Parametric T-spline Face Morphable Model for Detailed Fitting in Shape Subspace

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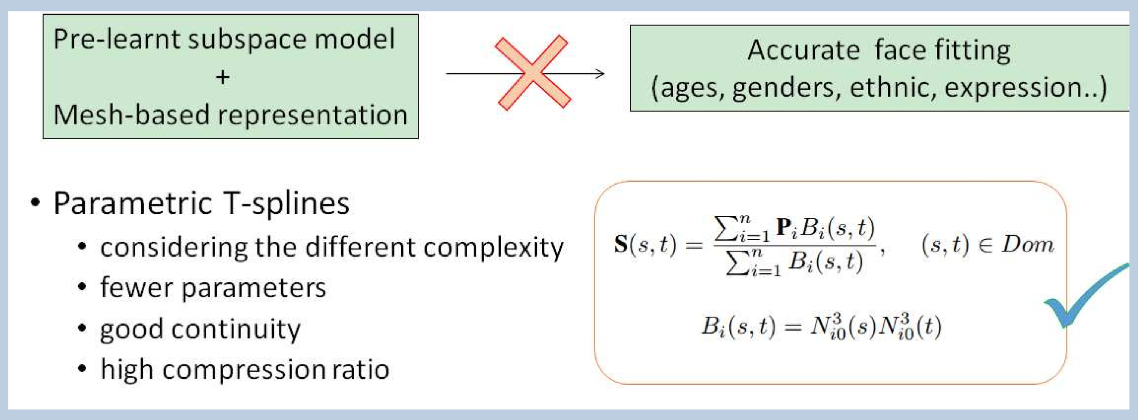
Motivation



Motivated by the linear subspace idea of 3DMMs, as well as their amendable limitations, in the paper we propose a parametric T-spline [1] morphable model (T-splineMM) based on a pre-learnt face subspace for 3D face representation.

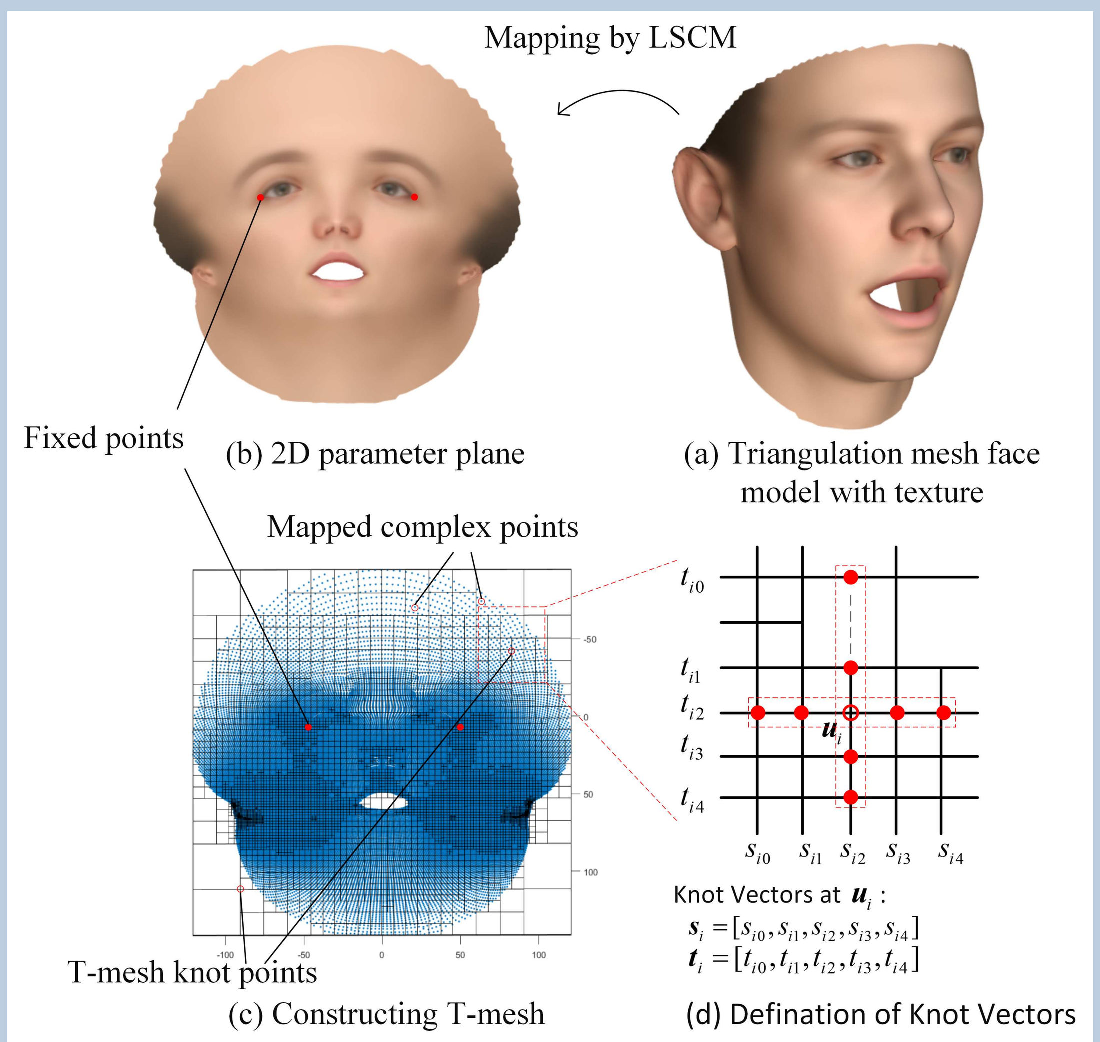
Contributions

- A parametric T-spline surface morphable model (T-splineMM) is proposed based on SUs division on T-mesh and pre-learnt face subspaces of both identity and expression. And it can implement a larger span of morphing beyond the prior statistical data.
- T-splineMM fitting algorithms are proposed to not only fits 3D data robustly to missing data, noise, ethnicity and expression, etc., but also separate the identity part from expression in detail.

T-spline face morphable model

T-spline surface

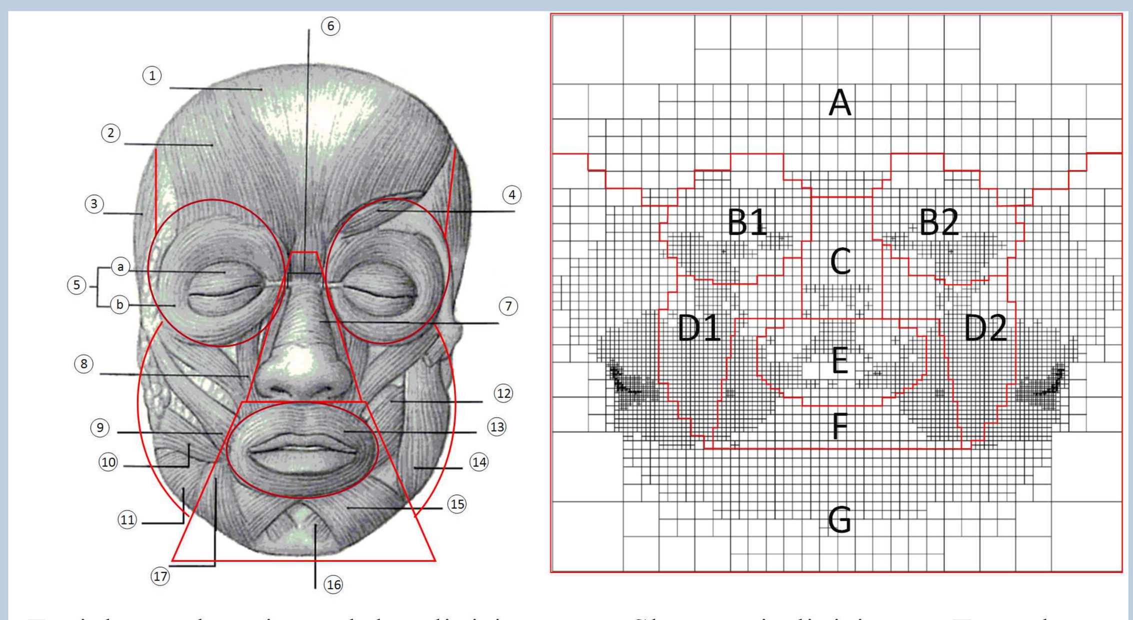
$$\mathbf{S}(\boldsymbol{u};\mathbf{P})=\boldsymbol{b}(\boldsymbol{u})^T\mathbf{P}, \quad \boldsymbol{u}\in Dom.$$



T-mesh construction for face According to Riemann mapping theorem, we use conformal map, e.g., LSCM [2], to find a parameterization, or an efficient 3D-to-2D mapping, in terms of both angular and edge distortion. Every surface point (x,y,z) is mapped to a complex points $s+i\cdot t$ of the complex plane. Secondly, space partition is carried on complex plane by using quad-tree division, which restricts the point numbers in all region is equal or lesser than a certain threshold. The edges of all rectangles form the T-mesh, and the junction point of edges are called the knots.

T-splineMM By referring to the 3DMM [3] assumption that a face shape can be linear combination of shape bases

$$\mathbf{S}(\boldsymbol{u};\boldsymbol{\alpha},\boldsymbol{\beta},\boldsymbol{\xi}_{id},\boldsymbol{\xi}_{ex})=\boldsymbol{b}(\boldsymbol{u})(\bar{\mathbf{P}}+\sum_{i=1}^{N_{id}}\sum_{j=1}^{9}\alpha_i^j\ddot{\mathbf{P}}_{id}^j(i) +\boldsymbol{\xi}_{id}+\sum_{i=1}^{N_{ex}}\sum_{j=1}^{9}\beta_i^j\ddot{\mathbf{P}}_{ex}^j(i)+\boldsymbol{\xi}_{ex}).$$



Facial muscle units and the division — Shape unit division on T-mesh

Shape Unit Division A pre-learnt facial shape subspace cannot bring a accurate representation because of face variety of human identities and expressions. To enlarge the representation span, shape units (SUs) division is done on a T-mesh according to the facial action coding system (FACS) [4].

3D fitting

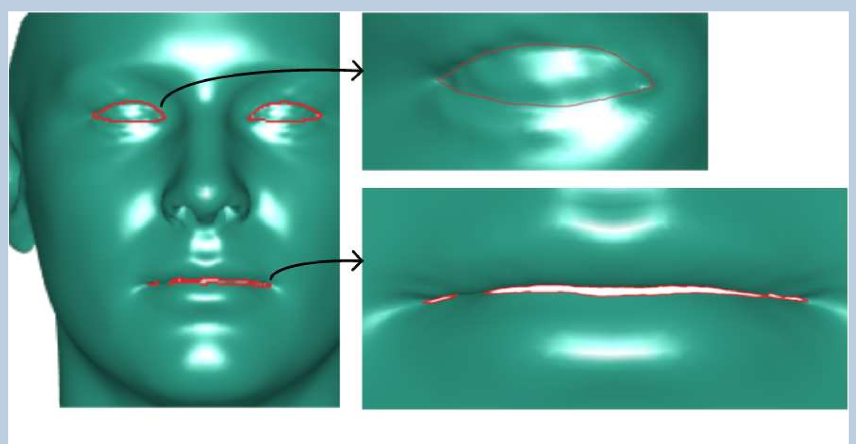
Moving control points along shape subspace of SUs

$$E_M(\boldsymbol{\alpha},\boldsymbol{\beta})=\lambda_1\cdot E_f(\boldsymbol{\alpha},\boldsymbol{\beta};\boldsymbol{\pi})+\lambda_2\cdot E_s(\boldsymbol{\alpha},\boldsymbol{\beta})$$

Final Refinement

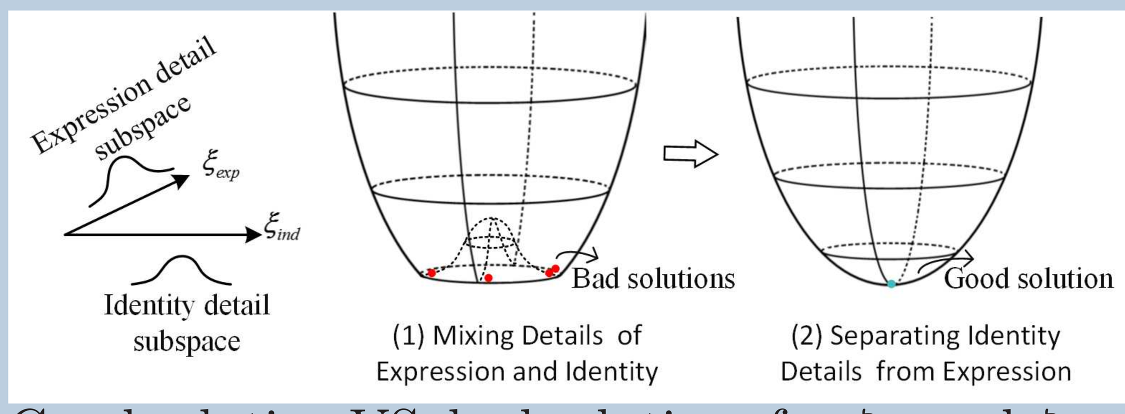
$$\begin{aligned}E_R(\boldsymbol{\xi}_{id},\boldsymbol{\xi}_{ex})=&\lambda_1\cdot E_f(\boldsymbol{\xi}_{id},\boldsymbol{\xi}_{ex};\boldsymbol{\alpha},\boldsymbol{\beta},\boldsymbol{\pi})\\&+\lambda_2\cdot E_s(\boldsymbol{\xi}_{id},\boldsymbol{\xi}_{ex};\boldsymbol{\alpha},\boldsymbol{\beta})\\&+\lambda_3\cdot E_s(\boldsymbol{\xi}_{id};\boldsymbol{\alpha})\\&+\lambda_4\cdot E_c(\boldsymbol{\xi}_{id};\boldsymbol{\alpha})\end{aligned}$$

where E_f's, E_s's and E_c are fitting term, smoothness term and contour constraint term, respectively.



Contour edges of mouth and eyes

Contours of mouth and eyes labeled by red lines.



(1) Mixing Details of Expression and Identity — (2) Separating Identity Details from Expression

Good solution VS. bad solutions for $\boldsymbol{\xi}_{id}$ and $\boldsymbol{\xi}_{exp}$ in expression detail subspace and identity detail subspace respectively: 1) red points indicates that the expression detail and the identity detail are mixed with each other; 2) green point indicates that the expression detail and the identity detail are separated from each other.

References

[1] T. W. Sederberg, J. Zheng, A. Bakenov, and A. Nasri. T-splines and t-nurccs. Acm Transactions on Graphics, 22(3):477Í484, 2002.

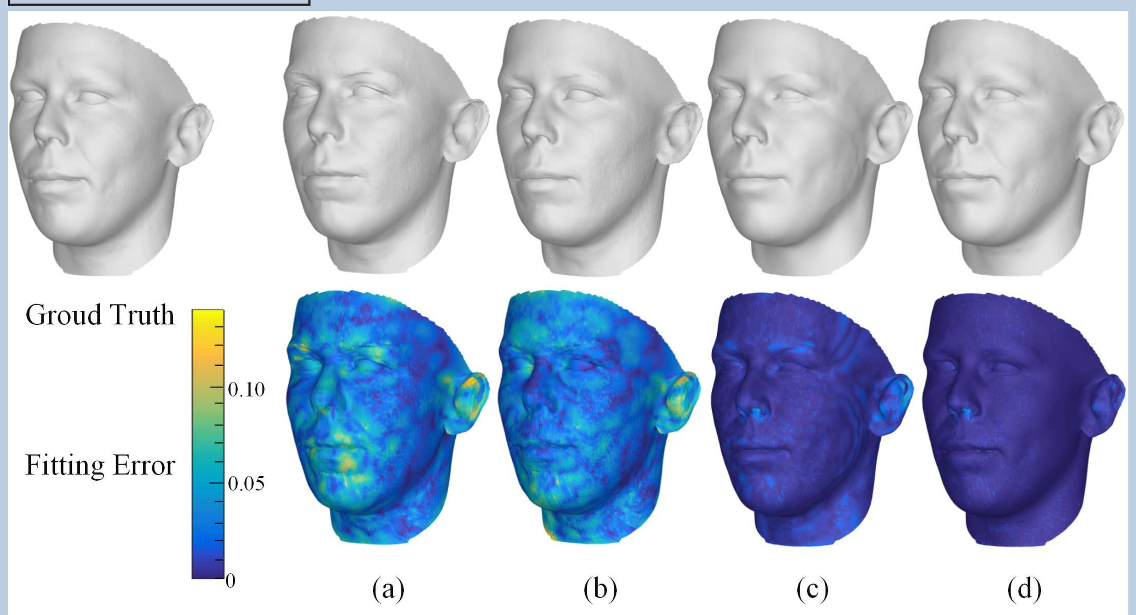
[2] B. Levy, S. Petitjean, N. Ray, and J. Maillot. Least squares conformal maps for automatic texture atlas generation. Acm Transactions on Graphics, 21(3):362Í371, 2002.

[3] V. Blanz and T. Vetter. A morphable model for the synthesis of 3D faces. In Annual Conference on Computer Graphics, pages 187Í194, 1999.

[4] P. Ekman and W. V. Friesen. Facial action coding system (facs): a technique for the measurement of facial actions. Rivista Di Psichiatria, 47(2):126Í38, 1978.

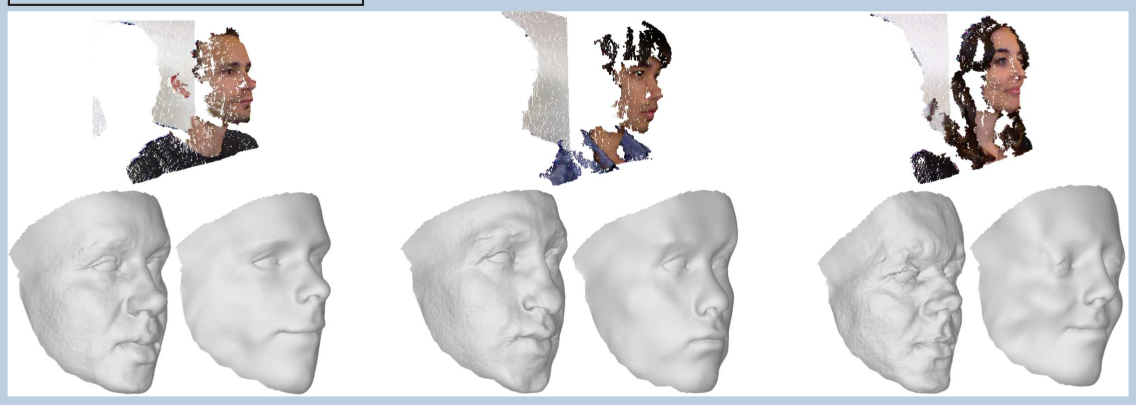
Results

Scan data



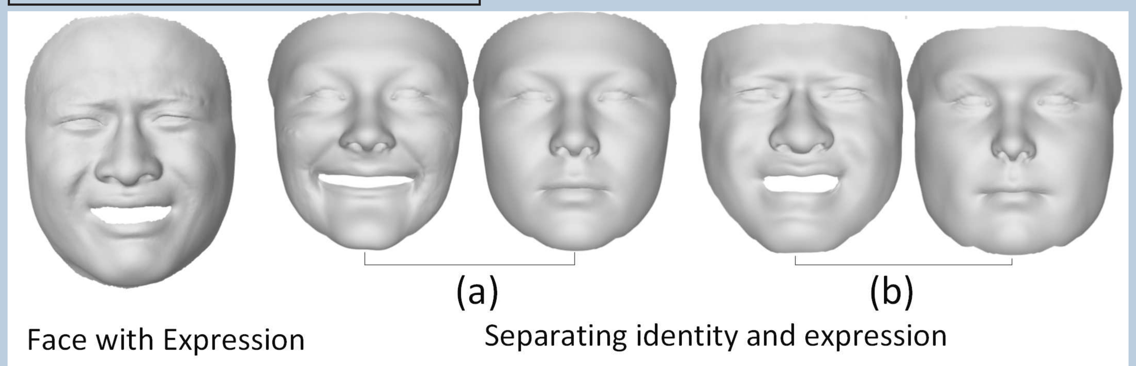
Fitting results and errors by four models: global 3DMM (a), segments based 3DMM (b), T-splineMM without refinement (c) and T-splineMM with refinement (d).

Kinect data



Fitting results on Kinect face data: the left is generated by 3DMM and the right one is by T-splineMM.

Space-time data



Separating identity from expression data by 3DMM (a) and T-splineMM (b): the left results are the expression reconstruction of fitting, and the right are the identity reconstruction.Mean fitting errors for expression and identity.

Table 1. Fitting errors of 4 methods

Method	3DMM_Glb	3DMM_Segs
Mean Error	8.68%	6.16%
Method	T-splineMM_SUs	T-splineMM_Ref
Mean Error	4.99%	1.21%

Table 2. Fitting errors for expression and identity

Method	3DMM	T-splineMM
Mean Errors (Ex)	12.64%	0.84%
Mean Errors (Id)	10.69%	8.50%

Conclusion

T-splineMM is presented for 3D face representation based on pre-learnt identity and expression subspace. Facial SUs is defined on T-mesh to enhance the representation performance of T-splines. A fitting algorithm is proposed to approach the details of both identity and expression. In fact, we solve a problem of incomplete subspace based on two key contributions: local SUs definition on T-mesh and refinement solution in fitting algorithm, both of which bring a good performance on various facial deformation.

Acknowledgements

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