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Joint Face Alignment and 3D Face Reconstruction

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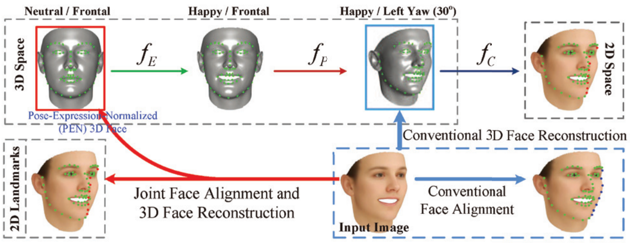
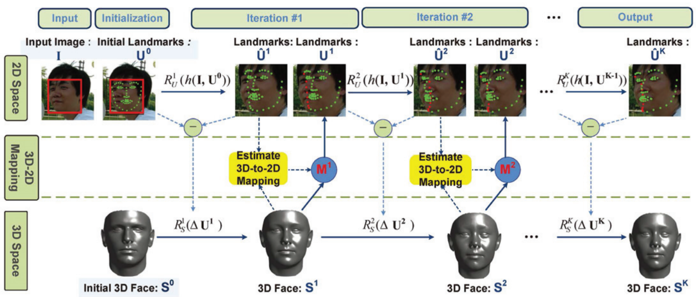
1. Introduction

- Existing studies tackle the problems of face alignment and 3D face reconstruction *separately.*
  - Face alignment methods mostly do not consider the visibility of landmarks. Consequently, their performance degrades for large pose face images.
  - 3D face reconstruction methods suffer from the invisible landmarks, and do not generate normalized 3D face for face recognition purpose.



- Objectives
  - To propose an effective cascaded coupled-regressor based method to jointly solve the two problems of face alignment and 3D face reconstruction in one unified framework.
  - To reconstruct pose-expression-normalized (PEN) 3D faces which are believed to be useful for face recognition.

2. Proposed Algorithm



Notations: 3D shape $\mathbf{S}$, 2D landmarks $\mathbf{U}$, SIFT descriptors h,

Ground truth training data $\{\mathbf{S}^*, \mathbf{U}^*\}$, shape and landmark regressors $\{\mathbf{R}_S^k, \mathbf{R}_U^k\}_{k=1}^K$.

- The coupled process in each iteration
  - *Step1*: Updating landmarks. The adjustment to the landmarks' locations is determined by the local texture features via a *landmark regressor*.
  - *Step2*: Updating 3D shape. The above-obtained landmark location adjustment is used to estimate the adjustment of the 3D shape via a *shape regressor*.
  - *Step3*: Refining landmarks. Once the 3D shape is updated, the landmarks with visibility can be further refined with a 3D-to-2D mapping matrix.
- Cascaded coupled-regressor learning
  - *Landmark regressors*: We employ linear regressors as the landmark regressors:

$$R_U^k = \arg\min_{R_U^k} \sum_{i=1}^{N} \left\| \left(U_i^* - U_i^k\right) - R_U^k\left(h(I_i, U_i^{k-1})\right) \right\|_2^2$$

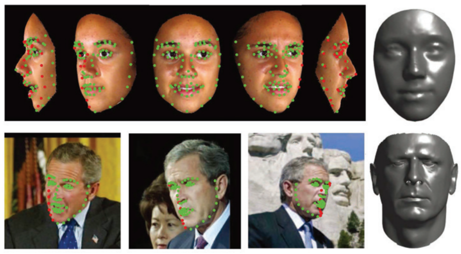
  - *Shape regressors*: Using similar linear regressors in shape space [1]:

$$R_S^k = \arg\min_{R_S^k} \sum_{i=1}^{N} \left\| \left(S_i^* - S_i^k\right) - R_S^k\left(\Delta U_i^k\right) \right\|_2^2$$

- 3D-to-2D mapping and landmark visibility
  - We assume that the expression and pose induced deformation can be approximated by a linear transform. The visibility of landmarks are computed based on the surface normal and the camera rotation matrix [2].

3. Training Data

- Two different models are trained using two training sets.



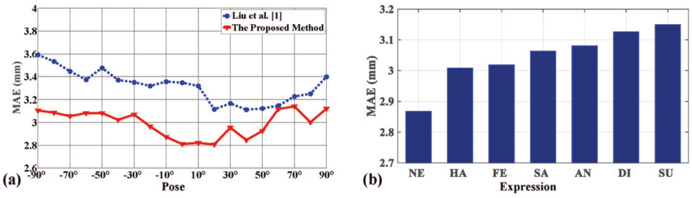
BU3DFE #100 subjects
2D images: #13,300
(19 poses, 7 expressions)
3D faces: #100
(frontal, neutral)

LFW #150 subjects
2D images: #4,149
3D faces: #150
(frontal, neutral)

- 3D shapes in BU3DFE have been established dense correspondence by [3].
- The 68 2D landmarks of LFW images are provided by the work of [4].
- The 3D neutral shapes of LFW are obtained by [1].

4. Experimental Results

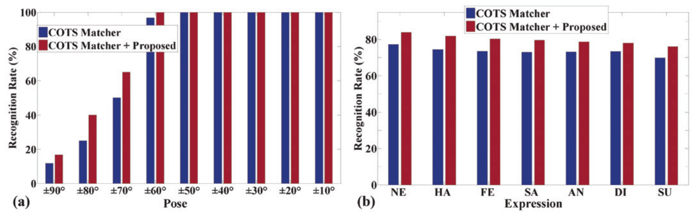
- 3D Face reconstruction accuracy on BU3DFE dataset



- Face alignment accuracy on AFW dataset

Method	CDM [5]	PIFA [2]	The proposed method
NME	7.52%	5.60%	3.15%

- Application to face recognition on BU3DFE dataset



  - The effect of the reconstructed PEN 3D face shapes on face reocgnition is evaluated by performing direct 3D-to-3D matching and fusion with conventional 2D face recognition.
- Computational efficiency
  - The Matlab implementation on a PC with i7-4710 CPU runs at ~26 FPS.

5. Summary

- By alternately applying cascaded landmark regressors and 3D shape regressors, the proposed method can effectively accomplish the two tasks of face alignment and 3D face reconstruction simultaneously in real time.
- Extensive experiments with comparison to state-of-the-art methods demonstrate the effectiveness of the proposed method in both face alignment and 3D face shape reconstruction, and in facilitating face recognition as well.

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[2] Jourabloo, A., Liu, X.: Pose-invariant 3D face alignment. In: ICCV. pp. 3694–3702 (2015)
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[5] Yu, X., Huang, J., Zhang, S., Yan, W., Metaxas, D.N.: Pose-free facial landmark fitting via optimized part mixtures and cascaded deformable shape model. In: ICCV. pp. 1944–1951. IEEE (2013)