

# AN APPROACH FOR 3-D FACE RECOGNITION BY DETECTING OCCLUSIONS WITH MASKED PROJECTION

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## Abstract

The three-dimensional (3-D) face has become an emerging biometric modality, preferred especially in high security applications. The occlusions covering facial surface is a great challenge, which should be handled to enable applicability to fully automatic security systems. Basic assumption is that facial expressions can be modeled as isometrics of the facial surface. This allows constructing expression-invariant representations of faces using the canonical forms approach. A system which is fully automatic 3-D face recognition system and robust to occlusions is proposed here. The problems occlusion handling for surface registration and missing data handling for classification based on subspace analysis techniques have been taken primarily. For the alignment problem, an adaptively-selected-model-based registration scheme is employed, where a face model is selected for an occluded face such that only the valid non occluded patches are utilized. After registering to the model, occlusions are detected and removed. In the classification stage, a masking strategy, which is called masked projection, is proposed to enable the use of subspace analysis techniques with incomplete data. Furthermore, a regional scheme suitable for occlusion handling is incorporated in classification to improve the overall results. Experimental results using registration based on the adaptively selected model together with the masked subspace analysis classification offer an occlusion robust face recognition system.

## Index terms

Biometrics, Canonical forms, Curvature descriptors, Face Recognition, Isometrics, Masking Strategy

## 1. INTRODUCTION

In biometric systems, human beings are identified by distinctive features, such as physiological and

behavioral characteristics. As a biometric modality, the human face is widely preferred because of several advantages: Due to its contactless acquisition, it is well accepted among users. Its applicability to non cooperative scenarios makes it suitable for a range of applications such as surveillance systems. However, in non cooperative and uncontrolled scenarios, recognizing individuals from their faces is a challenging task. The factors that degrade the performance of a face recognizer include presence of illumination differences, in-depth pose variations, facial expression variations, and the presence of occlusions.

In the three dimensional (3-D) domain, challenges caused by illumination, pose, and expression variations can be better handled. However, extreme occlusion variations still complicate the task of identification. In this system, 3-D face recognition system that is robust under realistic occlusions is proposed. In our approach, occlusion handling is considered in the registration and the classification stages. For alignment of occluded surfaces, we employ a registration scheme which adaptively selects an alignment model, where for each probe face; a model including the probable non occluded facial parts is employed. By adaptively selecting a model, it is possible to discard the effect of occluding surfaces on registration. After alignment, occluded regions are discarded. Occlusion-removed facial surfaces contain missing data points. In this paper, we propose a masked projection technique that can cope with missing data. Furthermore, we utilize a regional approach to improve the classification performance, where different regions serve as separate classifiers.

## 2. RELATED WORK

Developments in 3-D sensor technologies have increased interest in 3-D face recognition. It is shown that by using 3-D face, it is possible to obtain competitive results when compared with other modalities such as iris and high-resolution 2-D facial images. Thorough surveys of previously proposed 3-D face recognition have done and we focus on the recent face recognition approaches dealing with realistic occlusion variations, both in 2-D and 3-D.

### A) 2-D Techniques

Although variations caused by pose and expression have attracted increased research effort, the problem of handling occlusions has not been discussed frequently.

In the 2-D face recognition studies, there have been a few approaches considering occlusion variations. In most of these studies, the occlusion handling for recognition and the registration problem is not considered. Experimental results [2], [4] are usually reported on databases where the faces are assumed to be accurately registered prior to recognition. Some studies [9], [10] are based on subspace analysis methods, where the aim is either occlusion-robust projection or missing data compensation consider occlusions caused only by eyeglasses and propose a method to compensate for the missing data. Initially, the glass region is extracted using color and edge information. The offline-generated faces from a set of no occluded images are then used together with the extracted glasses region for missing data compensation.

### B) Principal Component Analysis

An approach for combining discriminative and reconstructive methods [9] is given for better handling of images with outlier pixels. The general discriminative model is rewritten by incorporating the feature vectors corresponding to the reconstructive model. In addition, the truncated projection matrix is extended to retain the complete discrimination power. Other holistic approaches can be considered as model-based methods proposed an iterative approach for the parameter estimation of 3-D morphable model fitting procedure. Concurrently, a visibility map defining the occlusions is modeled by Markov Random Fields (MRF), which accounts for spatial coherence of occlusions. The visibility map is used to exclude occluded regions from further computations where structural information

residing in a facial surface as an Attributed Relational Graph.

### C) 3-D Techniques

A part-based method [1], [3] using 3-D facial data, considered only a few facial occlusion detection, removal, restoration, and missing data handling. In Colombo it was proposed to detect occlusions by analyzing the difference between an original face and its approximation by the Eigen face approach. The regions detected as occlusions are removed and the locations of the missing parts are employed in the restoration process. PCA Identification was performed by the Fisher faces approach [6] they have refined the occlusion detection method by including the difference of the input image from the mean face. In the experiments, it was reported that restoration does not offer improvement for faces occluded by more than 30%. PCA is utilized to discriminate between face and no face images. In that they have integrated their previous occlusion detection approach [9] into the face recognition pipeline and experimental results both on synthetically occluded faces and on the Bosphorus database includes realistic occlusion variations.

## 3. PROPOSED SYSTEM AND CONTRIBUTION

This system introduces a new technique called masked projection for subspace analysis with incomplete data. The system consists of the preprocessing module which includes the registration and occlusion removal steps. For alignment, the adaptive registration module is utilized, which registers the occluded surfaces. By adaptively selecting the model, it is possible to discard the effect of occluding surfaces on registration. The occlusions are detected on the registered surfaces by thresholding point distances to an average face model the training module works offline to learn the projection matrices from the training set of no occluded faces for different regions. The classification module uses the occlusion mask of the probe image to compute the masked projection, and projects the probe image to the adaptive subspace. The identification is handled in the subspace by 1-nearest neighbor (1-NN) classifier. The proposed system is evaluated on two main 3-D face databases that contain realistic occlusions: (1) The Bosphorus, and (2) the UMB-DB databases.

### 3.1 REGISTRATION AND OCCLUSION REMOVAL

The occlusion resistant registration approach initially proposed is employed. For the integrity of the

system, the details of the registration and occlusion detection processes are given

#### A) AUTOMATIC NOSE DETECTION

Iterative Closest Point (ICP) algorithm [8] is one of the most widely preferred methods for rigid registration of 3-D surfaces. However, iterative approaches like ICP are highly dependent on the initial conditions. In most of the current 3-D face recognition systems, the surface initialization is handled by accurately locating a set of facial landmark points. However, in the presence of occlusions, localization of the nose area rather than individual points appears to be a more effective detection. The nose detection algorithm is based on the surface curvature information, which is advantageous due to its rotation and translation invariance.

#### B) ADAPTIVE MODEL-BASED REGISTRATION

To decrease the overall computational cost of ICP, an average face model is employed as a common registration reference. However, when occlusions are present, the extraneous objects alter the surface. The altered information causes the correspondence matching and the registration steps to fail. Here, we employ a model-based registration approach which can cope with occlusion variations: For an occluded face, the non occluded patches are determined and a model with the corresponding average patches is selected. Therefore, only the non occluded facial points are considered in correspondence matching.

#### C) OCCLUSION DETECTION

After the facial surfaces have been registered, it is important to locate facial areas occluded by exterior objects. The most straightforward approach for occlusion detection is to analyze the difference of the input image from a mean face. If there is an exterior object covering a part of the facial surface, the difference for this specific area will be more evident. Therefore, occluded areas can be detected by thresholding the difference map obtained by computing the absolute difference between the average face and the input face. Prior to occlusion detection, the facial surfaces are resampled from a regular grid to construct the depth coordinates, namely the depth values, to be considered for a sufficient comparison. If the depth images for the input face and the average face model are denoted by  $x$  and  $x_{avg}$  respectively, the occlusion mask is obtained by thresholding the absolute difference:

$$m(j) = \begin{cases} 1 & \text{if } |x(j) - x_{avg}(j)| > t, \\ 0 & \text{Otherwise} \end{cases}$$

where  $m(j)$  denotes the predefined threshold value. On this initial mask, post processing operations, namely morphological dilation and connected component analysis are applied to obtain the final occlusion mask.

### 3.2 MASKED PROJECTION TO ADAPTIVE SUBSPACES

#### A) GLOBAL CLASSIFICATION

A useful property of the model-based registration scheme is that the extracted facial features are ordered vectors of the same size, enabling the use of subspace analysis techniques. However, subspace approaches assume complete facial feature vectors. Therefore standard subspace approaches cannot be applied directly on occlusion-free faces. The first idea to deal with incomplete data would be to remove the pixels that are not present in the probe image from all of the training and gallery images. Using the masked training images, the subspace representing the partial surfaces can be learned by the Fisher faces approach [4]. However, this approach is not feasible, since each probe face will have different pixels missing and a separate training phase is required. In this work, we propose a projection masking approach to obtain the adaptive subspace: The general projection matrix is learned using a set of non occluded complete training images. Then, the adaptive projection matrix is obtained by masking. The masked probe and gallery images are projected onto the subspace, and classification is performed. The algebraic details of the approach are given below.

Let  $X$  be the registered facial surface vector, and  $W$  represents a projection matrix. The surface vector can be defined

$$x = \mu + Wy$$

Where  $\mu$  is the mean of the training images, and is the coefficient vector residing in the subspace defined by  $W$ . To simplify equations, we assume that  $\mu$  is zero. The coefficients are computed as,

$$y = \bar{W}x$$

where  $\bar{W}$  is the transpose of  $W$ . Now, suppose there is an incomplete version of, namely whose missing components are encoded in the occlusion mask. Let's assume that we have the coefficient vector, where the input image can be approximated as

$$\bar{x} = W \bar{y}$$

where  $x$  is the approximated complete version of the input image.



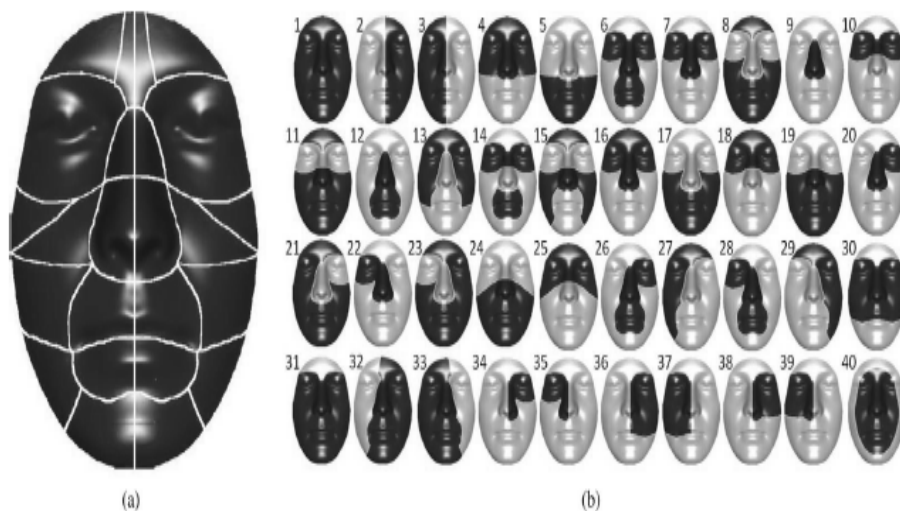
### 3.3 REGIONAL CLASSIFICATION USING MASKED PROJECTION

For further improvement in the classification phase, it is proposed to consider the 3-D surface as a combination of several regions. If the facial area is partially occluded by external objects as in Fig 1.b, the incorrect information regarding the covered regions will cause the global classification approaches to fail. Therefore, in the presence of occlusions, it is beneficial to incorporate separate regional classifiers. In regional techniques, each region acts as an independent classifier, and the regional recognition results are fused to obtain an improved overall performance. For the construction of the regions, we have divided the facial surface into several non overlapping patches. Then, combinations of these patches are merged to generate facial regions. The proposed regional division scheme consists of 40 regions as illustrated the 24 symmetrical patches defined on the average face model are given. The facial surface is partitioned considering both the semantic structure (eyes, mouth, forehead, cheeks) and the facial symmetry. When the patch sizes and locations are set, the extent of the local regions to be constructed is taken into account. For the determination of patch combinations, possible real life occlusion scenarios are considered. The regions created using different subsets

of patches are visualized (except for the last region, which is obtained by eroding the global face model). To incorporate regional classifiers with the proposed subspace method, a separate regional subspace should be learned.

Therefore, for each alignment model and for each region given in Fig 1.b, a separate projection matrix  $W$  is trained. Each projection matrix defines a separate subspace for the corresponding region, where the training images are registered with the corresponding alignment model. When a probe face is examined, all of the regional subspaces of the corresponding model are employed: Regional features are computed by regional masked projections, where the occlusion and regional masks are merged to obtain the final masks employed in the projection stage. Then, separate regional subspace features are compared against corresponding feature sets of gallery images, and the regional classification results are fused. Although training of separate subspaces as a time consuming process, it is handled in an offline manner and does not affect the duration of the classification phase.

**Fig.1 Regional division scheme: (a) patches, (b) regions (in red). The regions in (b) are constructed as combinations of patches of (a) (except for region 40, which is obtained by eroding region 1).**



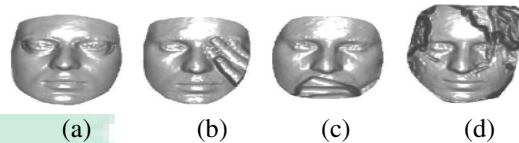
### 3.4 EXPERIMENTAL RESULTS

Three databases are employed in this work: FRGC, Bosphorus, and UMB-DB. The FRGC neutral subset, containing a total of 2365 images of 466 subjects serves as a separate training set for: (i) the construction of the average face & patch models, (ii) the training phase of the Fisher faces method, and (iii) the determination of threshold values. The Bosphorus and UMB-DB databases, containing occlusion variations, are utilized to evaluate the system performance. The Bosphorus database includes a total of 4666 scans collected from 105 subjects, including expression, pose, and occlusion variations. The database contains a total of 299 neutral scans. The first neutral scan of each subject is used to construct the gallery set (105 scans). The images with occlusion variations, consisting of 381 images, form the probe set.

In the four types of occlusions present in the Bosphorus database are which are shown in Fig 2: (a) occlusion of the eye area by eyeglasses, (b) occlusion of the eye area by a hand, (c) occlusion of the mouth area by a hand, (d) occlusion caused by hair. The expression and pose variations of the Bosphorus database are considered in the experiments handled in Section IV-G to evaluate the performance of the system under different acquisition scenarios. The UMB-DB database is acquired from a total of 142 subjects, and there are a total of 1473 scans. In the experiments, the experimental protocol of is considered: The gallery set contains first neutral scan of each subject, and the probe set consists of the occlusion subset. The gallery and probe sets contain 142 neutral and 590 occluded scans, respectively. The occlusions in this database are more challenging and they can be caused by hair, eyeglasses,

hands, hats, scarves, and other objects. Furthermore, the location and amount of occlusion vary gently.

**Fig. 2 Samples for Occlusions**



### 4. CONCLUSION

3-D face recognition has become an emerging biometric technique. However, especially in non cooperative scenarios, occlusion variations complicate the task of identifying subjects from their face images. In this system, we present a fully automatic 3-D face recognizer, which is robust to facial occlusions. For the alignment of occluded surfaces, a model based registration scheme is utilized, where it is selected adaptively to the facial occlusion. The alignment model is formed by automatically checking patches for validity and including only no occluded facial patches. By registering the occluded surface to the adaptively selected model, a one-to one correspondence is obtained between the model and the no occluded facial points.

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