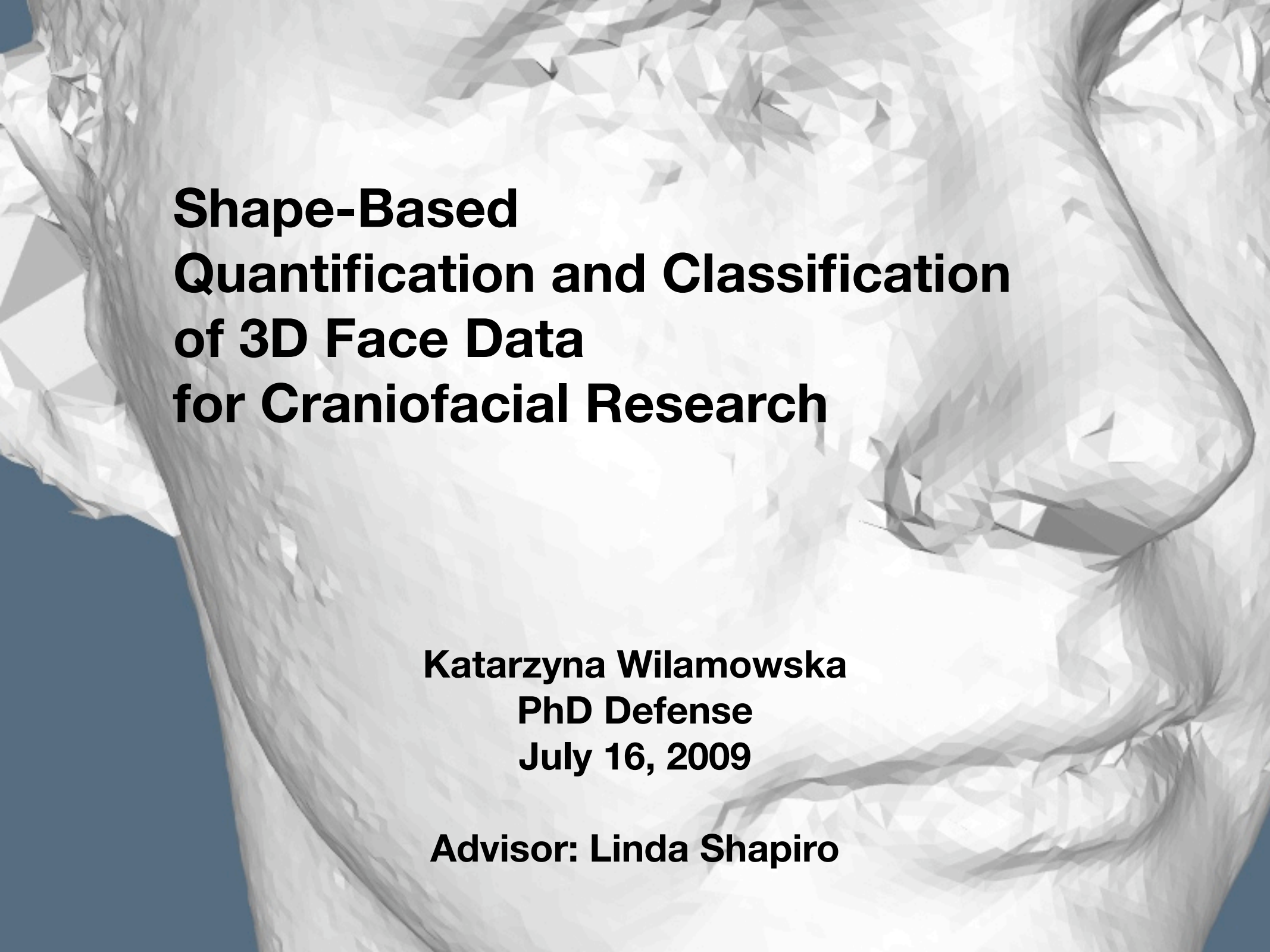


Shape-Based Quantification and Classification of 3D Face Data for Craniofacial Research

Katarzyna Wilamowska

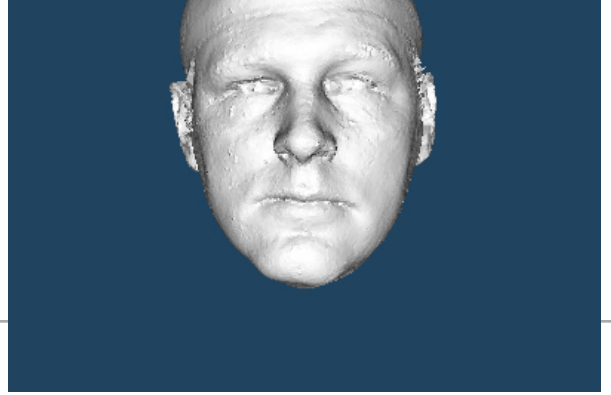
PhD Defense

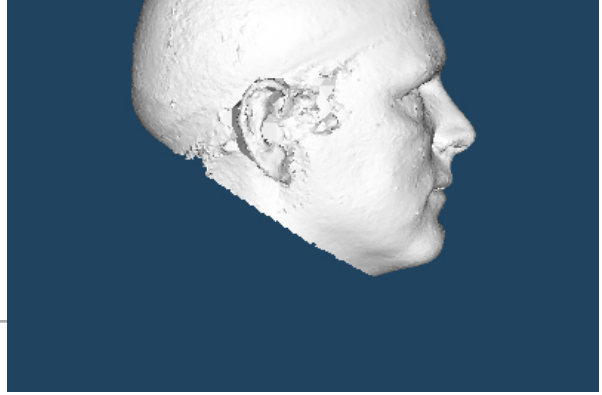
July 16, 2009

Advisor: Linda Shapiro

Expert Survey

- 43 affected / 43 control
- 3 expert assessments
- Quantify features
- Prioritize research





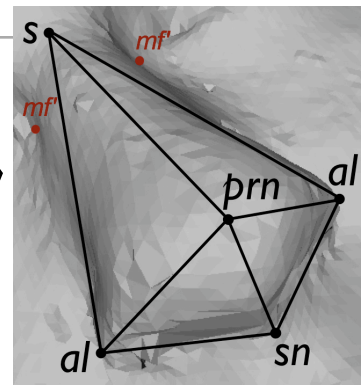
1

	Definitely YES	Probably YES	Probably NO	Definitely NO
Does this individual have 22q11?	○	○	○	○
Do you know this individual?	○	○	○	○

	Opposite of 22q11	Not 22q11	Moderate 22q11	Severe 22q11	Not enough data
Overall face					
22q Facial Phenotype	○	○	○	○	○
Asymmetric	○	○	○	○	○
Square/Rectangular	○	○	○	○	○
Hypotonic appearance	○	○	○	○	○
Eyes					
Hooded appearance	○	○	○	○	○
Nose					
Prominent nasal root	○	○	○	○	○
Tubular appearance	○	○	○	○	○
Bulbous nasal tip	○	○	○	○	○
Small nasal alae	○	○	○	○	○
Ears					
Small	○	○	○	○	○
Protuberant	○	○	○	○	○
Midface					
Relatively flat	○	○	○	○	○
Forehead					
Square	○	○	○	○	○
Prominent on profile	○	○	○	○	○
Mouth					
Small	○	○	○	○	○
Open	○	○	○	○	○
Downturned corners of mouth	○	○	○	○	○
Retrusive chin	○	○	○	○	○

System Diagram for Quantification

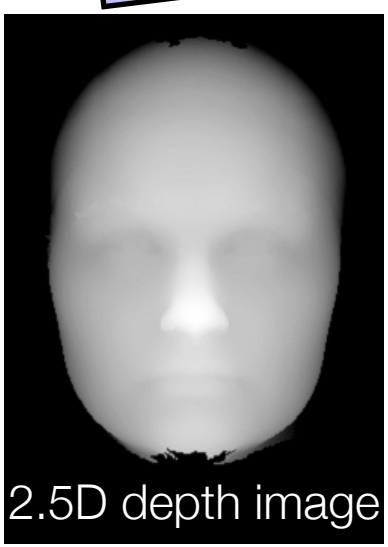
auto landmark detection



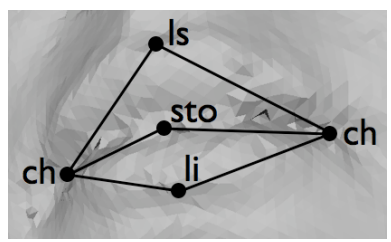
automatically detected landmarks

landmark based descriptors

compare to expert survey

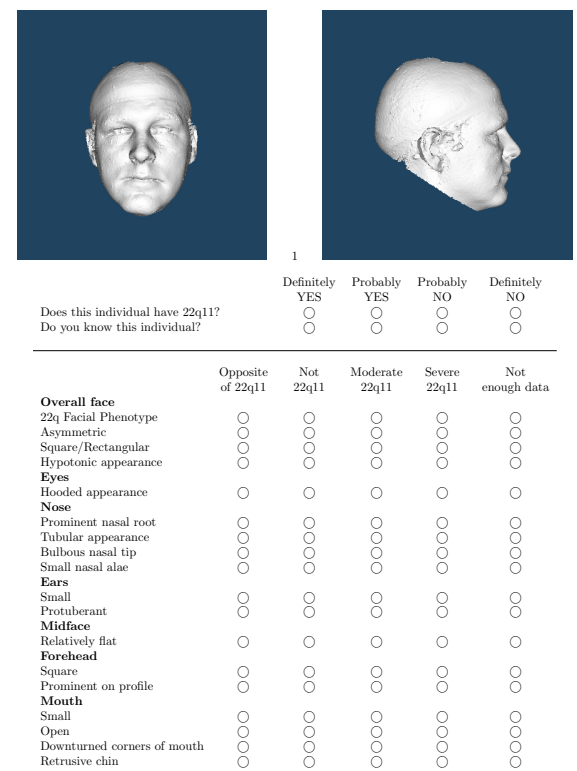


2.5D depth image



shape based descriptors

compare to expert survey



1

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Does this individual have 22q11?	○	○	○	○
Do you know this individual?	○	○	○	○

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Asymmetric	○	○	○	○	○
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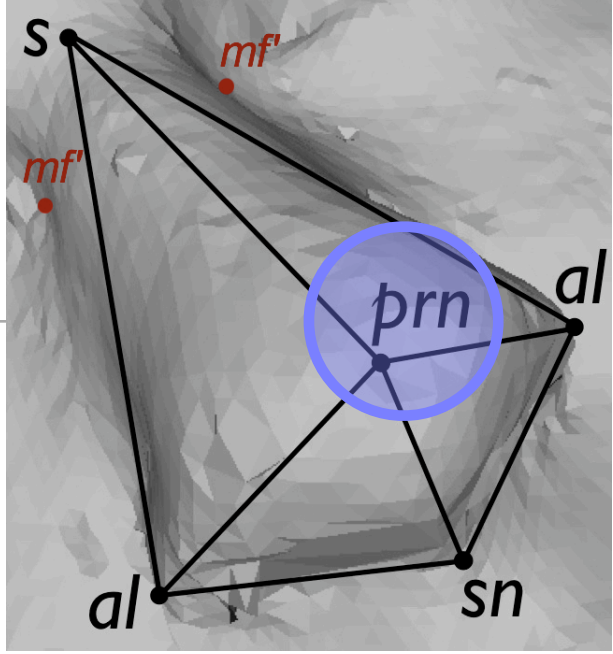
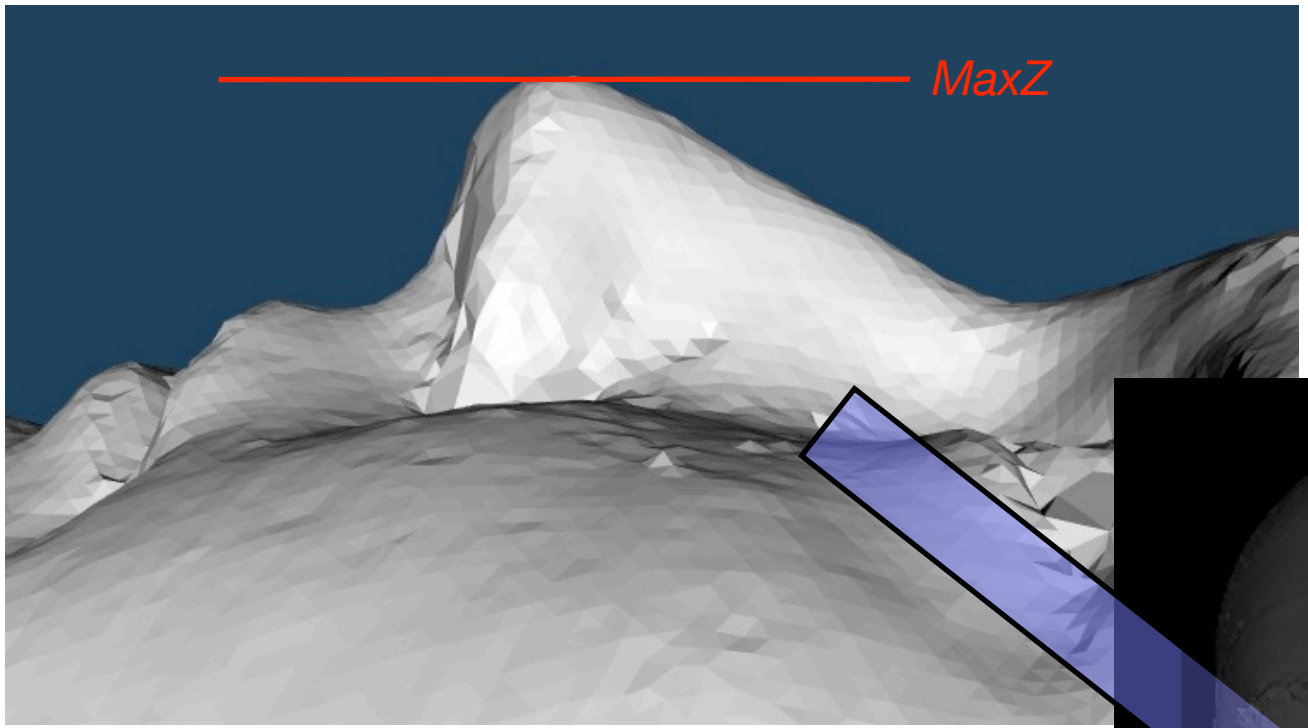
Hypotonic appearance	○	○	○	○	○
Eyes					
Hooded appearance	○	○	○	○	○
Nose					
Prominent nasal root	○	○	○	○	○
Tubular appearance	○	○	○	○	○
Bulbous nasal tip	○	○	○	○	○
Small nasal alae	○	○	○	○	○
Ears					
Small	○	○	○	○	○
Protuberant	○	○	○	○	○
Midface					
Relatively flat	○	○	○	○	○
Forehead					
Square	○	○	○	○	○
Prominent on profile	○	○	○	○	○
Mouth					
Small	○	○	○	○	○
Open	○	○	○	○	○
Downturned corners of mouth	○	○	○	○	○
Retrusive chin	○	○	○	○	○
Additional comments					

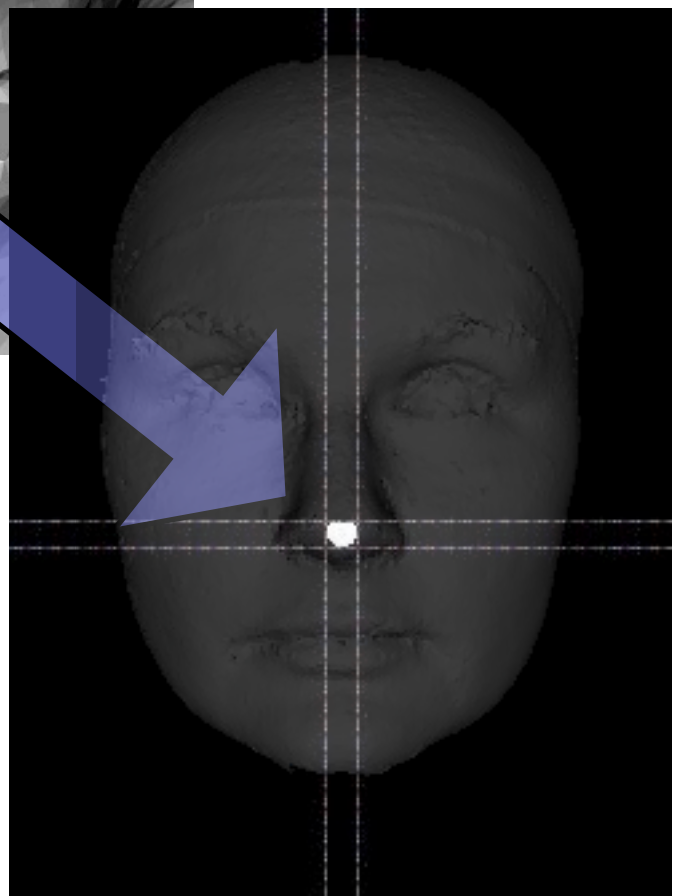
3 expert survey

Automatic Landmark Detection

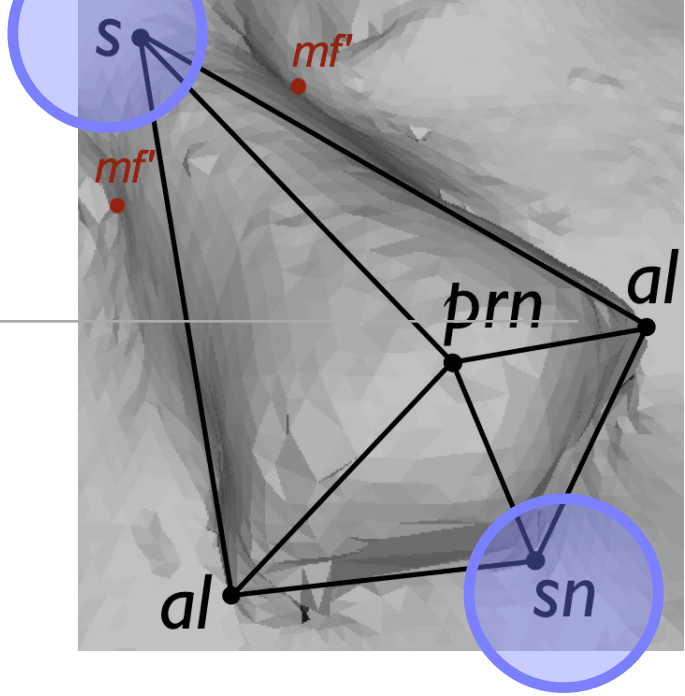
Nasal

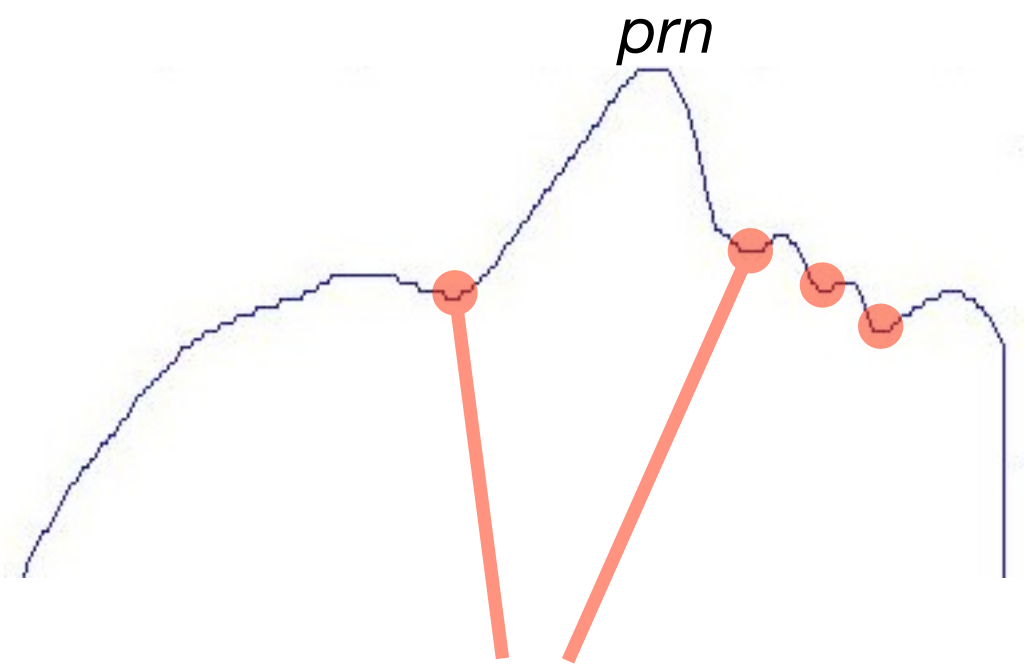






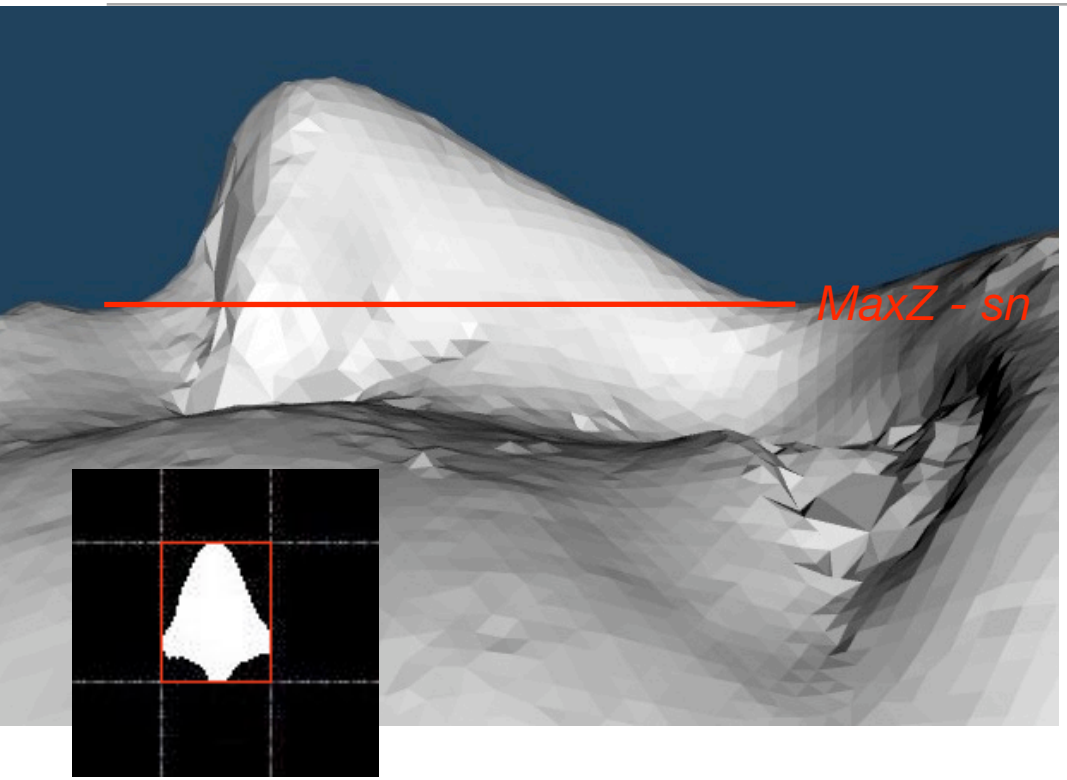
Automatic Landmark Detection
Nasal

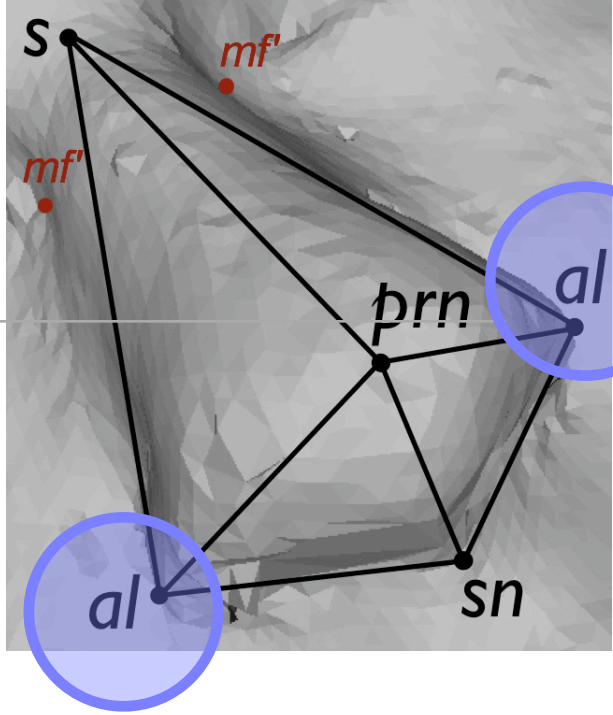




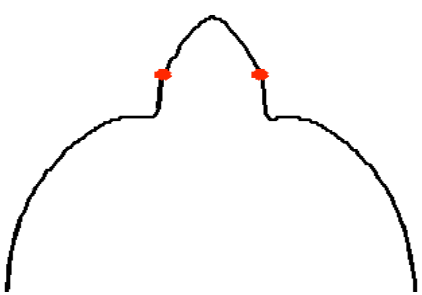
Local Minima next to Nose Tip

Automatic Landmark Detection
Nasal

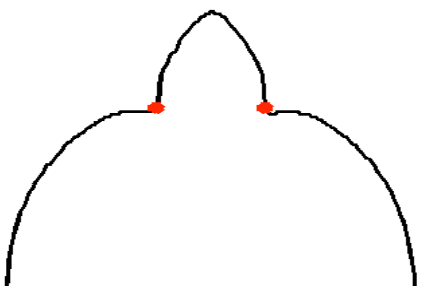




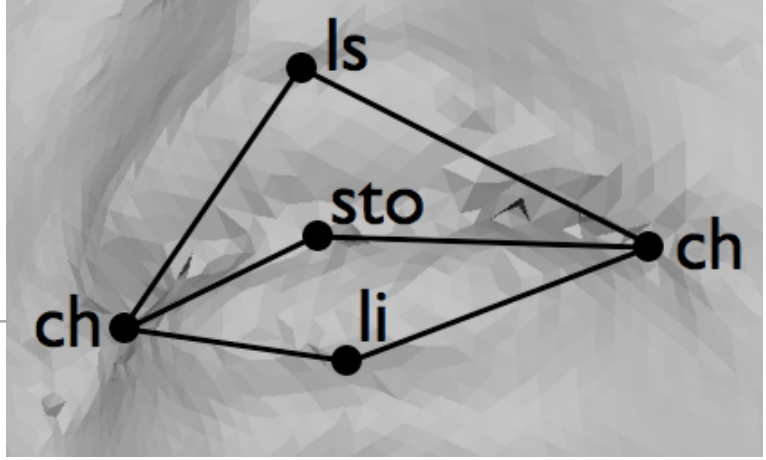
find average of border *y*-values



correct *x* positions



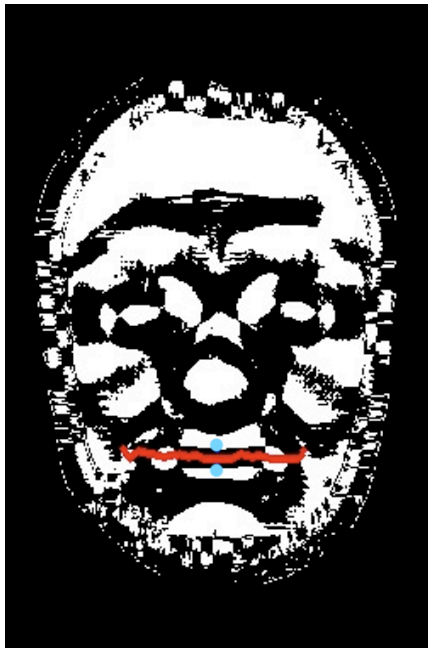
Automatic Landmark Detection
Oral



- Peak curvature values

- Trough within mouth

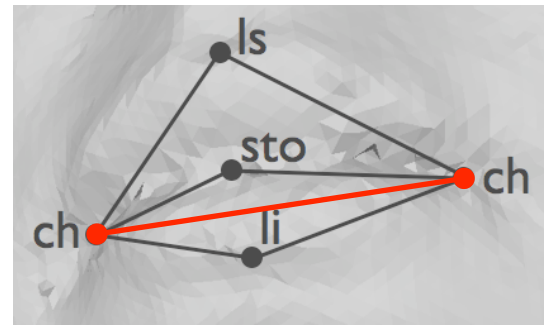




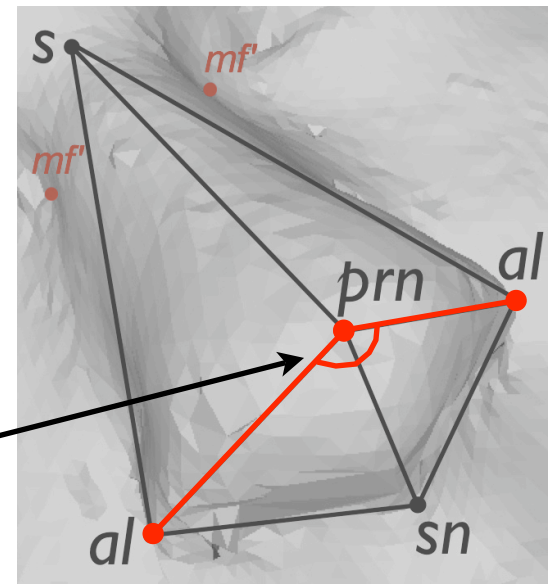

ls	sto	li	ch^L	ch^R
94%	95%	93%	92%	92%

Landmark-based Descriptors

- Distances between landmarks
- Angles of facial features
- Normalized to size of face



Description	Name	Mathematical Definition
Normalized nose depth	L_1^N	$= Depth_{nose}/Depth_{face}$
Normalized nose width	L_2^N	$= Width_{nose}/Width_{face}$
Normalized nasal root width	L_3^N	$= Width_{Nroot}/Width_{face}$
Normalized nasal root depth	L_4^N	$= Depth_{Nroot}/Depth_{face}$
Average nostril inclination†	L_5^N	$= \text{avg}[\angle(mf'^L, al^L, al^R), \angle(mf'^R, al^R, al^L)]$
Nasal tip angle†	L_6^N	$= \angle(s, prn, sn)$
Alar-slope angle†	L_7^N	$= \angle(al^L, prn, al^R)$
Nasal root-slope angle†	L_8^N	$= \angle(mf'^L, s, mf'^R)$



Shape-based Descriptors

	Control	Affected
Bulbous Nasal Tip	16%	67%
Prominent Nasal Root	30%	47%
Tubular Appearance	23%	47%
Small Nasal Alae	19%	74%
Open Mouth	12%	19%
Small Mouth	14%	37%
Downturned Corners of Mouth	21%	56%
Retrusive Chin	0%	18%

Shape-based Descriptors

	Control	Affected
Bulbous Nasal Tip	16%	67%
Prominent Nasal Root	30%	47%
Tubular Appearance	23%	47%
Small Nasal Alae	19%	74%
Open Mouth	12%	19%
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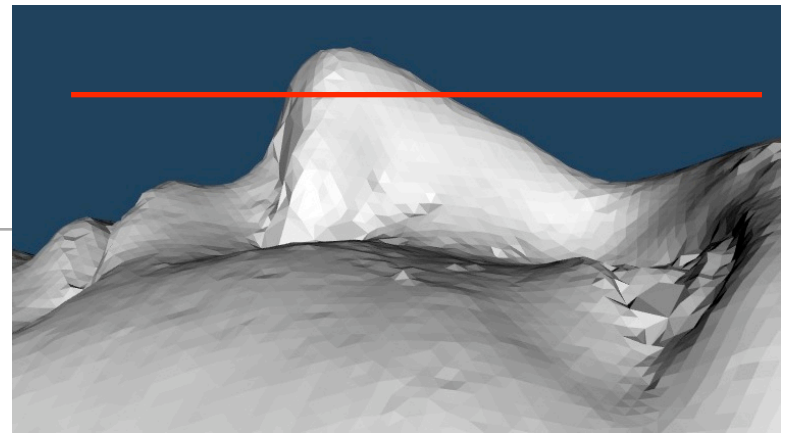
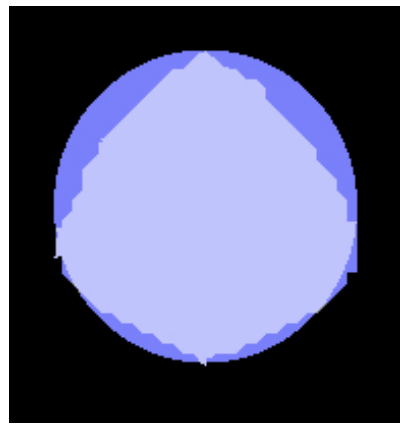
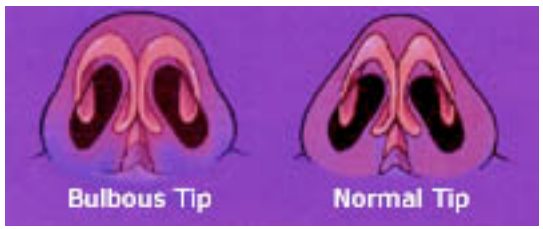
Downturned Corners of Mouth	21%	56%
Retrusive Chin	0%	18%

Shape-based Descriptor
Bulbous Nasal Tip

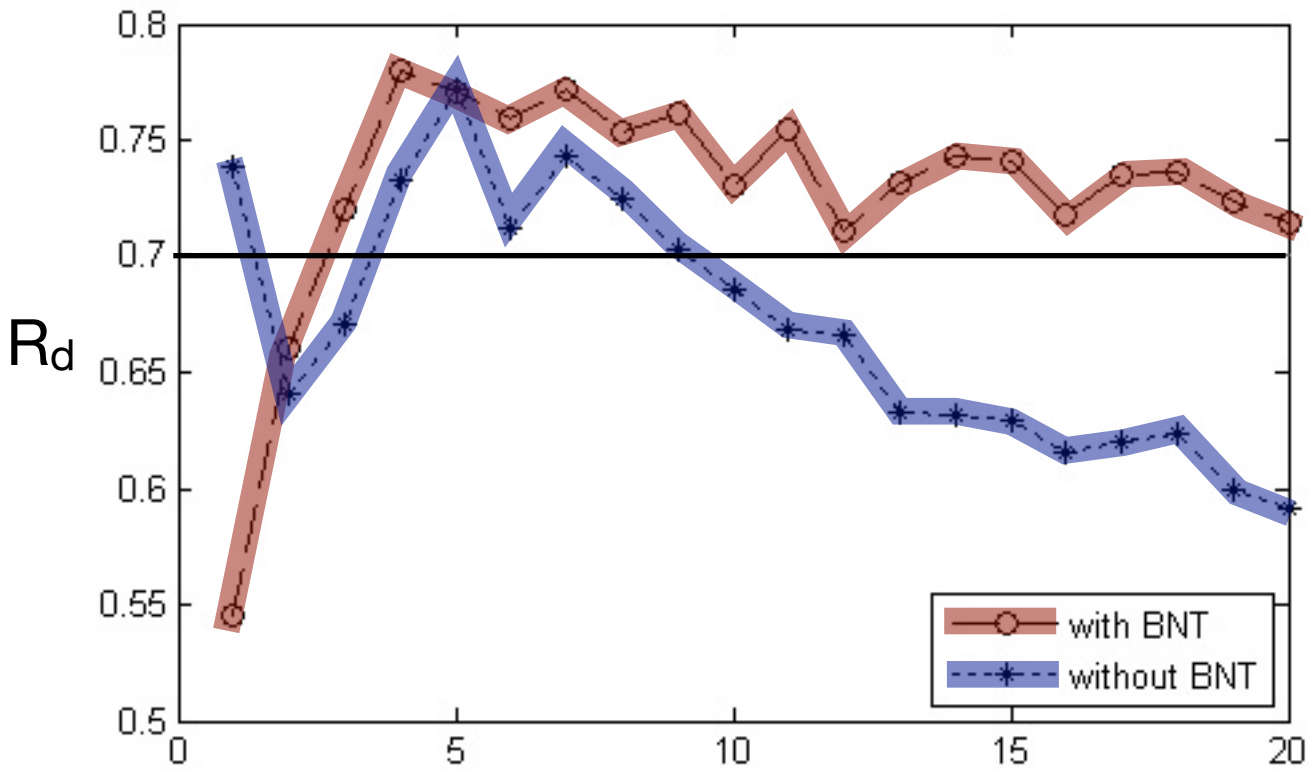


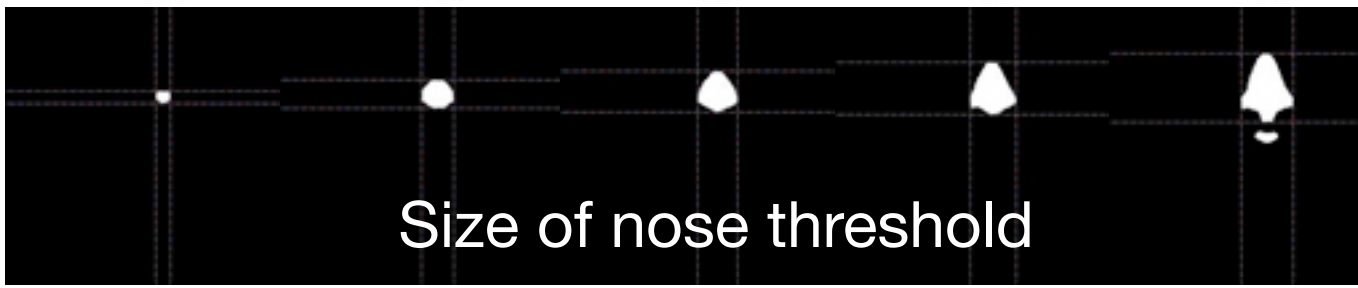




Shape-based Descriptor
Bulbous Nasal Tip **Rectangularity Measure**

$$R_d = \frac{\text{num}(NT_d = 1)}{\text{area}(B_d)}$$

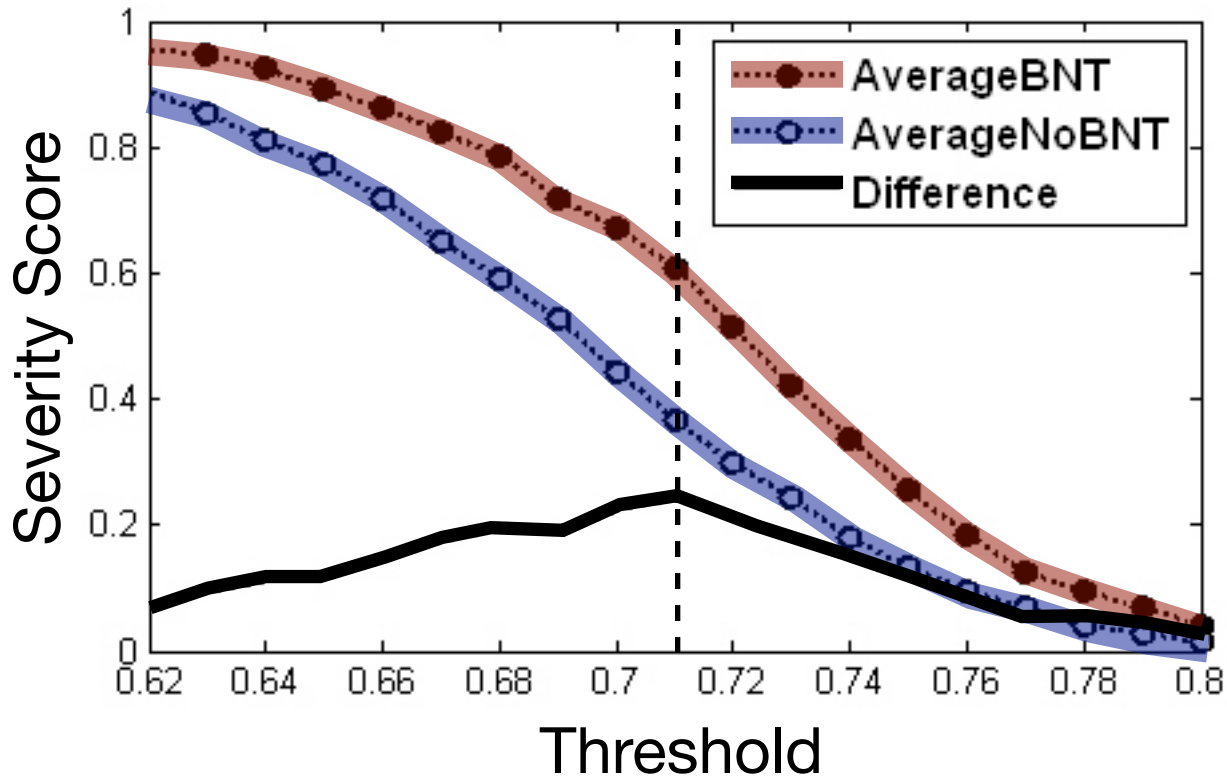




Shape-based Descriptor
Bulbous Nasal Tip

Severity of Shape

$$Severity_{Rectangle} = \frac{\#\ (R_d > \ \text{Threshold})}{\text{Depth of Nose}}$$

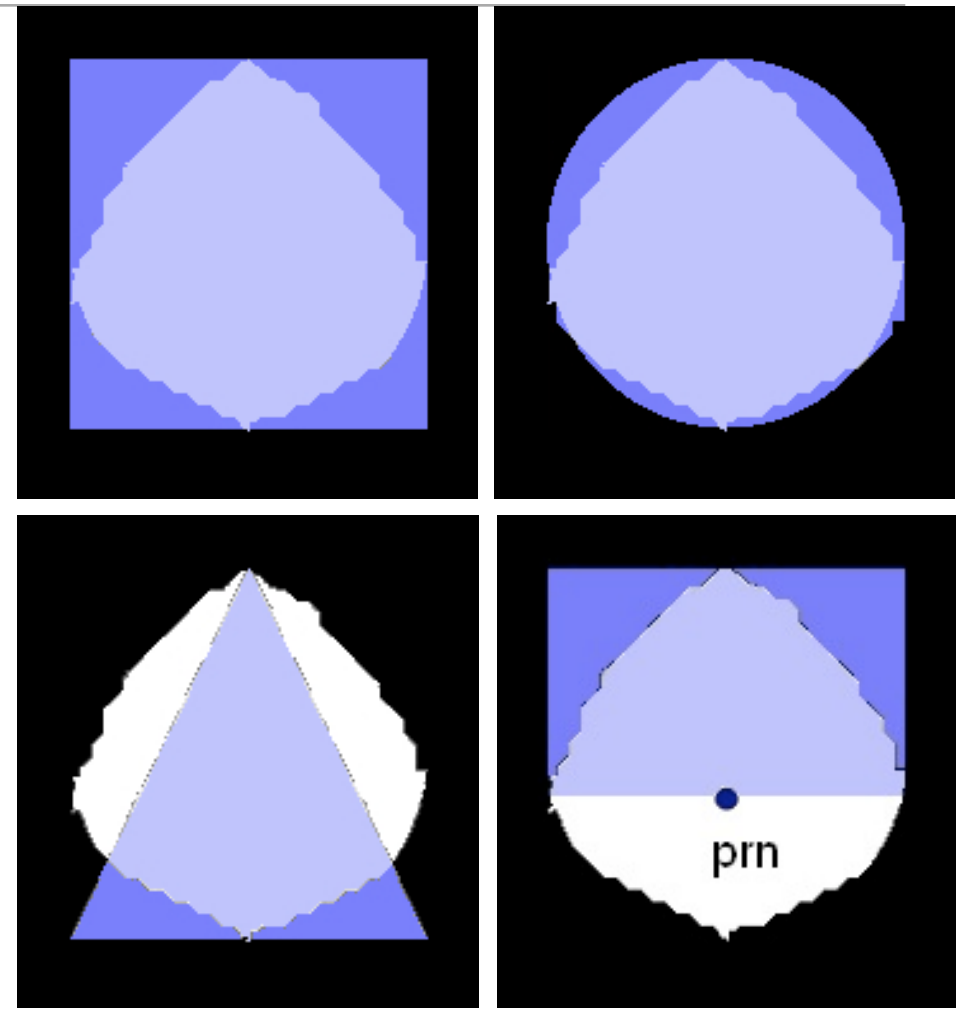


Shape-based Descriptor
Bulbous Nasal Tip

- Four severity measures
  - Rectangle
  - Circle
  - Triangle
  - Upper Rectangle

- Combined Bulbous Measure

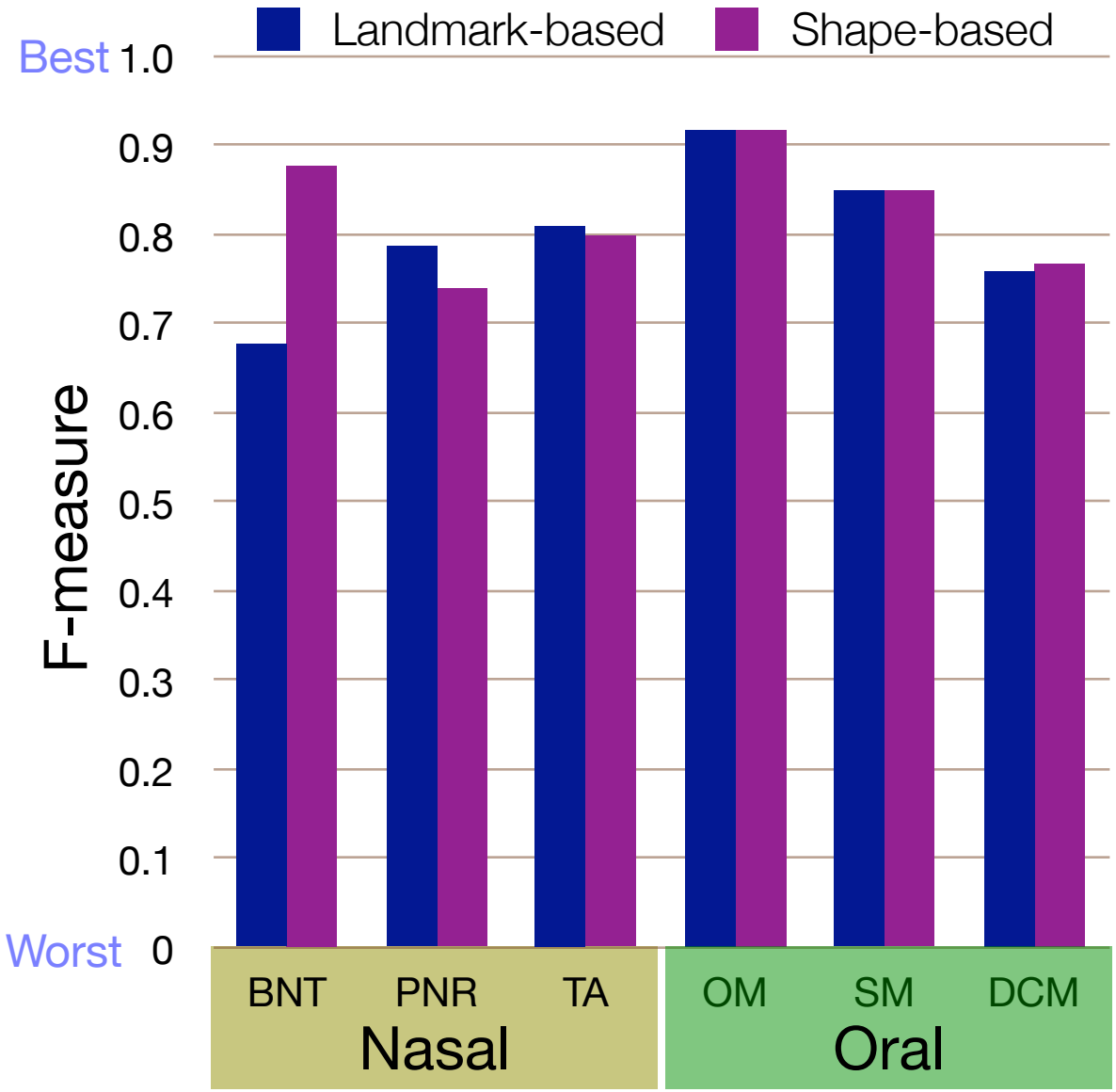
$$\beta = Severity_{Rect}(1 - Severity_{Circ})$$



Experiment Setup

- 43 affected, 43 control individuals
- Age range 10 months to 39 years
- Data labeled by median expert score for each facial feature
- W86 data set is 43:43 and ethnically similar
- Classifier used is SVM

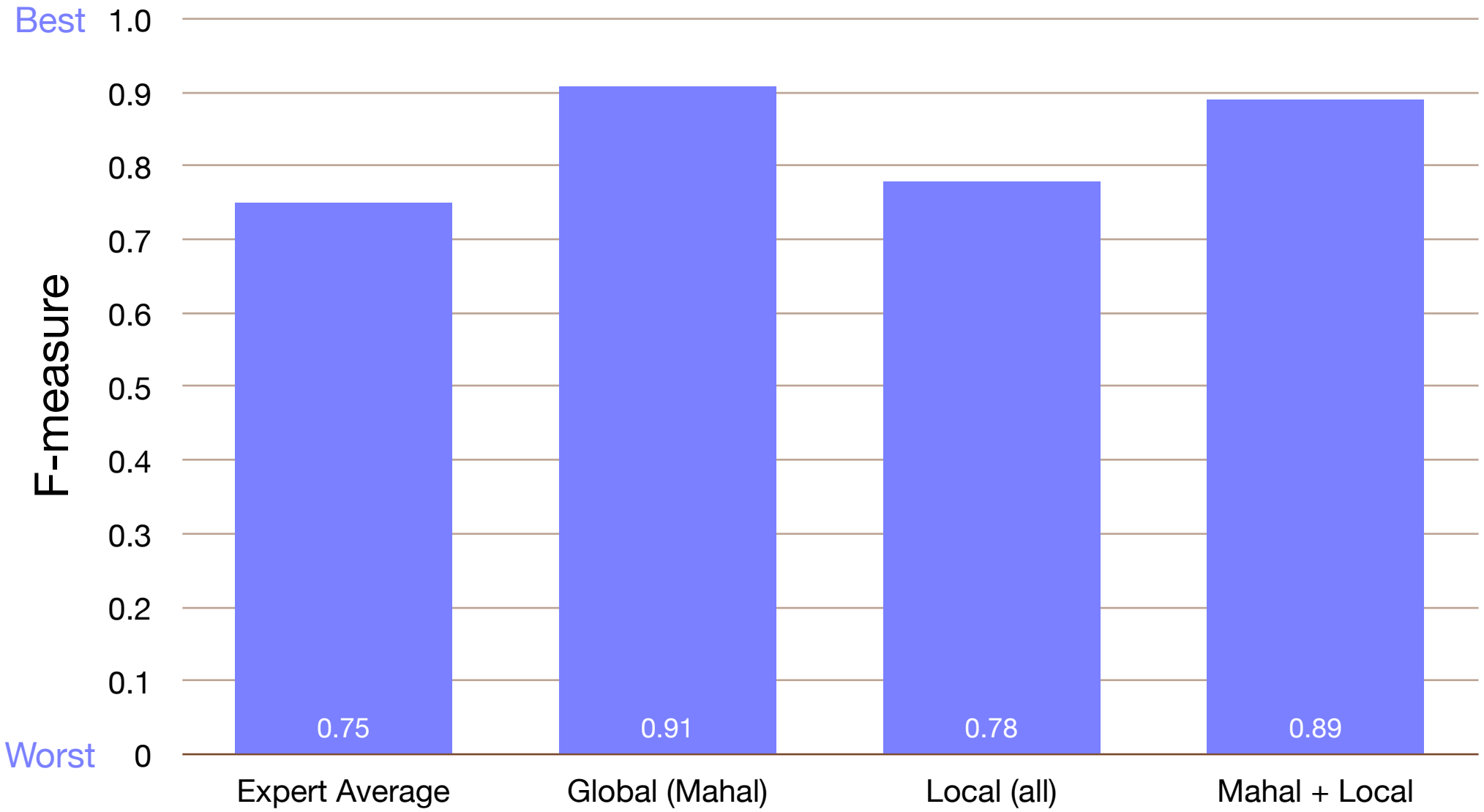
Similarity to Expert Assessment



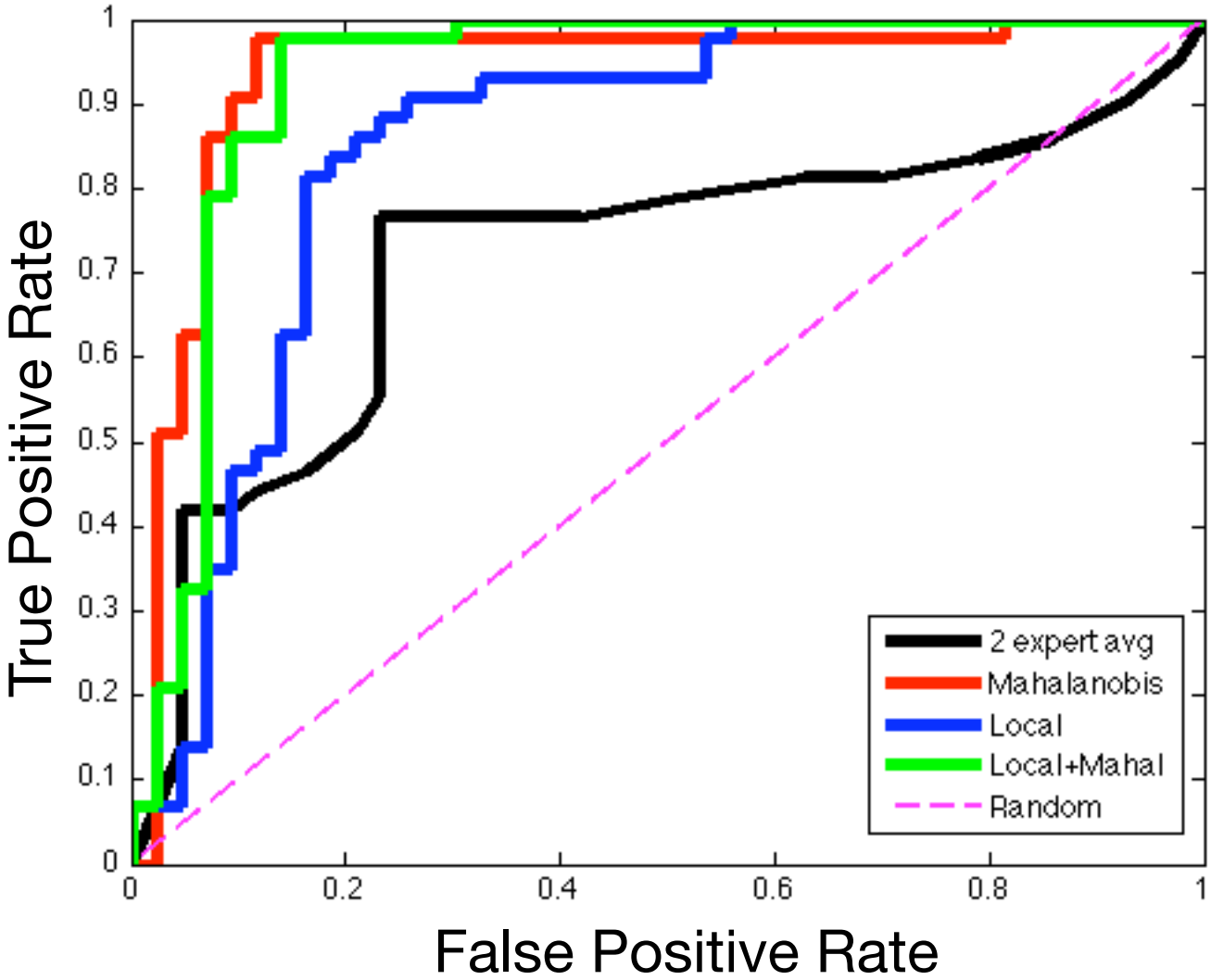
Correlation between experts

	E1	E2	E3
E1		-0.01	0.00
E2	0.30		0.34
E3	0.13	0.45	

Classification using Local Features



Classification of 22q11.2DS



Talk Outline

- Motivation
- Related Work
- Classification of 22q11.2DS
- Quantification of Local Facial Features
- Conclusions

Contributions

- Automated facial pose alignment
- Global data representations
- Automated nasal and oral landmark detection
    - Landmark-based descriptors
    - Shape-based descriptors
- Classification performance rivals experts
- Quantification of nasal and oral facial features

Potential Uses

- Automatic Craniofacial Assessment
- Genetic Test Filter
- Research into Genetic Causes of Facial Dysmorphology
- Biometrics

Future Directions

- Local facial feature description
  - Ears
  - Eyes
  - Midface Hypoplasia
  - Pinched Nasal Alae
  - Retrusive Chin

- Quantitative facial description

Acknowledgements

- PhD Committee Members

  Linda Shapiro, PhD; James Brinkley, MD, PhD; Maya Gupta, PhD
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  Michael Cunningham, MD; Erik Stuhaug; Kristen Upson

- Research Group

- Practice talk participants

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