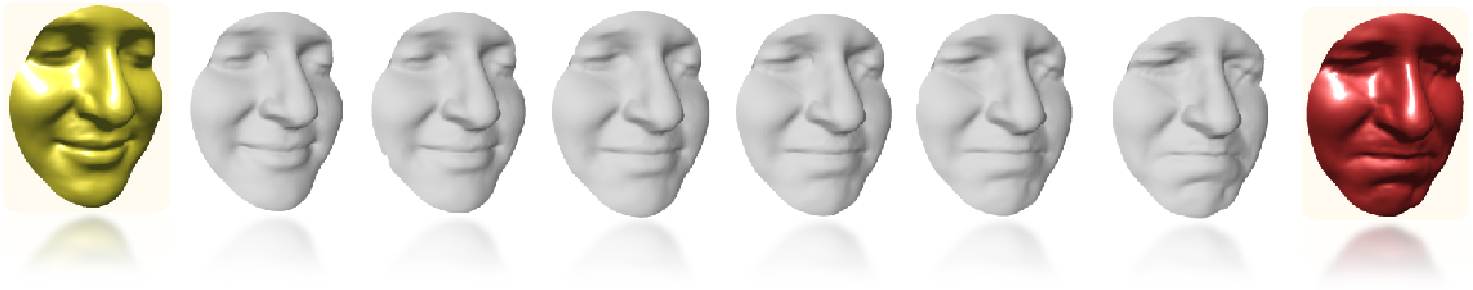
ANR

AGENCE NATIONALE DE LA RECHERCHE

3D FACE ANALYSIS AND RECOGNITION



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USTL

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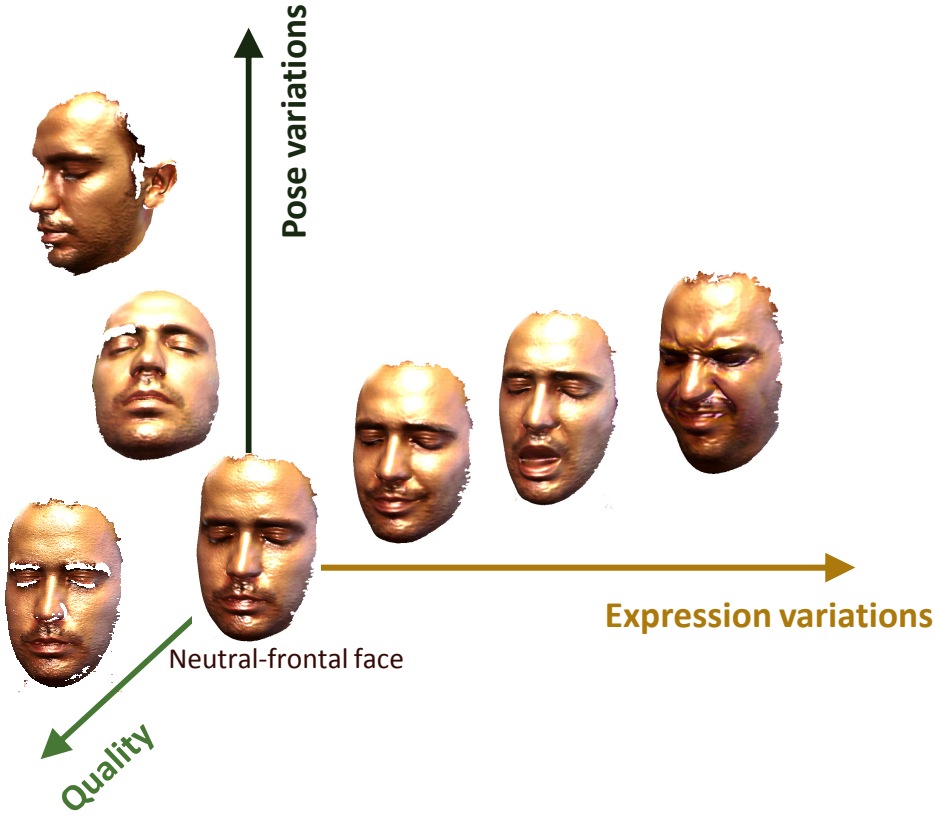
Boulbaba BEN AMOR,
Mohamed DAOUDI,

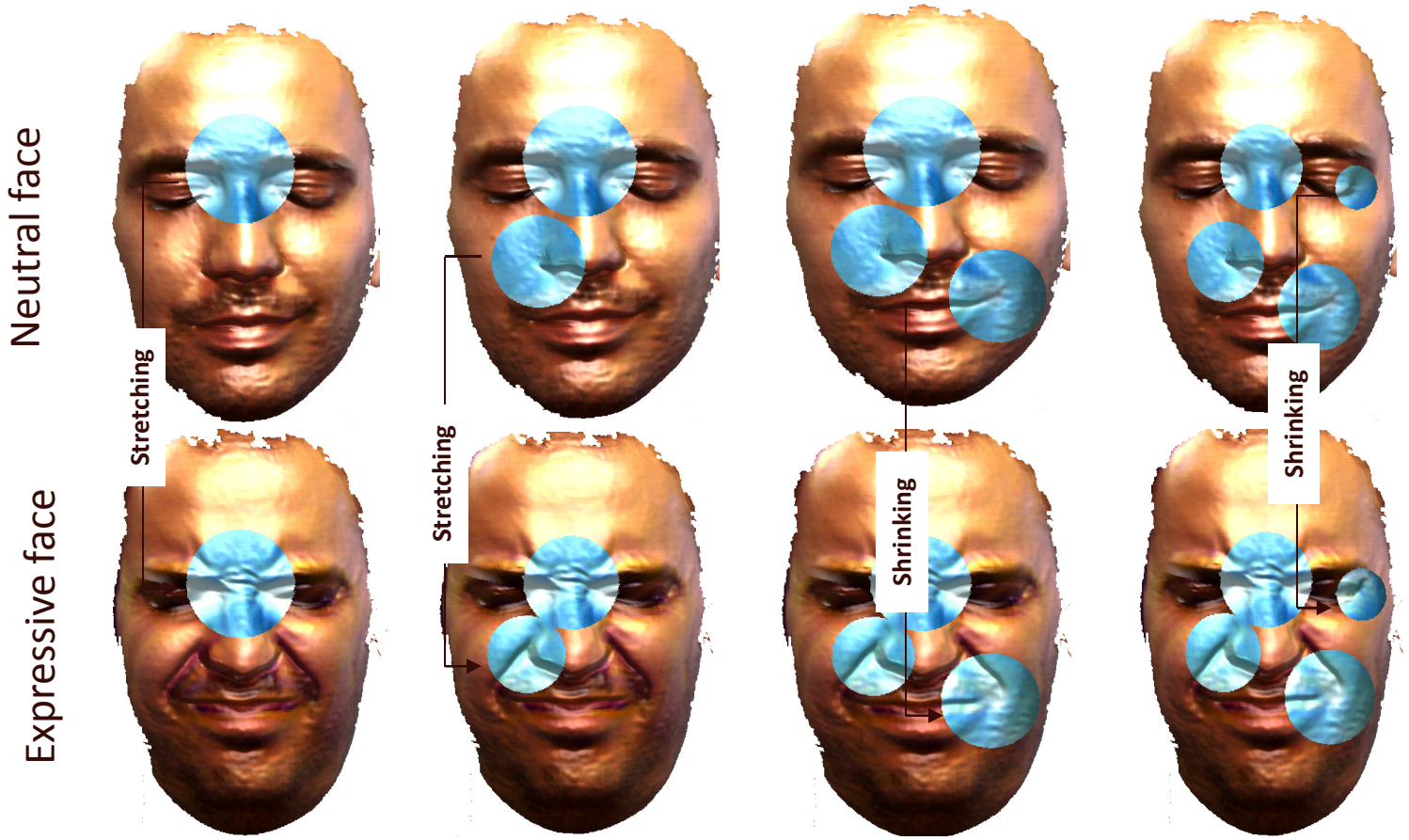
Why 3D shape of face?

- **2D technology limitations**
  - Pose and scale variations
  - Illumination variations
- **New 3D Challenges**
  - Facial deformations
  - Data quality
    - Holes/noise/resolution



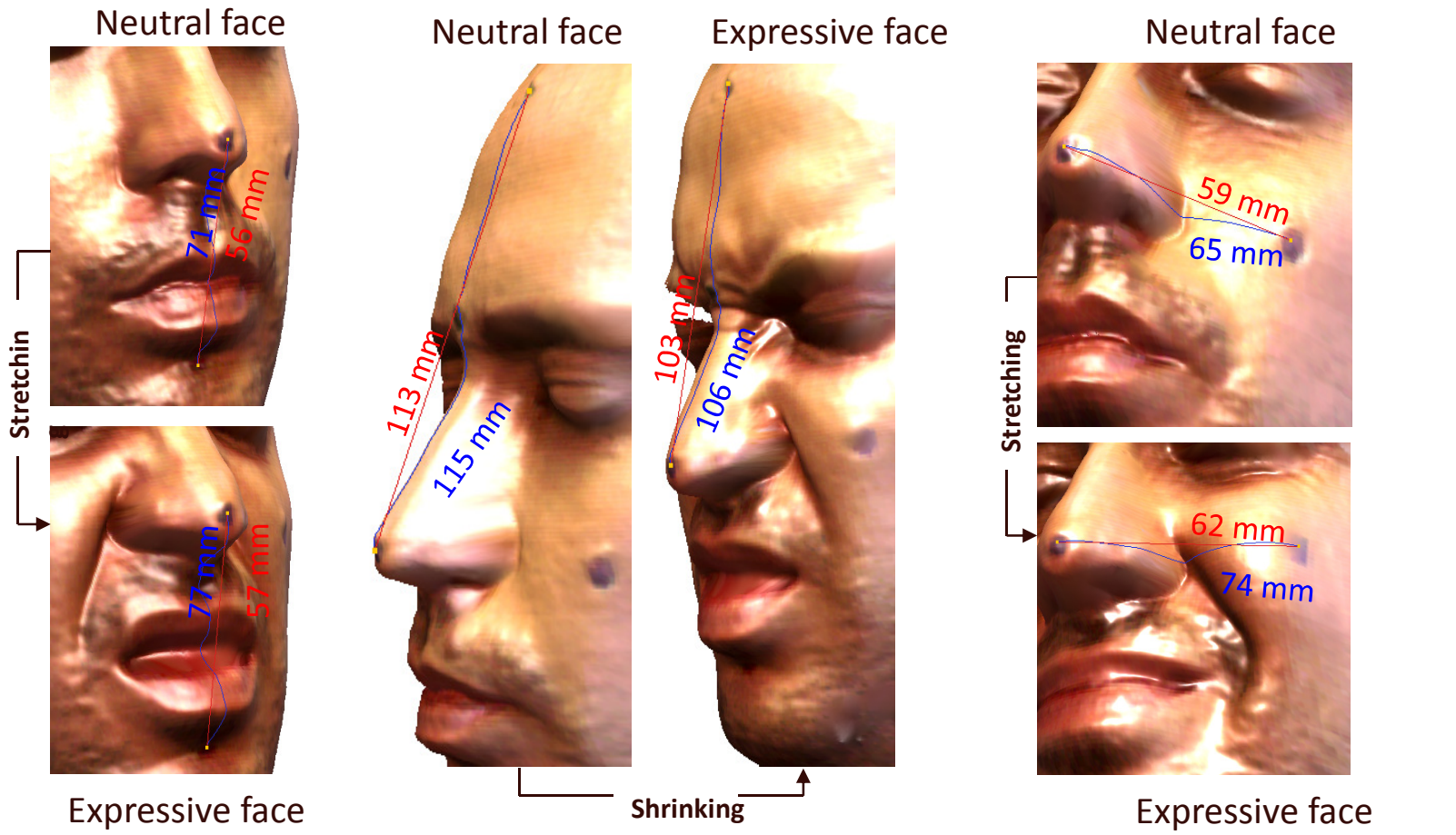
Scientific challenge

- ***Elastic deformations*** (stretching/shrinking)



Scientific challenge

- ***Elastic deformations***



Outline

Introduction and motivation

1. **3D face recognition using radial curves**
   - Method overview
   - 3D face shape analysis: elastic metric
   - Evaluation experiments
   - Hierarchical organization
2. **Partial biometric**
   - 3D nose analysis
   - Experimental results
   - Hierarchical organization

Conclusion and future work

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1 3D face recognition using radial curves

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2 Partial biometric

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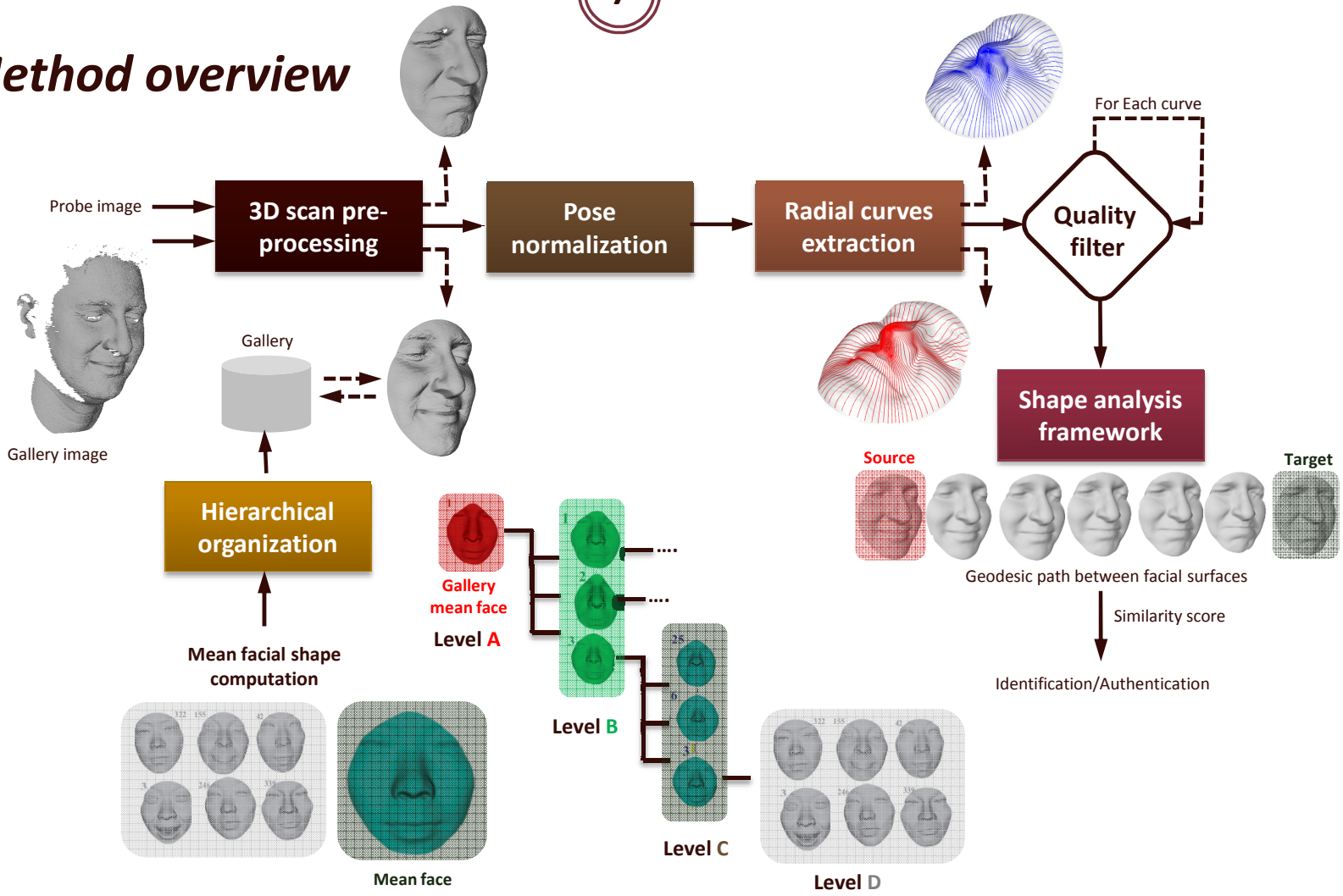
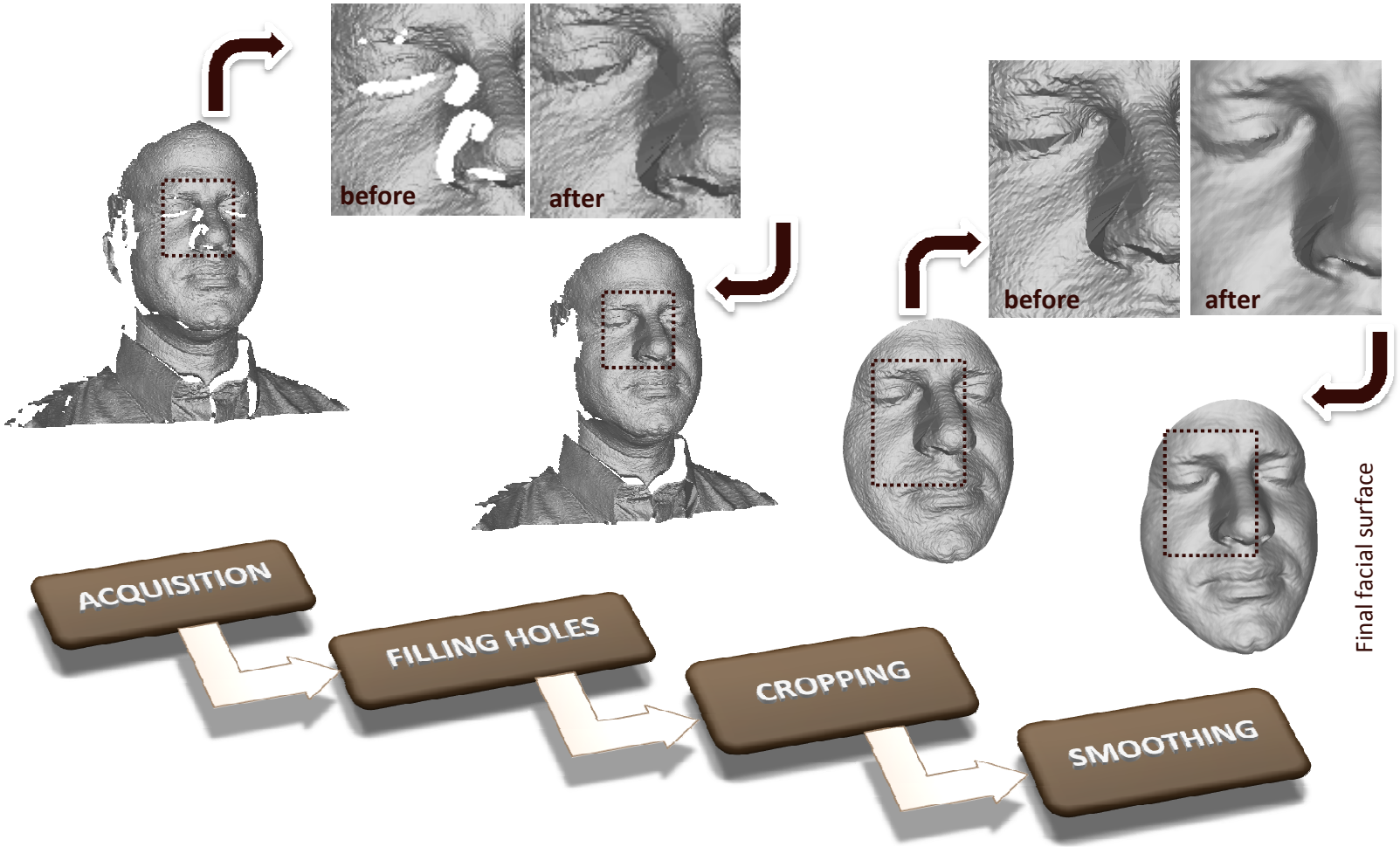
3D face recognition method

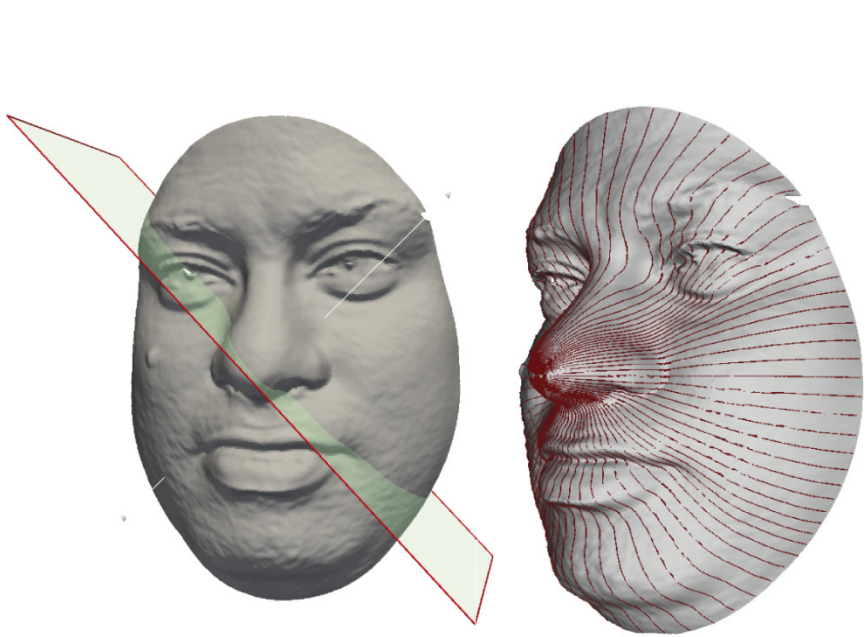
- ***Method overview***

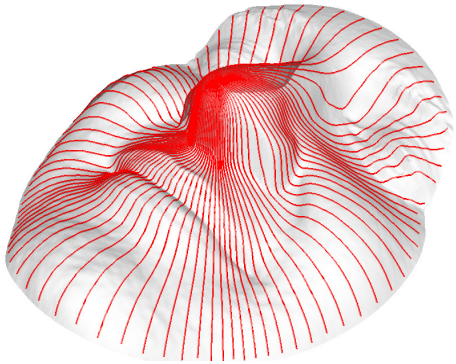


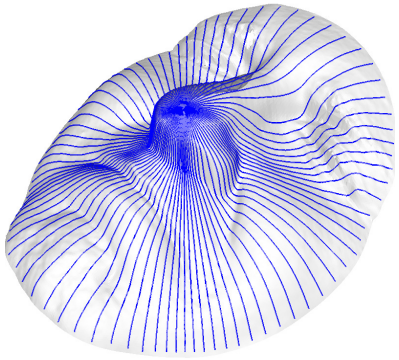
3D scan pre-processing



Radial curves extraction







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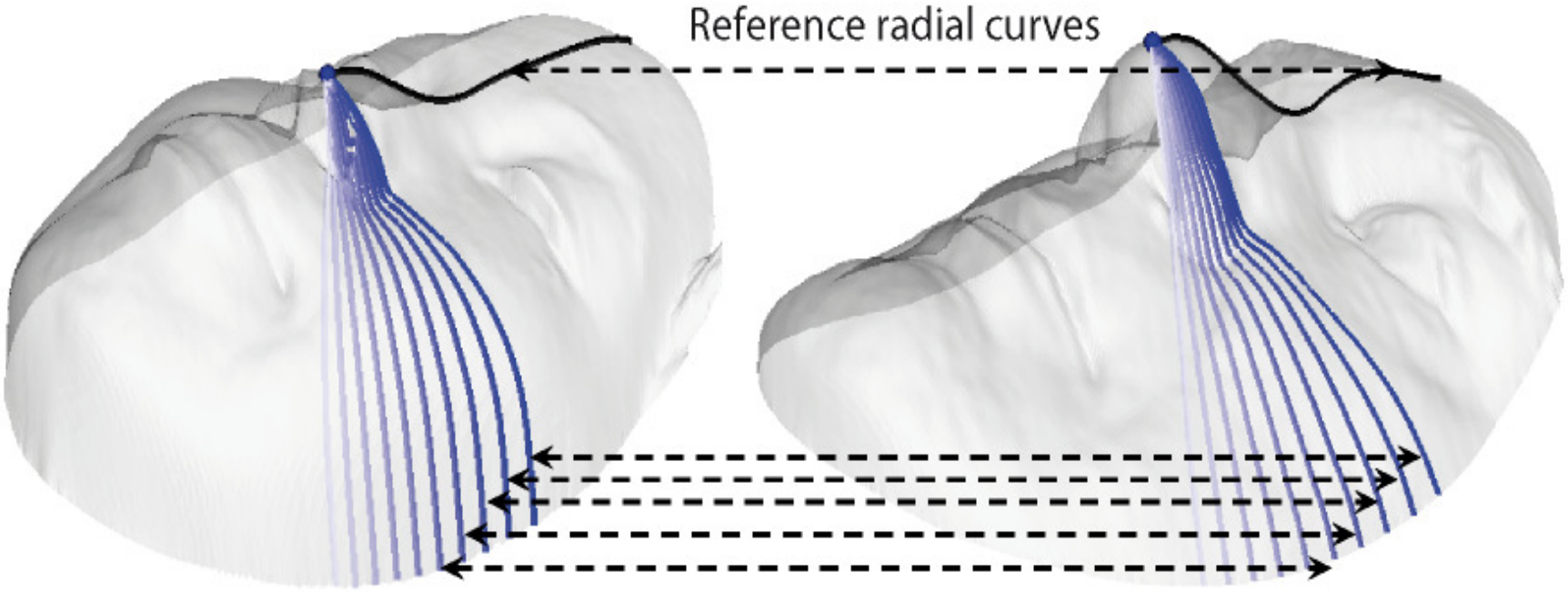
Face comparison



$$S_1 = \bigcup_{\alpha} c_{\alpha}^{1}$$

$$S_2 = \bigcup_{\alpha} c_{\alpha}^{2}$$

Facial Curve Parameterization

- Curve parameterization which take into account elastic deformations of facial surfaces

Let : $\beta : \mathbb{S}^1 \longrightarrow \mathbb{R}^3$

$s \longmapsto \beta(s)$

Facial curve

$$\dot{\beta}(s) = \frac{d\beta}{ds}$$

Curvilinear speed

$$q : \mathbb{S}^1 \longrightarrow \mathbb{R}^3$$

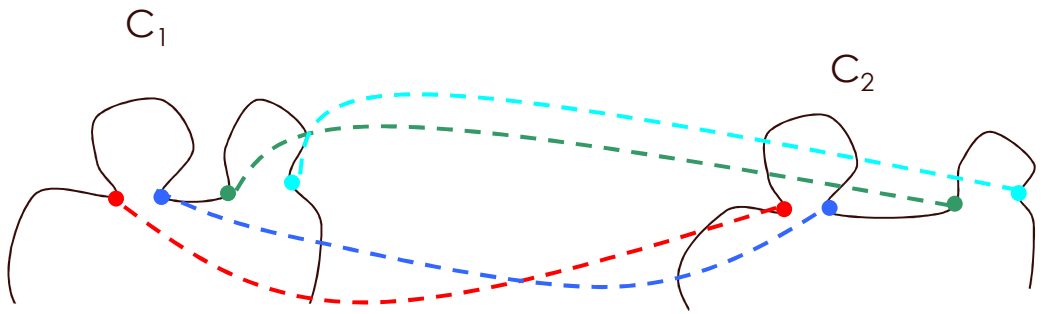
$$q(t) \doteq \frac{\dot{\beta}(t)}{\sqrt{\|\dot{\beta}(t)\|}}$$

Square-root velocity function(SQVF) [2]

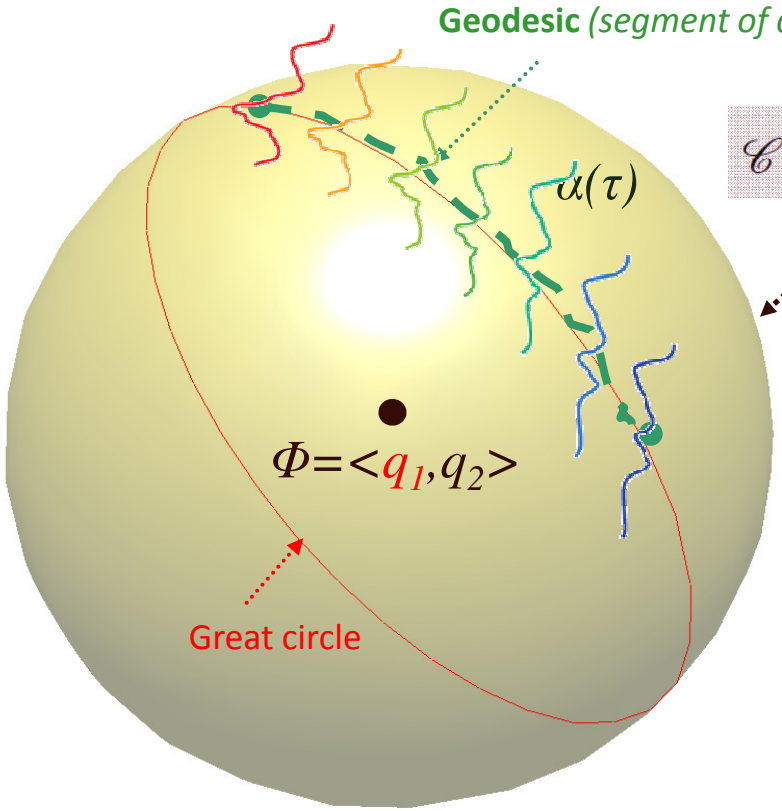
[Joshi et al. IEEE CVPR 2007]

Facial Curve Parameterization

- Why q?
  - $q \in IL^2$ (Hilbert space)
  - The IL^2 norm of q is the length of the curve C.
  - In order to let the curve stretch, shrink and bend freely



Elastic shape analysis of radial curves



$$\mathscr{C} = \{q : I \to \mathbb{R}^3 \,|\, \|q\| = 1\} \subset \mathbb{L}^2(I, \mathbb{R}^3)$$

The geodesic length between $q_1, q_2 \in \mathscr{C}$

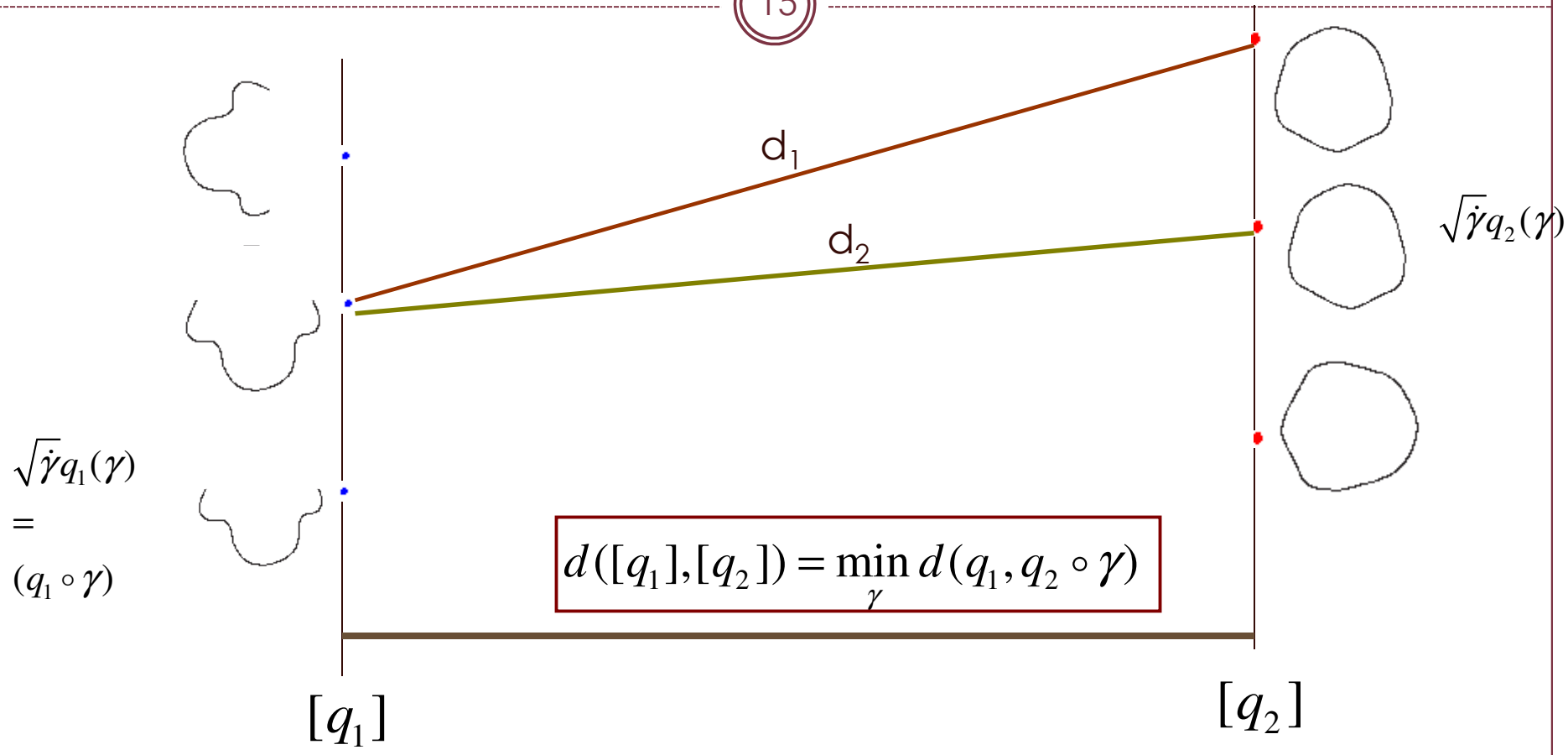
$$d_c(q_1, q_2) = cos^{-1}(\langle q_1, q_2 \rangle)$$

Geodesic path $\alpha : [0,1] \to \mathscr{C}$,

$$\alpha(\tau) = \frac{1}{\sin(\theta)}(\sin((1-\tau)\theta)q_1 + \sin(\theta\tau)q_2)$$

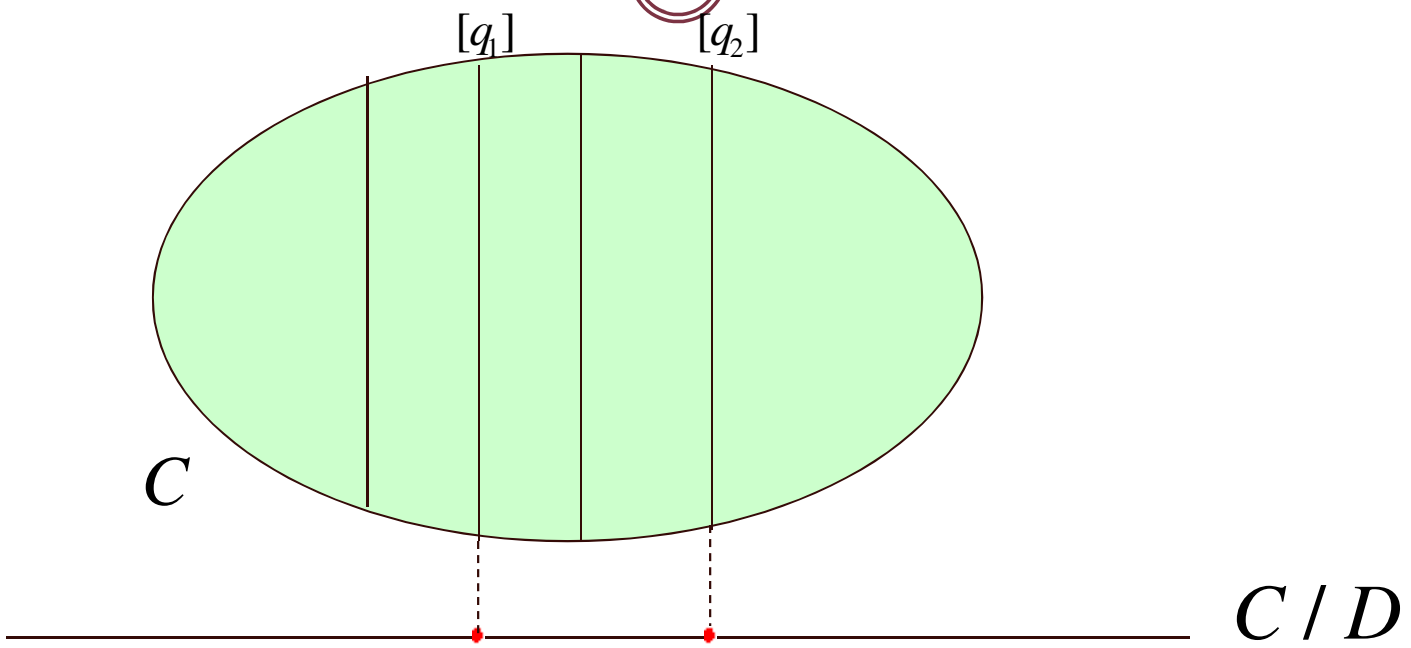
Where $\theta = d_c(q_1, q_2)$

Equivalent class



$$[q] = \left\{ \sqrt{\dot{\gamma}(t)} O q(\gamma(t)) \,/\, O \in SO(3), \gamma \in \Gamma \right\}$$

Shape space



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Geodesic distance computation between curves

Input: Two curves β^1 and β^2

1- For each $i = 1, 2$ compute the Square Root velocity Function $q^i(t) \doteq \frac{\dot{\beta}^i(t)}{\sqrt{\|\dot{\beta}^i(t)\|}}$

2- Compute the optimal rotation and re-parametrization O^* and γ^*

$$(O^*, \gamma^*) = \arg.min_{(O,\gamma) \in SO(3) \times \Gamma} d_c(q^1, \sqrt{\dot{\gamma}} O(q^2 \circ \gamma)) \ .$$

3- $q_2^*(t) = \sqrt{\dot{\gamma}^*(t)} O^* q^2(\gamma^*(t)))$

4- Compute the geodesic distance between q^1 and q_2^*. $d_c(q^1, q_2^*) = cos^{-1}(\langle q^1, q_2^* \rangle)$

5- $d_s([q^1], [q^2]) = d_c(q^1, q_2^*)$

Output: $d(\beta^1, \beta^2) = d_s([q^1], [q^2])$

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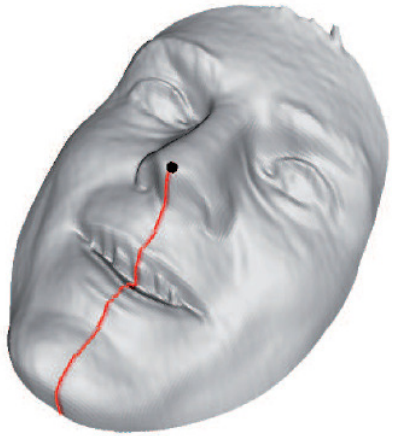
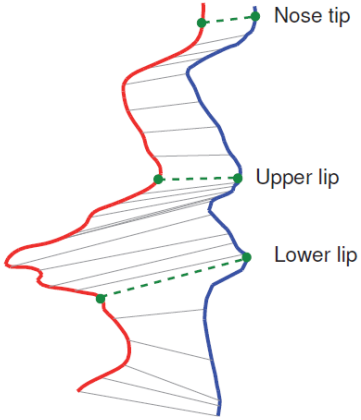
Elasticity illustration



Face with opened mouth



(i) Matching result using DP

Face with closed mouth

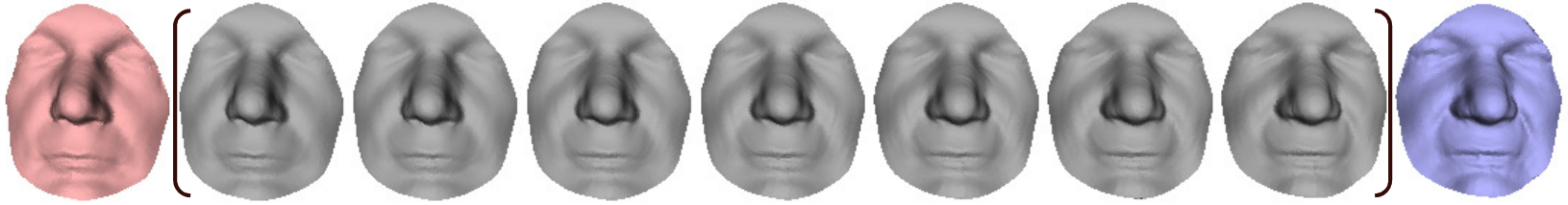
Source

(ii) Geodesic between curves

Target

Facial surface space metric

Let S_1 et S_2 two facial surfaces



$S^1 = \bigcup_\lambda c_\lambda^1$ Geodesic path from S_1 to S_2 $S^2 = \bigcup_\lambda c_\lambda^2$

Source face Intermediate faces Target face

The distance between S_1 and S_2 is the sum of distances between curves from the same level :

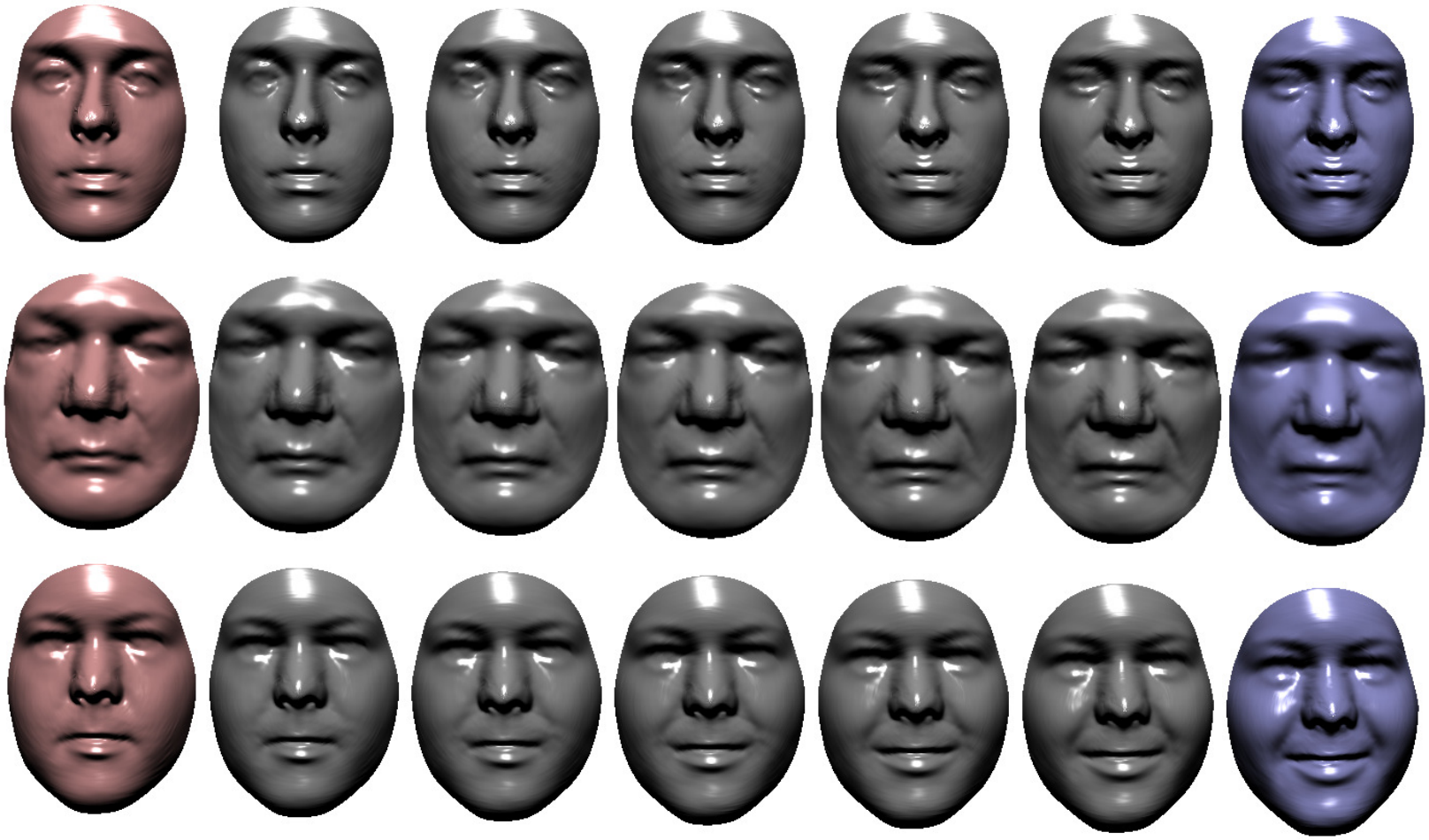
$$d_S : C^{[0,L]} \times C^{[0,L]} \rightarrow \Re^+$$

$$d_S(S_1, S_2) = \int_0^L d(c_\lambda^1, c_\lambda^2) d\lambda$$

Distance between two facial surfaces

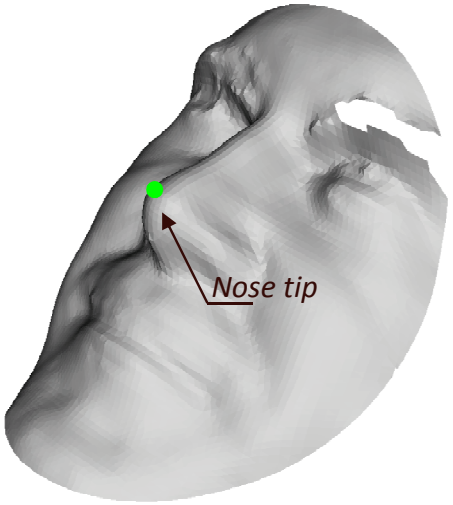
Examples of inter-class geodesics

Examples of intra-class geodesics

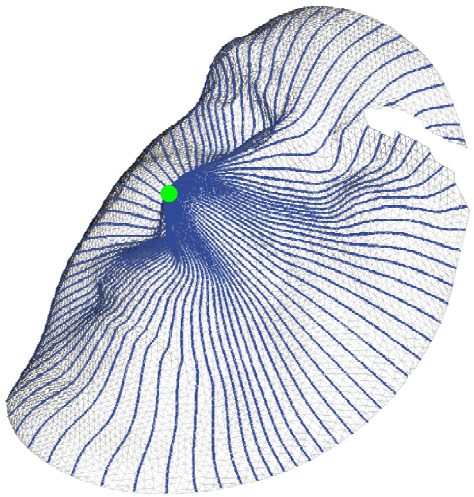


Robustness to Missing data/Pose

- *Radial curves extraction*
- *Criterion for curve quality inspection*
  - *(i) # of connected components = 1*
  - *(ii) Curve length > T (threshold)*

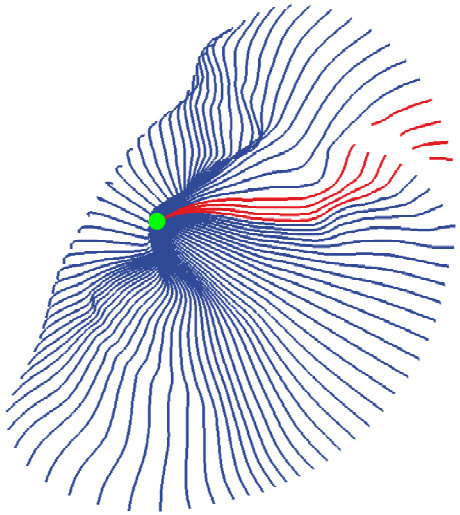


S *Triangulated mesh*



$S \approx \cup_\alpha \beta_\alpha = \cup_\alpha \{S \cap P_\alpha\}$

Curves quality inspection



Discarded curves Retained curves

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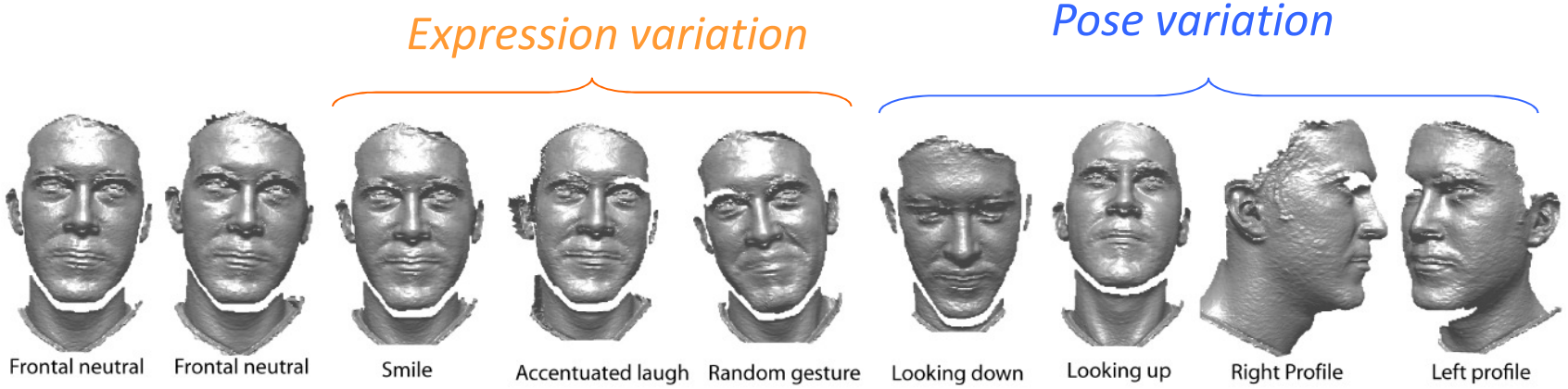
Evaluation experiments

- ***GavabDB****
  - *Public http://www.gavab.etsii.urjc.es/recursos_en.html*
  - *The most expression-rich and noise-prone 3D face dataset*
  - *61 subjects (45 male + female) Caucasian*
  - *9 sessions/subject*
    - *2 x Neutral frontal sessions*
    - *3 x Expressive sessions*
    - *4 x Neutral non-frontal sessions*



*A. B. Moreno and A. Sánchez. Gavabdb: a 3d face database. In Workshop on Biometrics on the Internet, pages 77–85, Vigo, March 2004.

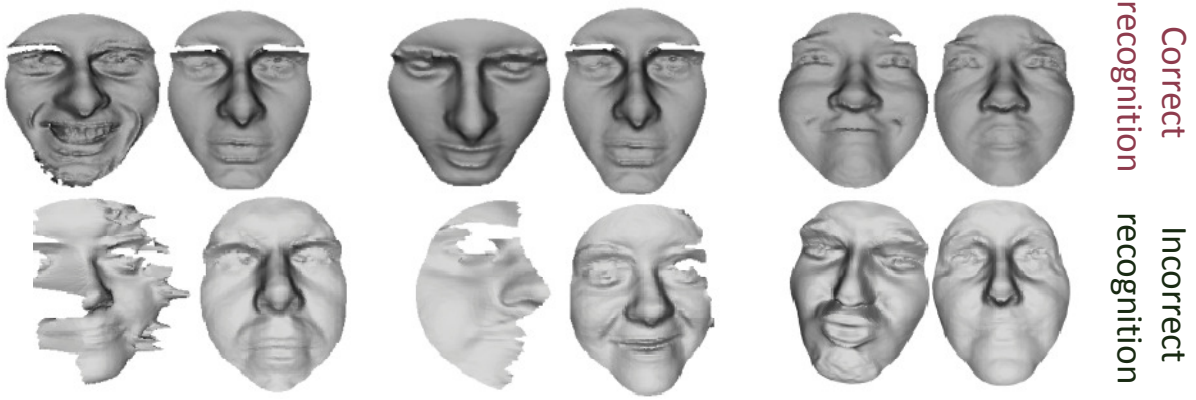
Evaluation experiments

- *Identification results and comparison with state-of-the-art approaches*

	Li et al. [8]	Moreno et al. [10]	Mahoor et al. [9]	Berretti et al. [1]	Mousavi et al. [11]	Our
(a)	96.67%	90.16%	95%	94%	-	100%
(b)	93.33%	77.9%	72%	81%	-	94.54%
(c)	94.68%	-	78%	84.25%	91%	94.67%
(d)	-	-	85.3%	80%	-	100%
(e)	-	-	88.6%	79%	-	98.36%
(f)	-	-	-	82.66%	81.67%	96.99%
(g)	-	-	-	-	-	70.49%
(h)	-	-	-	-	-	86.89%

***(a)** Neutral, **(b)** Expressive, **(c)** Neutral + Expressive, **(d)** Rotated looking down, **(e)** Rotated looking up, **(f)** Overall, **(g)** Right profile ,**(h)** Left profile*

- *Examples of correct and incorrect recognition*

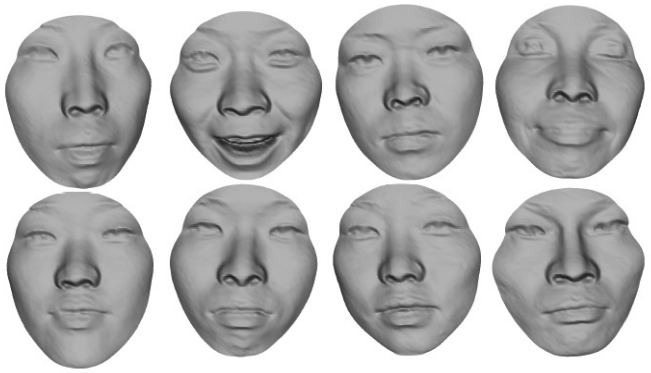


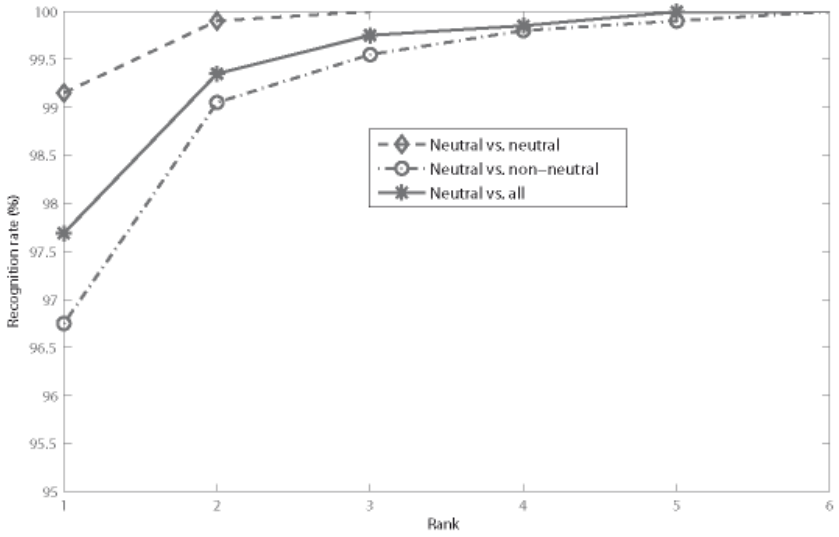
Evaluation experiments

- ***FRGCv2.0*** (With expressions)

  -466 subjects
  -4007 sessions

  From 1 to 22 sessions/subjects





Evaluation experiments

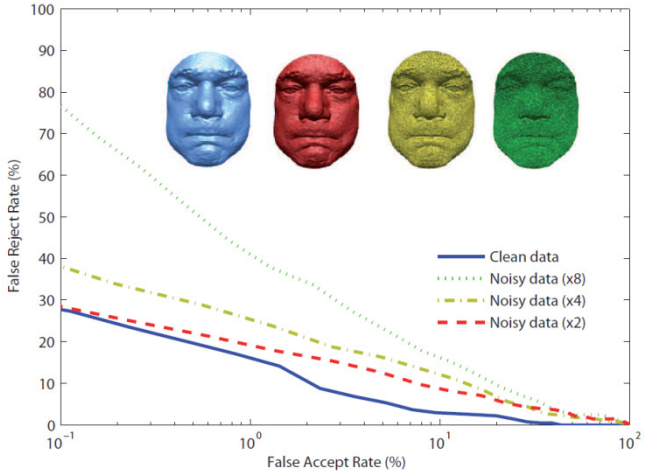
- *Identification results and comparison with state-of-the-art approaches*

Recognition results comparison of different methods on FRGCv2 dataset (neutral vs. all senario).

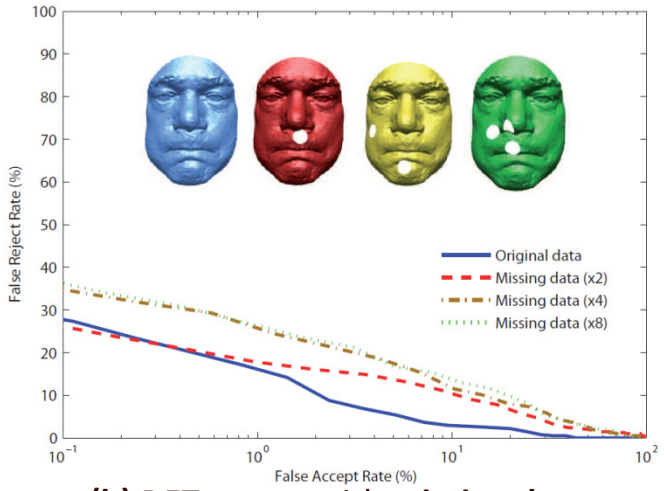
Approaches	Berretti et al. [4]	Chang et al. [10]	Mian et al. [26]	Faltemier et al. [14]	Our approach
Rank-1	94.1%	94.6%	96.2%	98.1%	97.7%

[14] Faltemier et al. *IEEE Transactions on Information Forensics and Security 2008*
[4] Berretti et al. *IEEE Transactions on Pattern Analysis and Machine Intelligence 2010*
[10] Chang et al. *IEEE Transactions on Pattern Analysis and Machine Intelligence 2006*
[26] Mian et al. *IEEE Transactions on Pattern Analysis and Machine Intelligence 2007*

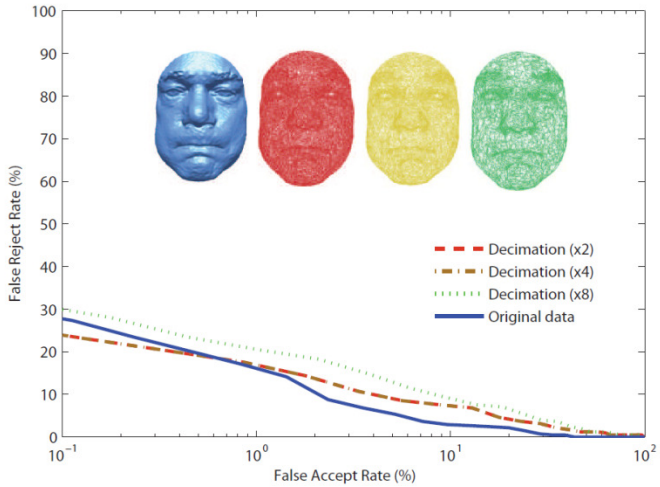
Evaluation on quality degradation



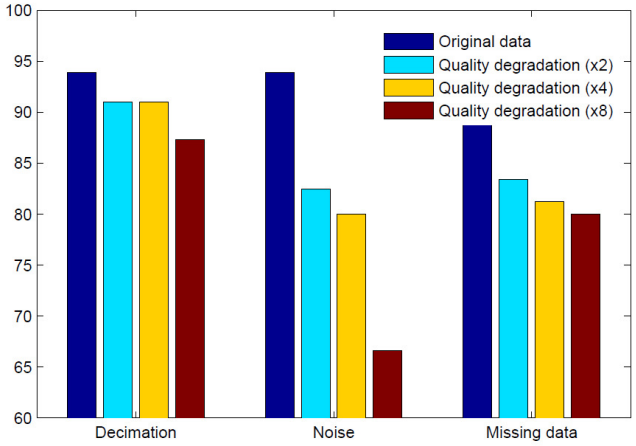
(a) DET curves with **noisy** dataset



(b) DET curves with **missing data**



(c) DET curves with **decimation**



(d) Recognition accuracy under # variability

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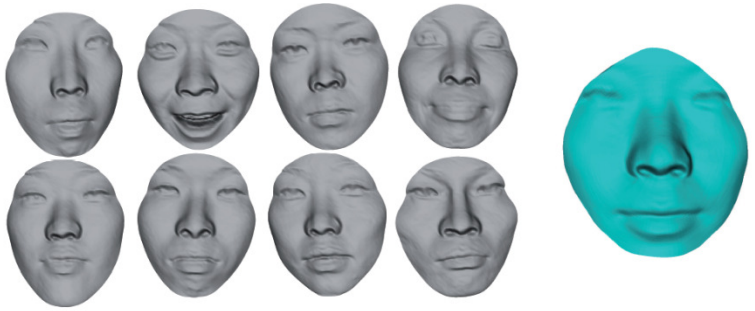
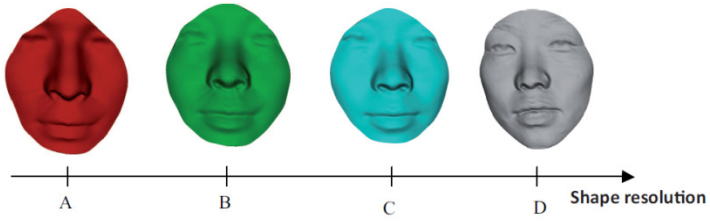
Hierarchical Gallery Organization



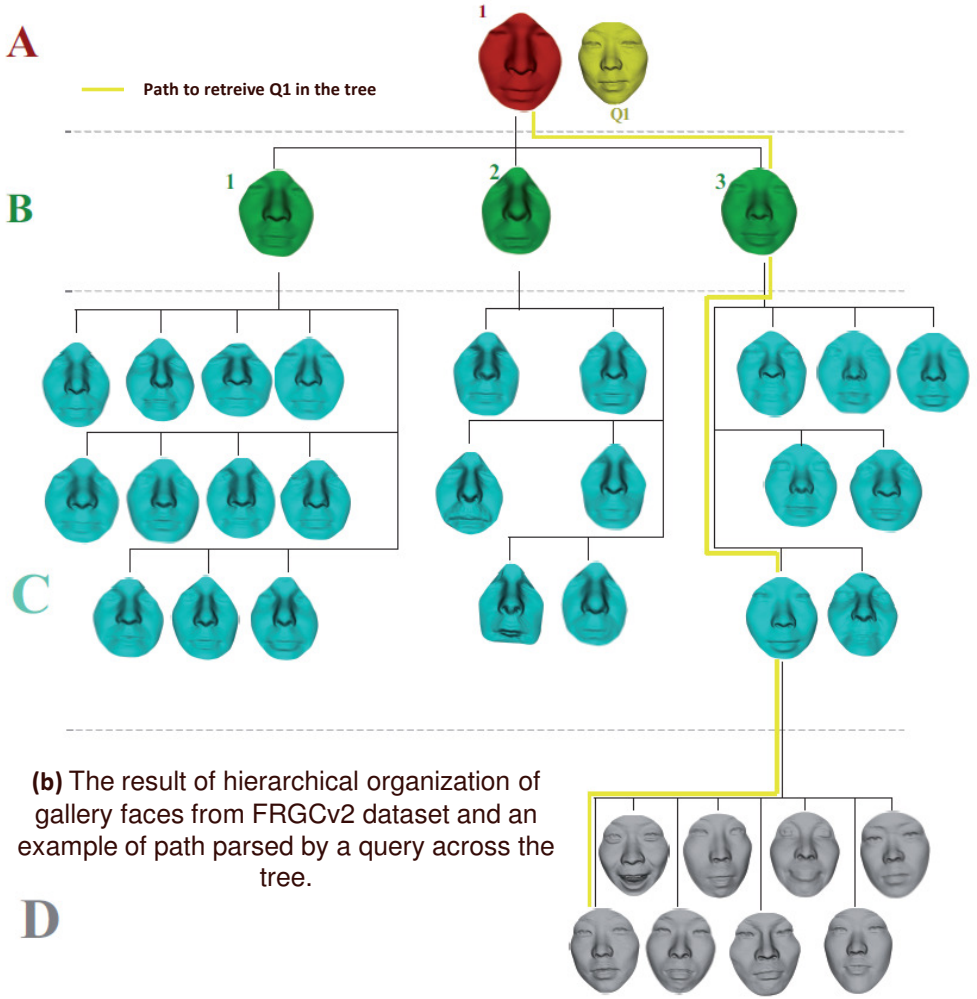
(a) Example of facial shape mean computation



(c) Path from top to bottom in the tree show increasing shape resolution.

Query	Exhaustive(mn)	Hierarchical(mn)	Result
Qi, i in [1,8]	52	3.5	Correct
Q9, Q10	52	3.5	Incorrect

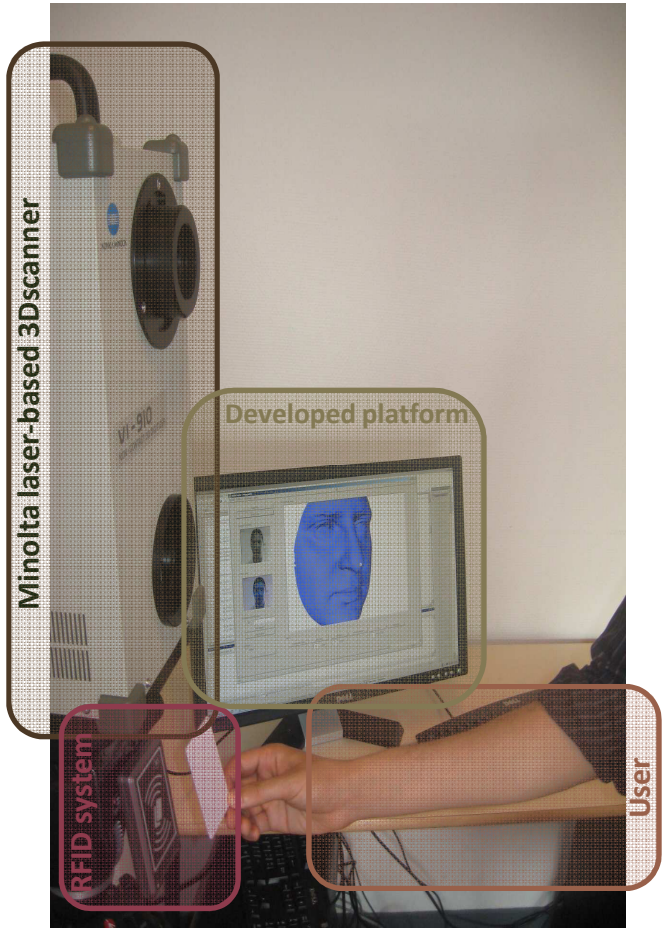
(d) Time consumed to identify a given query face in the gallery set (including 410 faces).



(b) The result of hierarchical organization of gallery faces from FRGCv2 dataset and an example of path parsed by a query across the tree.

Open platform for 3D Face Recognition

- **F**ace **A**nalysis and **R**ecognition using **3D** (**FAR3D**) financed by the *French National Research Agency (ANR)*
  - http://www-rech.telecom-lille1.eu/far3d/
  - 2008-2010
  - University Lille1 (TELECOM Lille1) – ***coordinator***
  - Ecole Centrale de Lyon
  - Eurecom Institute
  - Thales R&T



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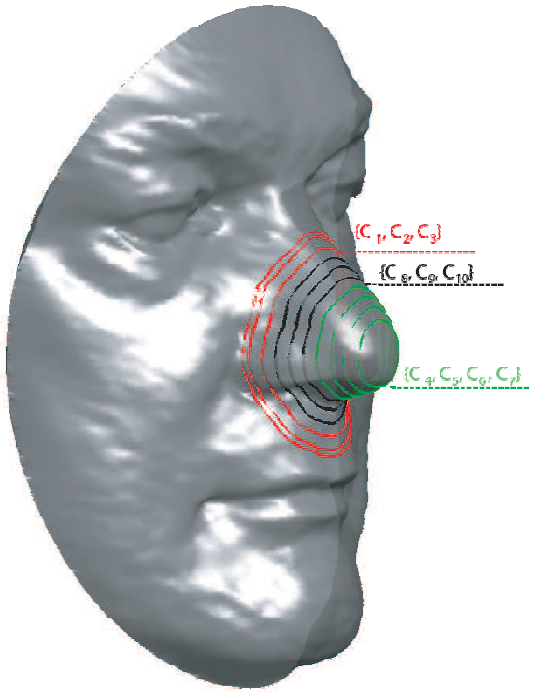
Conclusion and future work

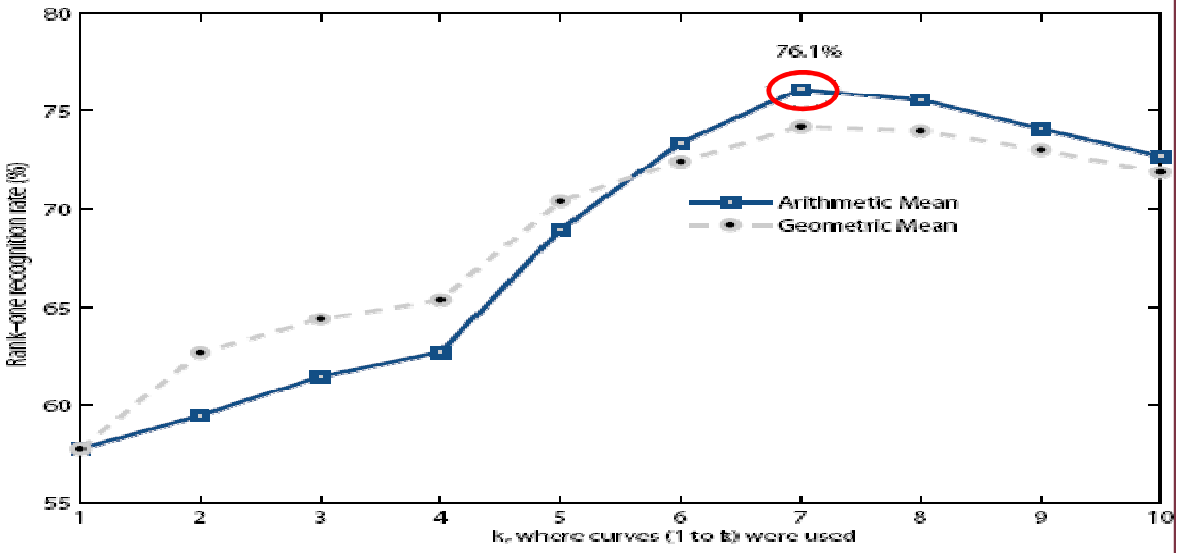
Experimental results

Protocole:

- 2000 faces in gallery
- 2000 faces in probe

2000 x 2000 matrix





Experimental results

Protocole:

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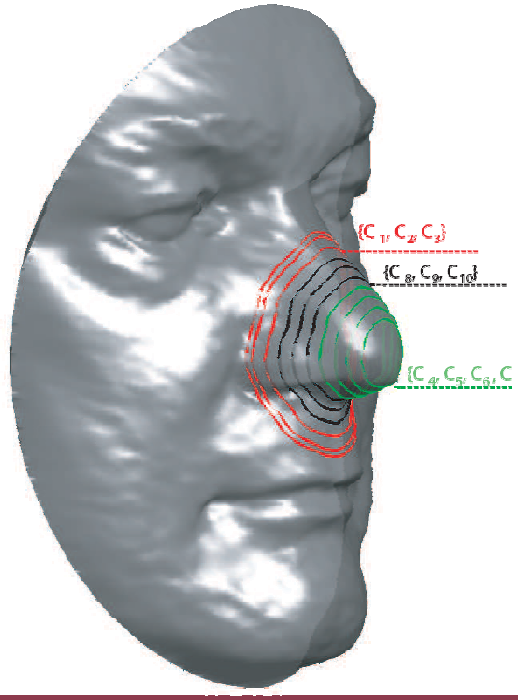
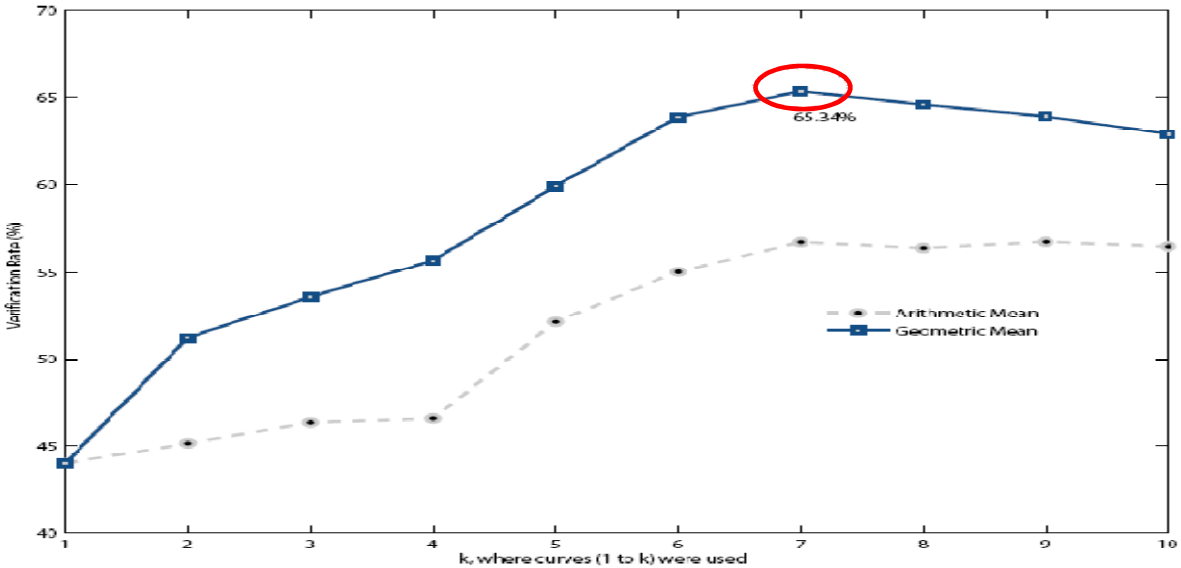
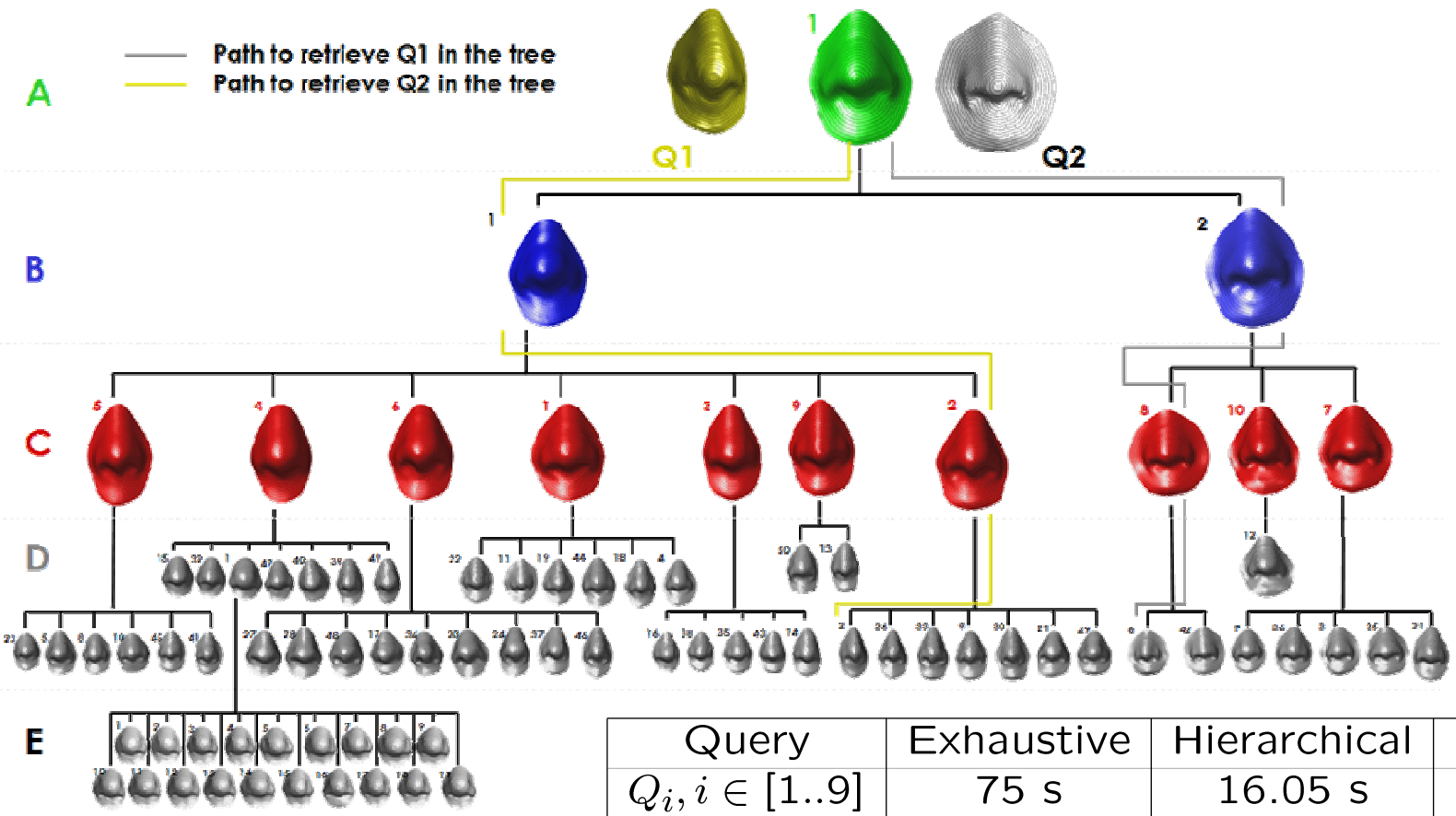




HIERARCHICAL NASAL SHAPES ORGANIZATION AND RETRIEVAL



Query	Exhaustive	Hierarchical	Result
$Q_i, i \in [1..9]$	75 s	16.05 s	correct
Q_{10}, Q_{11}	75 s	16.5 s	incorrect

Conclusions and future directions

- Scientific contributions
  - Propose original 3D face recognition algorithms robust to expressions and missing data (pose and data quality)
  - Mathematical tools for statistics (mean facial shape, etc.)
    - Hierarchical organization of gallery
  - Develop ***an open technology platform*** that integrates matching algorithms based on 3D facial shape
- Future directions/Open problems
  - ***On-the-fly*** 3D face recognition algorithms.
  - Facial attributes recognition using 3D (age estimation, expression, ethnicity, gender, etc.)

Thank you for your attention
Questions

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Publications related to this work

1-**H. Drira**, B. B. Amor, A. Srivastava, and M. Daoudi. A Riemannian analysis of 3d nose shapes for partial human biometrics. In ***IEEE International Conference on Computer Vision, 2009.***

2-**H. Drira**, B. B. Amor, M. Daoudi , and A. Srivastava. Nasal Region Contribution in 3D Face Biometrics Using Shape Analysis Framework ***In IEEE/IAPR International Conference on Biometric, 2009.***

3- **H. Drira**, B. Benamor, M. Daoudi, and A. Srivastava. Pose and expression-invariant 3d face recognition using elastic radial curves. In *Proceedings of the* ***British Machine Vision Conference*****, 2010**.

4-**H. Drira**, B. Ben Amor, M. Daoudi, A. Srivastava, Elastic Radial curves to model 3D face deformations **, in 3DOR workshop, ACMMMultimedia 2010 (ACMMM) 2010.**

4- **H. Drira**, B. Benamor, M. Daoudi, and A. Srivastava. Pose and Expression-Robust 3D Face Recognition Using Elastic Radial Curves Submitted to ***IEEE Transactions on Pattern Analysis and Machine Intelligence.***