Regional Registration and Curvature Descriptors for Expression Resistant 3D Face Recognition

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Motivation

• In 3D face recognition, registration is crucial to the system performance.

•Under severe expression variations, classical ICP-based global registration suffers from facial surface deformations.

•Our aim in this work, is to propose a 3D face recognition system, invariant to facial expression variations.

Contributions

• We propose an automatic landmark localization algorithm for coarse registration.

•For facial registration, region-based ICP registration is proposed.

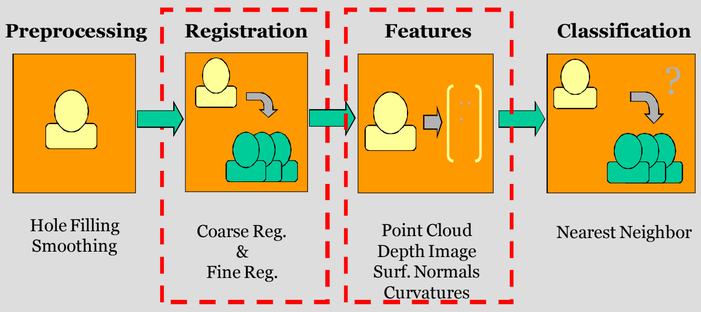
•Classification of faces is performed by fusion of local matchers.

•For improved performance, curvature-based 3D surface descriptors are used for facial representation.

Overall Structure of a 3D Face Recognition System

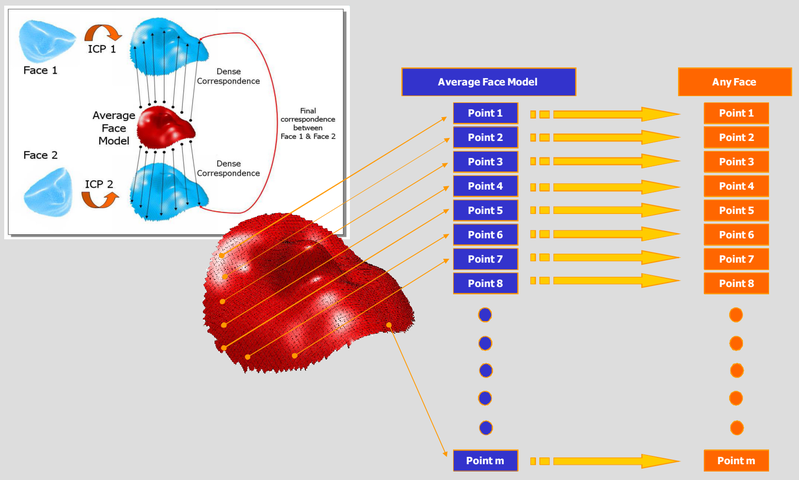
• A 3D Face Recognizer contains four components:
(1) preprocessing,
(2) registration,
(3) feature extraction,
(4) classification.

• This work focuses on steps (2) and (3).



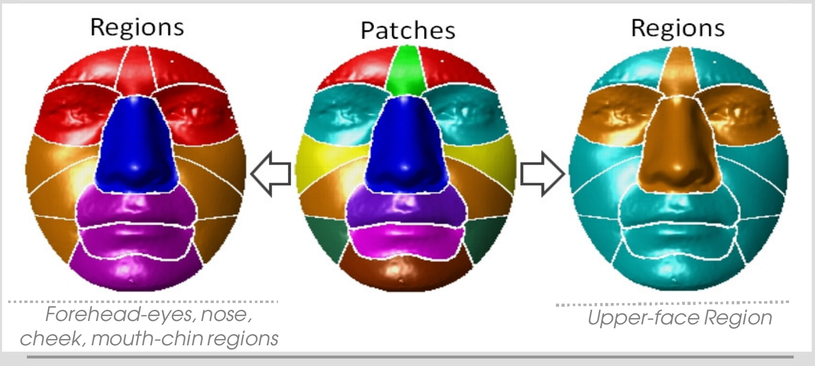
General Approach for Registration: AFM

For registration, the Average Face Model (AFM) based approach is utilized, where the AFM acts as an index file. The gallery faces are already registered to the AFM, and the test surface is registered once and for all with the AFM to obtain correspondence with the whole gallery. As a result, the test face will have the same number of points as all the gallery faces.



Regional Registration

In this work, instead of considering the whole face and registering via an AFM, a facial surface is divided into parts and the registration processes on local facial parts independently. The manually divided average model is called the Average Region Model (ARM).

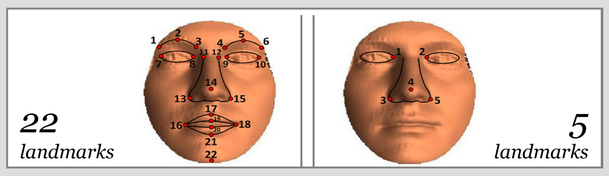


- To construct the ARM, AFM is divided into patches. Patches are local facial parts that are used to construct meaningful facial regions.
- A collection of patches forms regions, which are higher level components. In the above figure, two different sets of regions are shown.

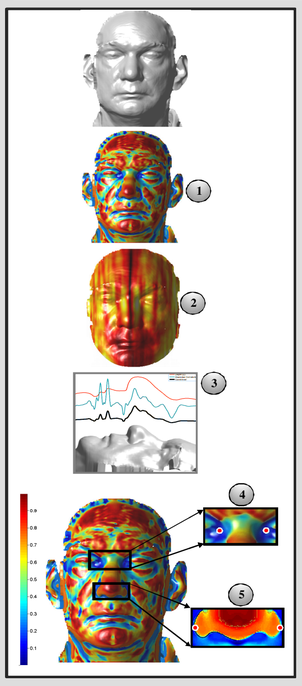
Landmark Sets

For better convergence of the ICP algorithm, coarse alignment via landmarks is necessary. For the Bosphorus 3D Face Database, there are 22 landmarks , manually labeled for each facial surface.

Besides this 22 landmark set, a set of five landmarks belonging to the region that is least affected by expression variations is also used in the experiments. This set of five landmarks, is also automatically labeled by a method proposed based on 3D shape information. Below, are the details of this method.



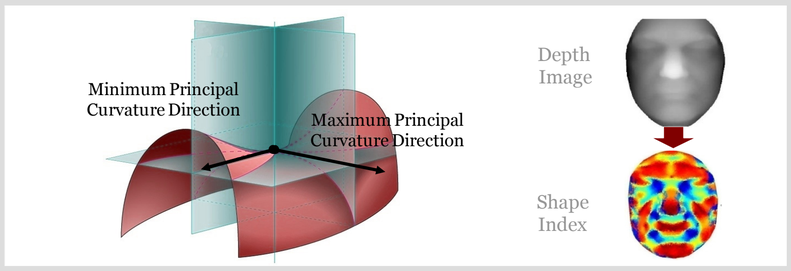
Automatic Landmark Localization



1) First, the shape index map is computed. Shape index is a curvature based descriptor, invariant to translation and rotation.
2) From shape index map, symmetry map is computed. A local window is placed which is centered around each pixel, and the average difference between the symmetric pixel inside the window is computed. The vertical line having the minimum symmetry column sum is the vertical symmetry axis.
3) On the symmetry axis, the nose tip is localized using the depth and Gaussian curvature values.
4) In a search window in the upper nose region, the points with the lower shape index values are located as the inner eye pits.
5) In the lower nose region, the nose contour is determined as the points with shape index value of 0.4. The left-most and right-most points of the nose contour are located as the left- and right- nose borders.

3D Shape Descriptors

• The principal curvatures measure the maximum and minimum bending of a regular surface at each point.
• Principal curvature directions are the directions in which the principal curvatures occur. Principal curvatures and directions express local surface shape variation independent of rotations and translations.
• In our representation, each facial surface point is represented by its two principal curvature directions. The similarity is calculated by the angle between corresponding curvature directions

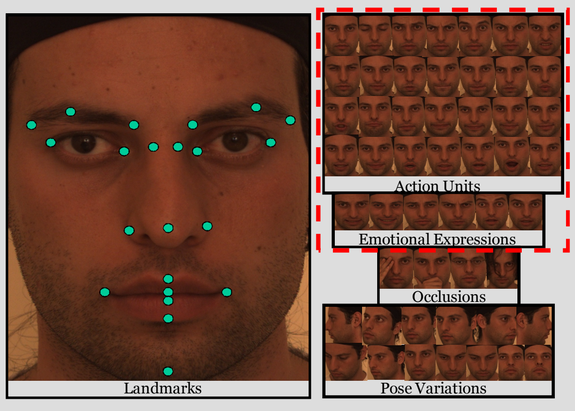


Bosphorus 3D Face Database

• We have used a subset of the Bosphorus database containing expression variations: facial action units (AU) and emotional expressions.

• Action Units: Upper, Lower, and Combined AUs.

• Emotional Expressions: happiness, surprise, fear, sadness, anger, disgust.



• The dataset used in the experiments, consists of 47 subjects, with 34 scans per each subject. There are a total of 1504 scans.

• The gallery contains one neutral scan for each subject, and the probe set contains the expression scans.

Performance of Automatic Landmarker

The first set of experiments measures the performance of the automatic landmark localization method. Table below shows the average errors (2D pixel distance) for each landmark.

On the right, landmarks automatically located on faces with various expressions are shown.

Red: Manually located
Black: Automatically located

To better analyze the performance of the automatic landmarker, an experiment to measure the accuracy of manual labeling is also constructed. A sample set of 20 scans is labeled by 10 different people.

	Left-eye Pit	Right-eye Pit	Nose Tip	Left-nose Border	Right-nose Border
Automatic	4.15	4.16	3.06	2.62	2.86
Manual Set	2.70	2.32	2.96	1.68	1.82

The distance of the automatic landmarks to the original manual landmarks and the average distance of landmarks in the manual set to original manual landmarks don't have a significant difference.

AFM based Registration

• As a baseline algorithm, the AFM based registration is examined.

• Different landmark sets are tested: (1) manual 22 landmarks, (2) manual 5 landmarks, (3) automatically located 5 landmarks.

• As feautres, point cloud (PC) and curvature descriptors (CD) are utilized.

	22 lms	5 lms	
	manual	manual	automatic
PC	75.20	77.99	77.66
CD	-	98.14	94.54

• As the results show, the use of landmarks belonging to the region that is least affected by facial expressions is beneficial.

• Furthermore, the use of curvature descriptors as features has increased the recognition performance by ~20%.

ARM based Registration and Classifier Fusion

• Recognition performances are obtained using the five landmark set in coarse alignment and regional registration for fine alignment.

• The seven independent regions are fused using the product rule (PROD).

• The recognition results for the upper-face region, which is resistant to expression, are also reported.

	Manual PC	Automatic PC	Manual CD	Automatic CD
AFM	77.99	77.66	98.14	94.54
Nose	87.63	86.70	98.94	96.07
Right-eye	70.08	66.42	93.88	88.36
Lef-eye	67.82	63.83	91.09	84.36
Forehead	76.26	65.63	87.57	77.78
Right-cheek	35.97	37.50	52.73	51.50
Left-cheek	35.44	36.37	49.20	52.16
Mouth&Chin	40.76	38.10	69.81	69.99
PROD	96.41	93.75	98.20	95.54
Upper-face	90.89	89.63	98.87	96.34

• When point cloud is used as facial features, instead of global registration, it is beneficial to divide the face into regions and then fuse the independent regional results.

• When curvature descriptors are used, fusion of regional registration results does not change the recognition performance significantly.

• The performance drop due to the utility of automatic landmark points is only ~3%.

Conclusion

• The recognition performance of regional registration is higher than the performance of global registration. The performance increase is especially significant when point cloud is used as the facial feature.

• Facial descriptors based on curvature directions has a better performance than point clouds when global registration is used.

• Automatic localization of landmark points does not cause a significant performance degradation in both point cloud and curvature representations.