick the security system by covering the face with mask or some part of face with scarf or hands.

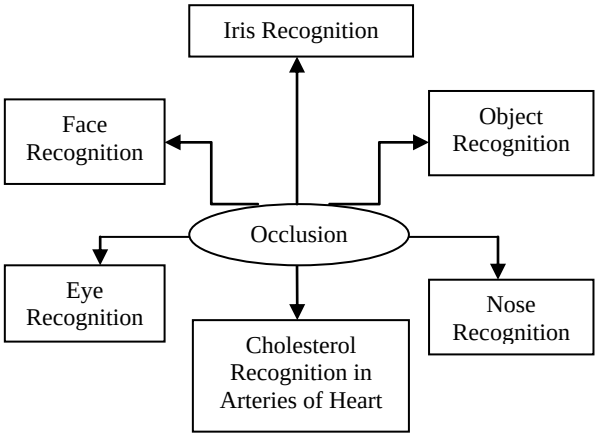

Fig 1: Challenging problems with occlusion variations.

5. DATABASES THAT ADDRESS OCCLUSION

To work on real time problems in Face Recognition the vast testing inputs should be available. The various face databases include various complexities with realistic issues and challenges. Occluded databases that address 3D faces are provided by UMB-DB Database and Bosphorus Database as shown in Table 1.

UMB-DB Database includes largest occluded faces as compared with 3D Databases. UMB-DB face database has been assembled to test algorithms and systems for analysis of 3D face in uncontrolled and challenging environment, particularly information of face affected by occlusion. Occlusion is present in face recognition due to external and internal objects. The UMB-Db consists of 1473 2D color images and 3D depth images of 143 subjects. The subjects include 98 males and 45 females. A vast majority of them are of age ranging from 19 to 50. Also, a pair of twins and a child of 4 years old age have been additionally included. Mostly, all the subjects (persons) included are from Caucasian race. For these subjects, the database has captured at least 9 acquisitions which include:

1. Three with a neutral expression.
2. Three subjects with non-neutral facial expressions mainly, Smiling, Angry, Bored.
3. Three subjects their face occluded by different objects like scarf, hat, and hands having random positions.

Majority of the subjects of UMB-DB database have been captured with eyeglasses, holding phones, partially occluded by hair and other types of objects. The aggregate number of occluded faces is 578. At the time of acquisitions, persons were allowed to cover distinctive parts of their faces. These features of the information of face are very useful for robustness of face analysis based approaches. The UMB-DB database provides an average of 42% of occlusion on a facial region, with a maximum of about 84%. This Dataset is created with the help of Minolta vivid-900 laser scanner. For every acquisition, 7 feature points are annoted manually like the eye corners, Nose tip and mouth corner [12].

6. STATE-OF-THE-ART ALGORITHMS

This section presents a brief overview of the work done till date now with the approaches related to occlusion removal.Alyuz et al. [13] have proposed work on face recognition with masked projection in the presence of occlusions. They have mainly considered two main problems;

1. Handling of Occlusion for surface registration

2. Handling of missing data for classification based on subspace analysis techniques.

To solve the alignment problem, they have introduced an adaptively selected model based registration technique. This technique includes the preprocessing of 3D face recognition technique, which includes registration and occlusion removal steps. Adaptive registration pipeline is composed of different stages mainly nose detection and adaptive model selection and Bosphorus Database. In adaptive modeling, only the useful important non-occluded patches are utilizes along with ICP based approach. After registration process occlusions are detected and removed. They have also proposed the masking strategy which is also known as masked projection in the classification stage. This technique enables the use of subspace analysis technique in presence of incomplete data. After that, regional scheme for handling the occlusions is included in classification stage to improve the performance.

Alyuz et al. [15] have focused on two occlusion detection approaches,

7. STATISTICAL FACIAL SURFACE MODELING

In this method, complex model of facial surface is computed with the help of pixel level GMM (Gaussian Mixture Model).

All pixels are checked for their fitness to the respective mixture model. Thus, pixels are passed through training phase. In order to obtain pre-aligned faces, they have employed the adaptive registration technique. After alignment, the facial surfaces are regularly re-sampled to give resulting depth images. This provides best performance compared to baseline approach. These approaches are tested for occlusion detection on UMB-Db database and Bosphorus Database [15].

Table 1. Database with inclusion of occlusion information

Sr. No	Database	Subject	Total Acquisition/Person	Poses	Number of Occluded Data	Reason of Occlusion
1	Bosphorus	105	4666 / (31 – 53)	13	381	Hair, Eye.
2	UMB – DB	143	1473 / (9 - 12)	1	578	Eyeglasses, Hat, Hands having random positions, goggles, hair, paper, scarf.

8. GRAPH CUT APPROACH (GC)

This approach considers the challenge of face detection with occlusion as binary segmentation problem. This approach includes the data residing in the neighborhood relations in the form of pixel wise cues. The regional cues of depth values are included with neighborhood cues and acquired surface is modeled in form of graph. The surface pixels are segregated as either face or occlusion with graph cut technique. GC results in outstanding results over the GMM. These researches are now working on encapsulating regional and neighborhood information detection [15].

Alyuz et al. [14] have proposed the approach to handle occlusion at the classification stage, known as masking strategy. They have focused to enable the use of subspace analysis approach with insufficient data. Additionally they have enhanced with regional scheme suitable for occlusion handling in classification stage, thus lead to recognition rate. Databases used are UMB-DB and Bosphorus Database.

A. Colombo et al. [3] have proposed the method which is tolerant against partially occluded faces. The detection algorithm considers salient features on the face such as eyes and the nose. Registrations of Candidate faces, which are acquired, are then done using ICP (Iterative Closest Point) based approach which focuses on avoidance of samples having occluding objects. Finally, the differences between face and non face are segregated using Gappy PCA (Principal Component Analysis) classifier. The UND Database is used for 100% face detection. It shows 90.4%accuracy for face detection, in uncontrolled scenarios. The presented algorithm is a first attempt to solve the occluding object problem in 3D face detection.

Agrawala et al. [5] have proposed a novel geometric framework for analyzing (detecting) 3D faces, with comparing, matching and averaging their shapes. They represented facial surfaces with radial curves starting from nose tips and use elastic shape analysis of these curves to develop a Riemannian frame work for analyzing shapes of full surface of face. This approach appears to be normal for measuring facial occlusion and it is powerful to the challenge like large pose variations. This approach is demonstrated to be promising from both exact and hypothetical perspectives. For evaluation, they used three databases FRGC2, GavabDB and Bosphorus. In unconstraint scenarios, to handle pose variations and missing information, they have proposed a local representation by utilizing a curved representation of a 3D face and a quality filter for selecting the curves. They have proposed an elastic shape analysis of 3D face for handling variations in facial expressions. To remove occlusion, statistical shape models are used.

Bagchi et al. [6], they have designed a robust face recognition system which is highly immune to pose and Also, It is immune to occlusions from the realistic world. Input face was taken and simultaneous registration is done using ICP (Iterative Closest Point) algorithm, with the residual distances between a probe model (Input Face) and gallery model. The performance of ICP depends highly on initial conditions .Thus the input registration is provided, so that improvement is done iteratively and after that it converges to the best possible alignment. Occlusions are automatically extracted by considering the threshold of depth map value of the 3D image. Then in accordance with PCA (Principal Component Analysis).Subsequently classification stage, extraction of features is done and the facial parameters of the face are restored. With the help of Bosphorus 3D face database, this occlusion invariant scheme provides 91.30% accuracy.

A. S. Gawali et al. [11] have represented surface of face by indexed set of radial geodesic curves on 3D meshes of face emerging from nose tip to the border of mesh and correlated the shapes of face area by comparing shapes of their analogous curves. For analysis they have used elastic shape analysis .For this experimentation, GavabDB and Bosphorus database are used.

Alyuz, et al. [16] have presented a 3D face recognition system that concentrated on automatic removal of occlusion objects and detects the facial image with the help of regional classifiers. Automatic localization of occluded regions is considered by using a generic face model approach. The restoration of missing data is done after the removal of occlusion which is computed by the application of (GPCA). This application of GPGA is an upgraded version of Gappy Principal Component Analysis, which is also known as partial Gappy PCA (pGPCA). After the elimination of noisy information the original data is segregated and the non-occluded data of faces are localized by local regional method. Local classifiers performing on these local areas are then combined to achieve occlusion invariant detection with good performance. There results show that, an experimental result obtained on originally occluded images of faces from the Bosphorus 3D face database provides large improvement in recognition rate from 78.05% to 94.20%.

9. DISCUSSION

After reviewing different methods presented by many authors, it can be concluded that most of work is done is on nose tip and masked projection strategy at classification stage. Methods adopted are ICP, PCA and Geodesic curve indexing method (GPCA). Many methods are developed for handling pose, illumination and occlusion, expression variations. In the above section partial occlusion in face recognition has been surveyed. Brief analysis of all techniques and methods are elaborated in Table 2. The table describes various methods, databases, recognition rate with respect to databases used.

Table2. Comparison of different techniques focused on handling occlusion invariant of 3D face recognition system.

Sr.No.	Author	Year	Database	Methods	Recognition Rate (%)		
					UMB-DB	Bosphorus	Other Database
1	Alyuz et al. [16]	2011	Bosphorus	Generic face model approach, GPCA (Gappy Principal Component Analysis)	-	94.20	-
2	Alyuz et al. [13]	2013	Bosphorus	ICP (Iterative closest point), Masking strategy, Adaptively selected method.	-	92.91	-
3	Colombo et [3]	2013	UND Database	ICP (Iterative closest point), GPCA (Gappy Principal Component Analysis).	-	-	90.4
4	Alyuz et al. [15]	2014	Bosphorus UMB-DB	Enhanced with regional scheme with classification stage.	69.15	87.4	-
5	Alyuz et al. [14]	2014	Bosphorus UMB-DB	Pixel level GMM (Gaussian Mixture Model)	66.27	87.66	-
6	Colombo [5]	2014	FRGC2, GavabDB, Bosphorus	Radial curves starting with nose tip , Curved representation, Elastic ICP and PCA.	-	91.3	-
7	Gawali et al. [11]	2014	GavabDB, Bosphorus	Geodesic curve indexing method	-	83.7	-

10. CONCLUSION

This survey focuses on various methods which are concentrated on occlusion invariant 3D face recognition system. Many researchers have worked on 2D – 3D face recognition system but very less work has been reported on various uncontrolled challenges coming across recognizing faces like occlusion, pose, illumination, expression variation. Occlusion in 3D face recognition is very challenging obstacle evident while processing. Many researchers are working to have robust occlusion invariant 3D face recognition. In this paper, comprehensive surveys of 3-D face recognition with challenges of occlusions are presented. Occlusions are due to internal factors or external factors of face data. Occlusion databases like Bosporus and UMB-DB databases are compared. Among Both Databases, UMB-DB database provides maximum number of occluded datasets with variations in expression with large number of information. The various occlusion removal approaches for robust occlusion invariant 3D face recognition are also presented. All have worked in the classification and regional stages. While dealing with occluded 3D face, misalignment gives path to new research. All these methods discussed are suitable and effective for retaining the spatial domain information of probe or input face given to 3D face recognition. Further, improvement can be done to have robust 3D face recognition system which will be highly invariant to occlusions. Most of the work is completed on 2D recognition approaches and results for 3D face recognition can be improved further.

Summarizing the overall methods, every presented method has its own advantages and disadvantages in their respective area. Some techniques are complex and not cost effective so new approach can be found for occlusion invariant 3D face recognition system.

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