AVERAGING FACIAL IMAGES

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Average Face in Three Dimensions

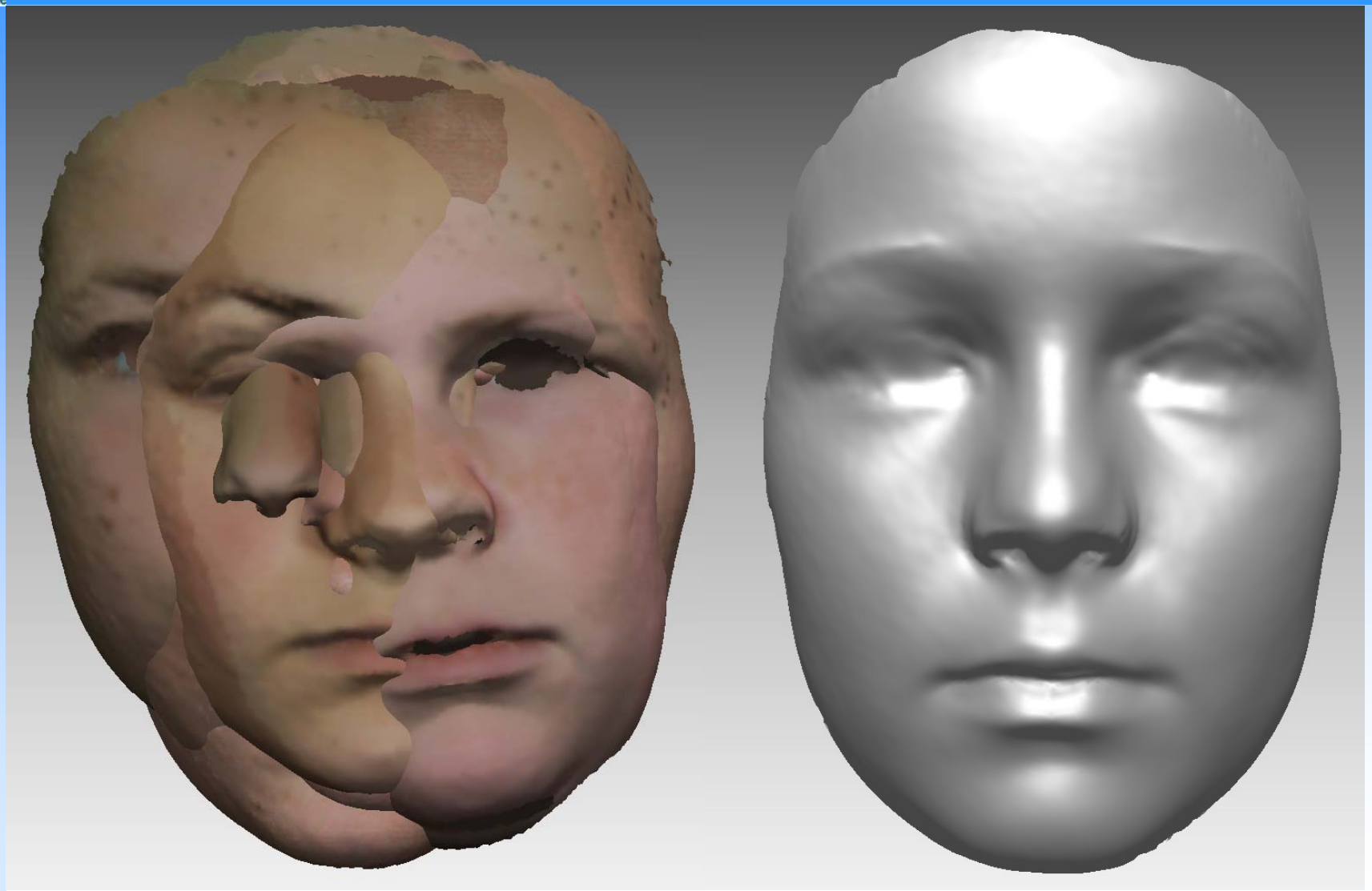


Image acquisition

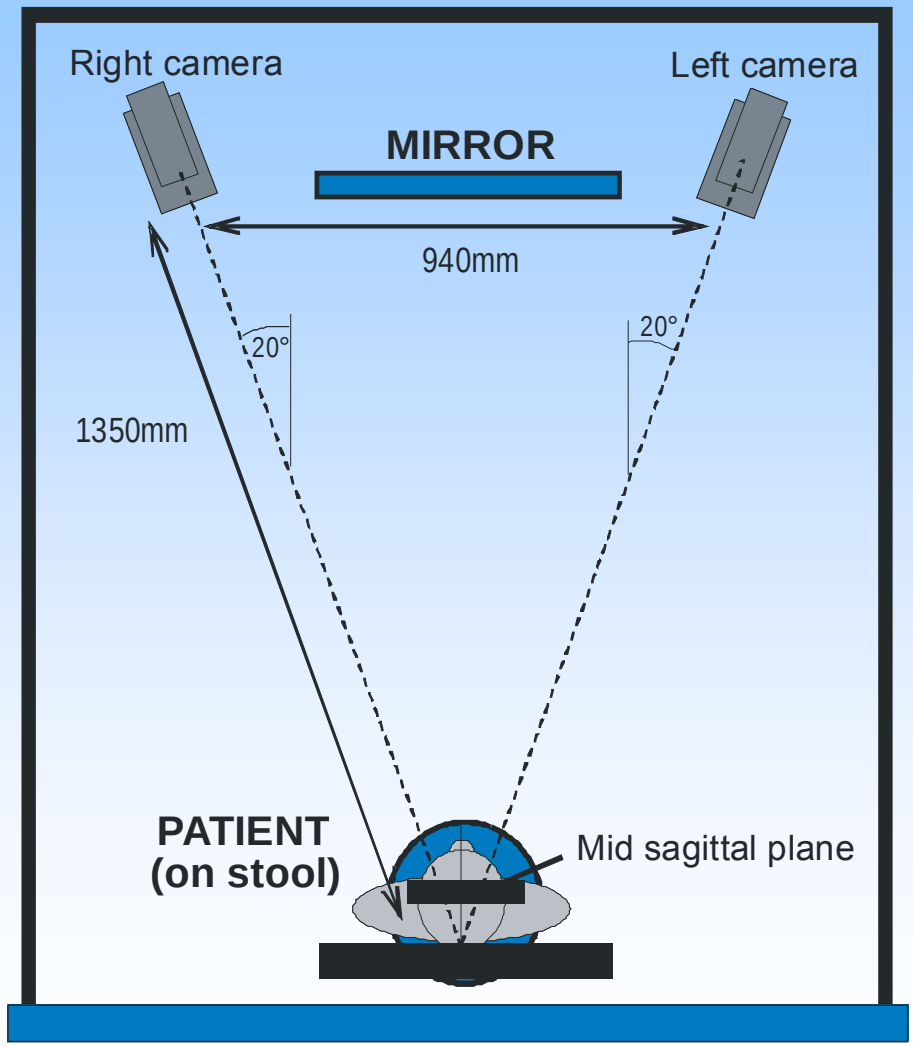


Image acquisition

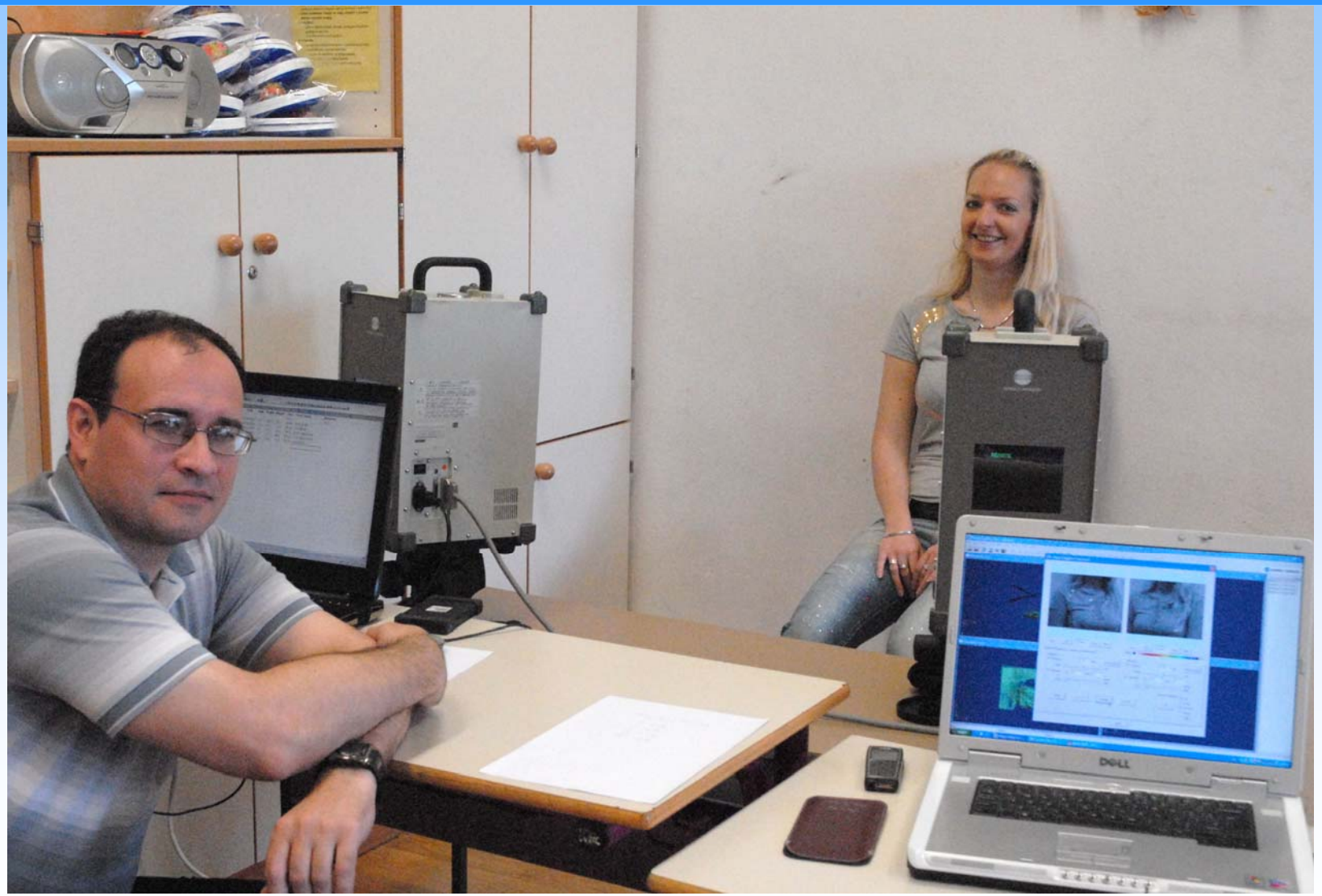
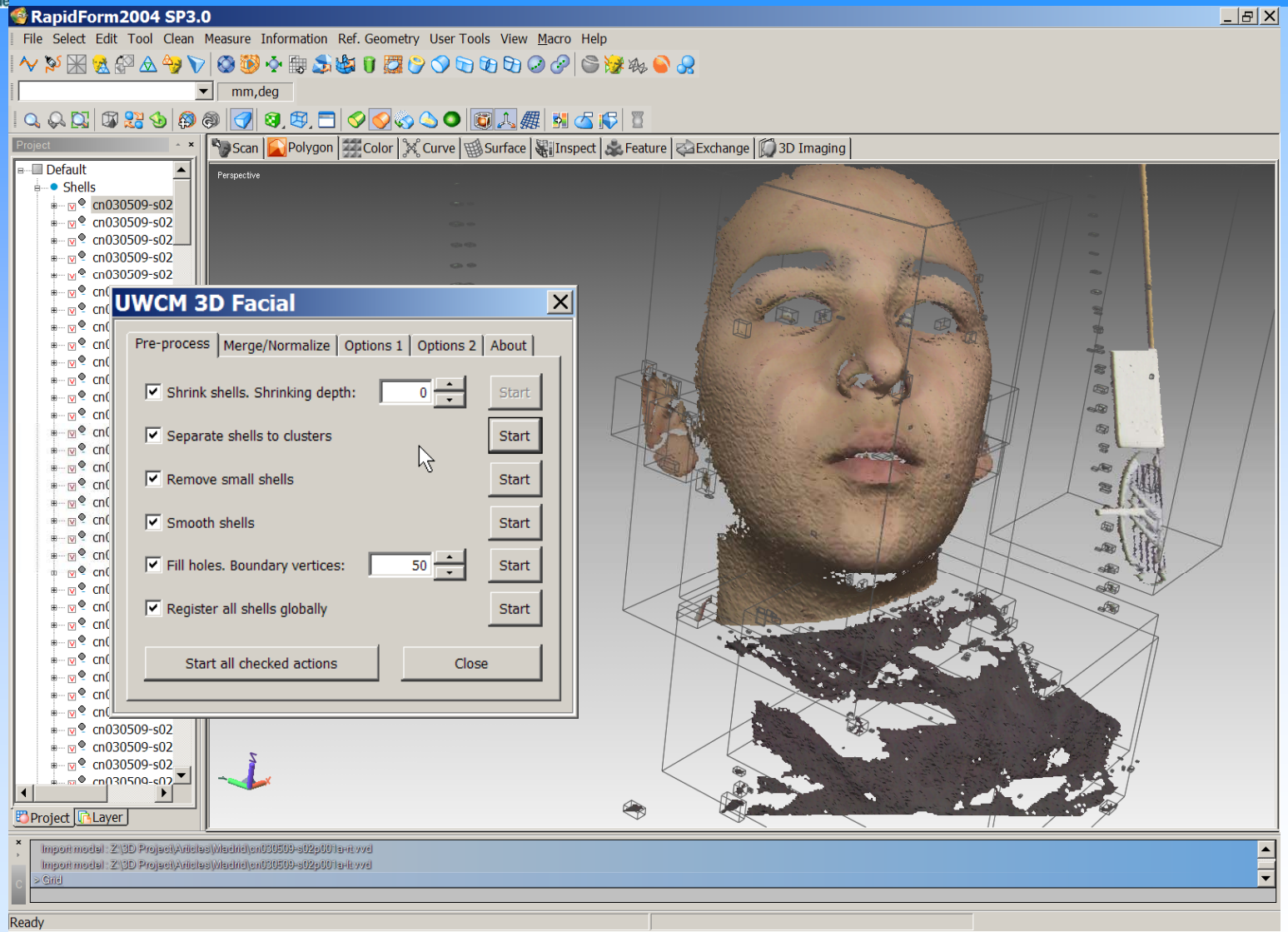
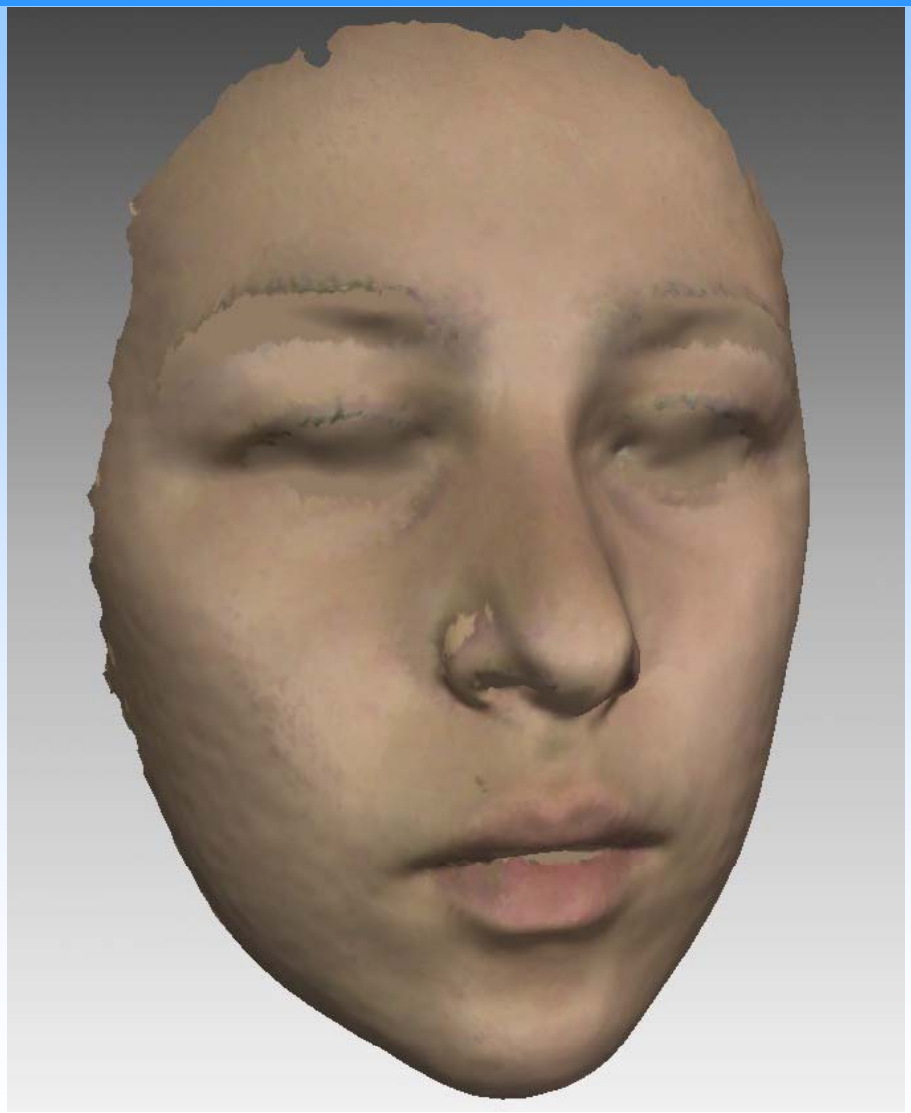


Image processing

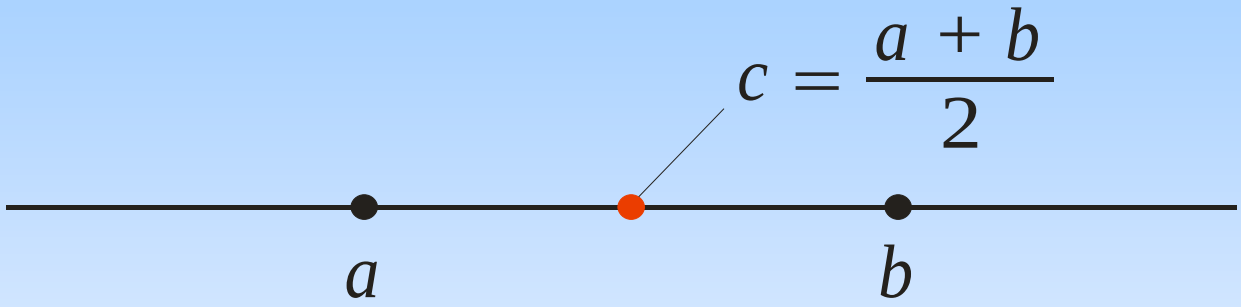


Resulting image



Averaging is one dimension

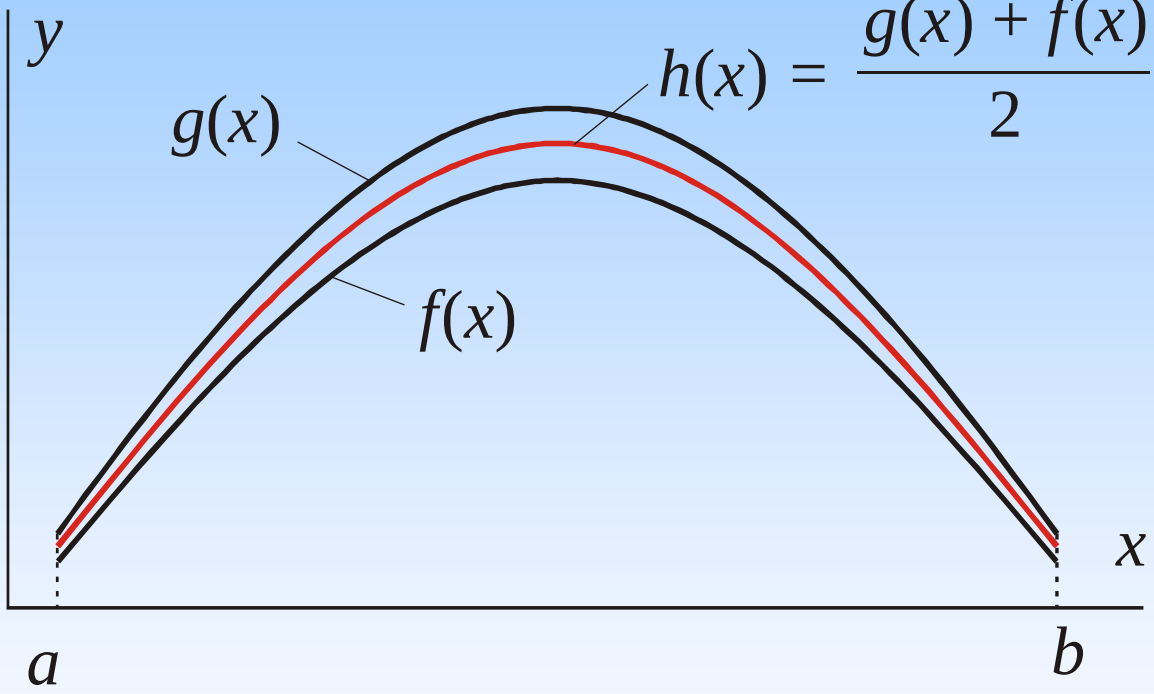
- One-dimensional data → Arithmetic mean



$$x_{\text{ave}} = \frac{x_1 + \cdots + x_N}{N}$$

Averaging in two dimensions

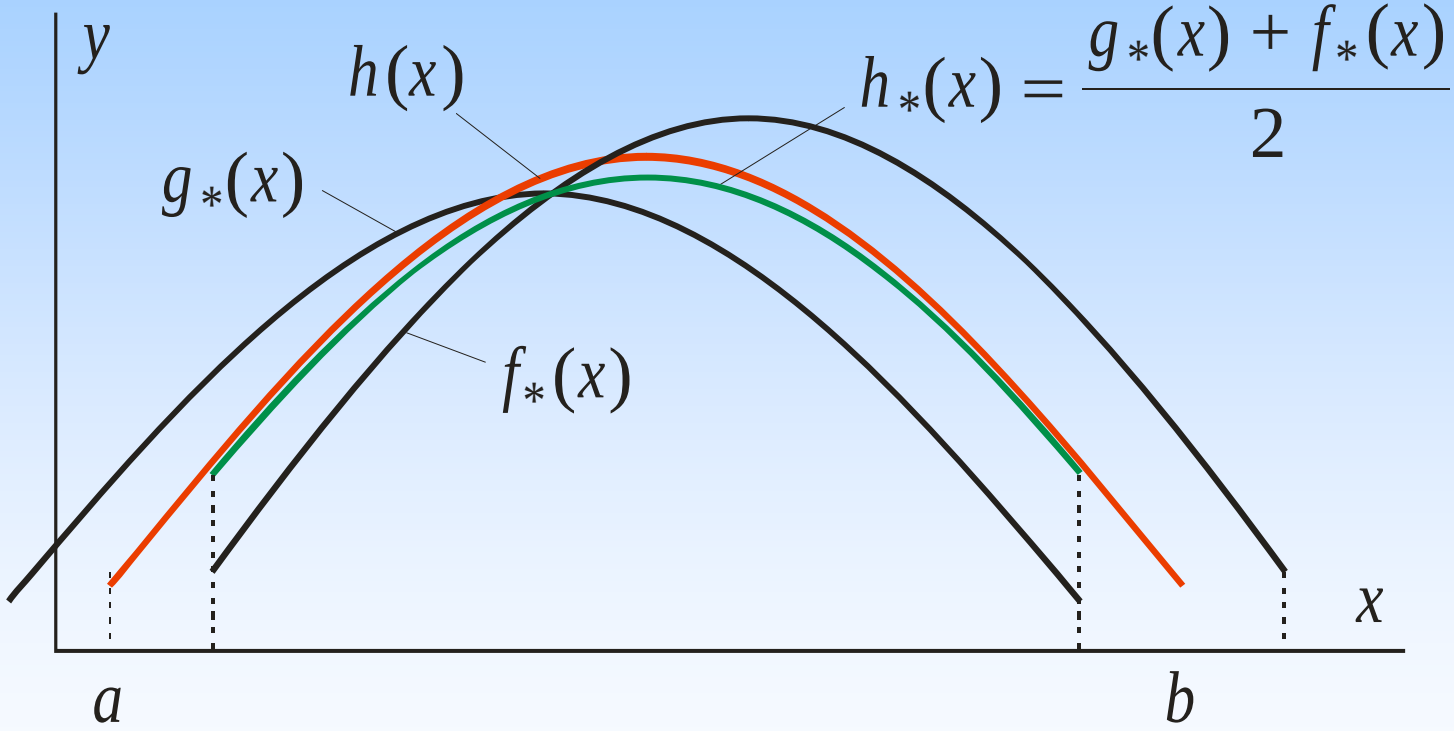
- Curves aligned



$$f_{\text{ave}}(x) = \frac{f_1(x) + \cdots + f_N(x)}{N}, \qquad a \le x \le b$$

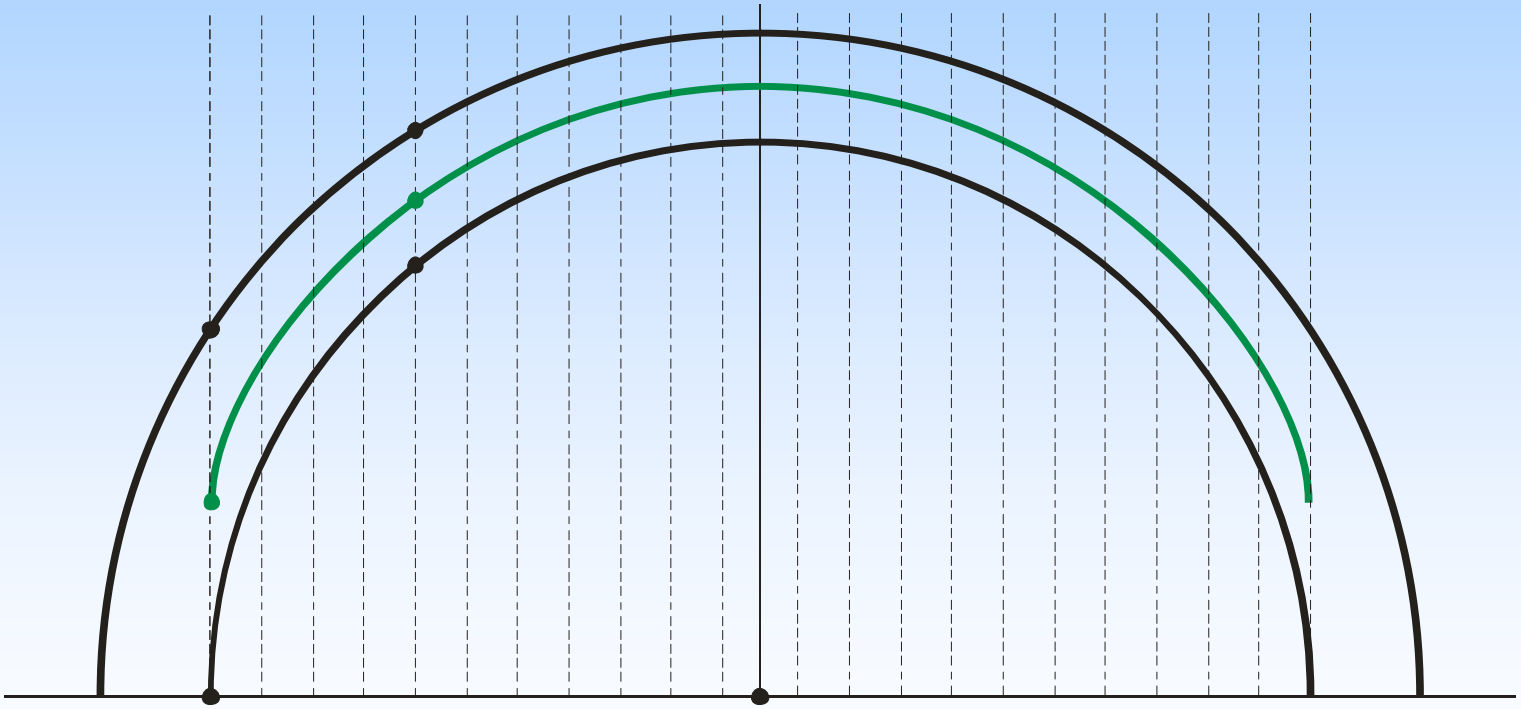
Averaging in two dimensions

- Curves unaligned



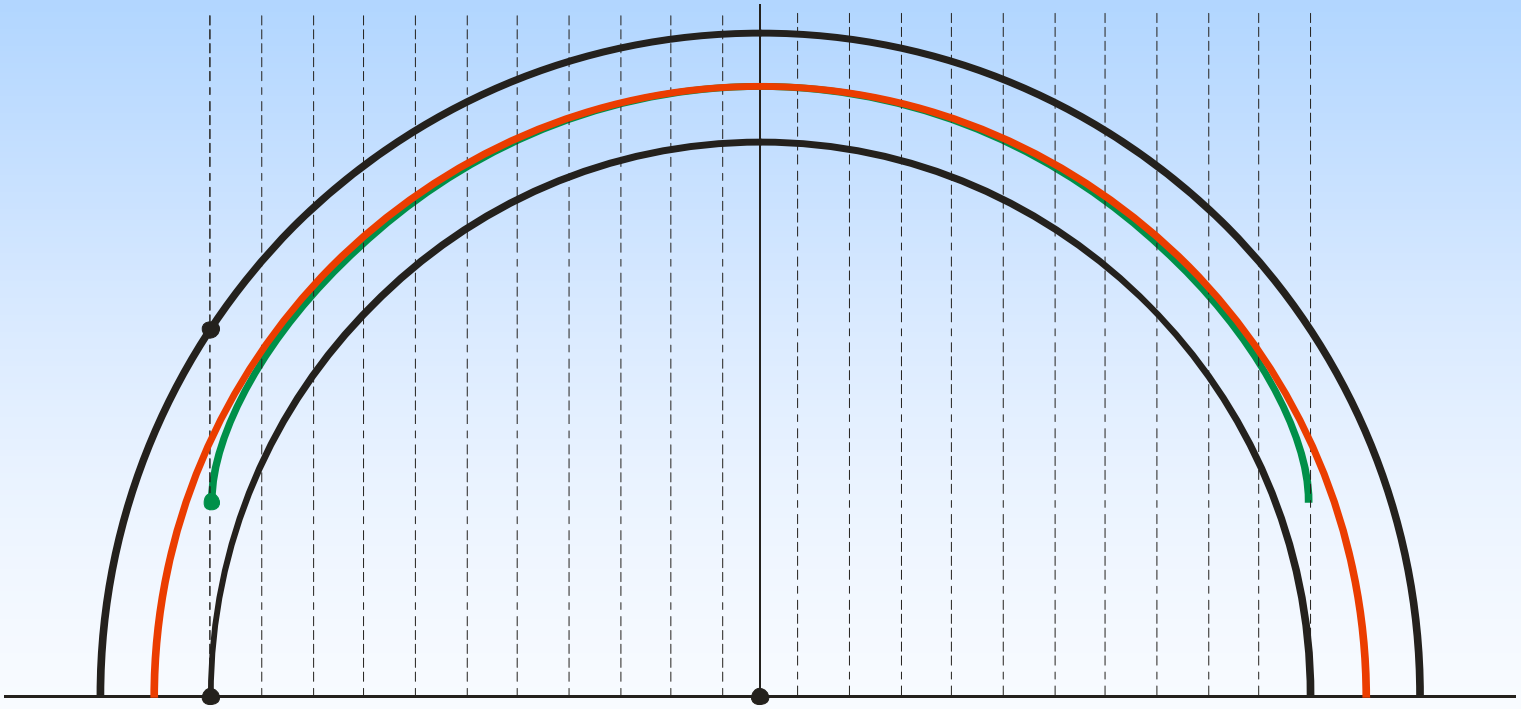
Example: Averaging of semicircles

- Averaging in vertical direction



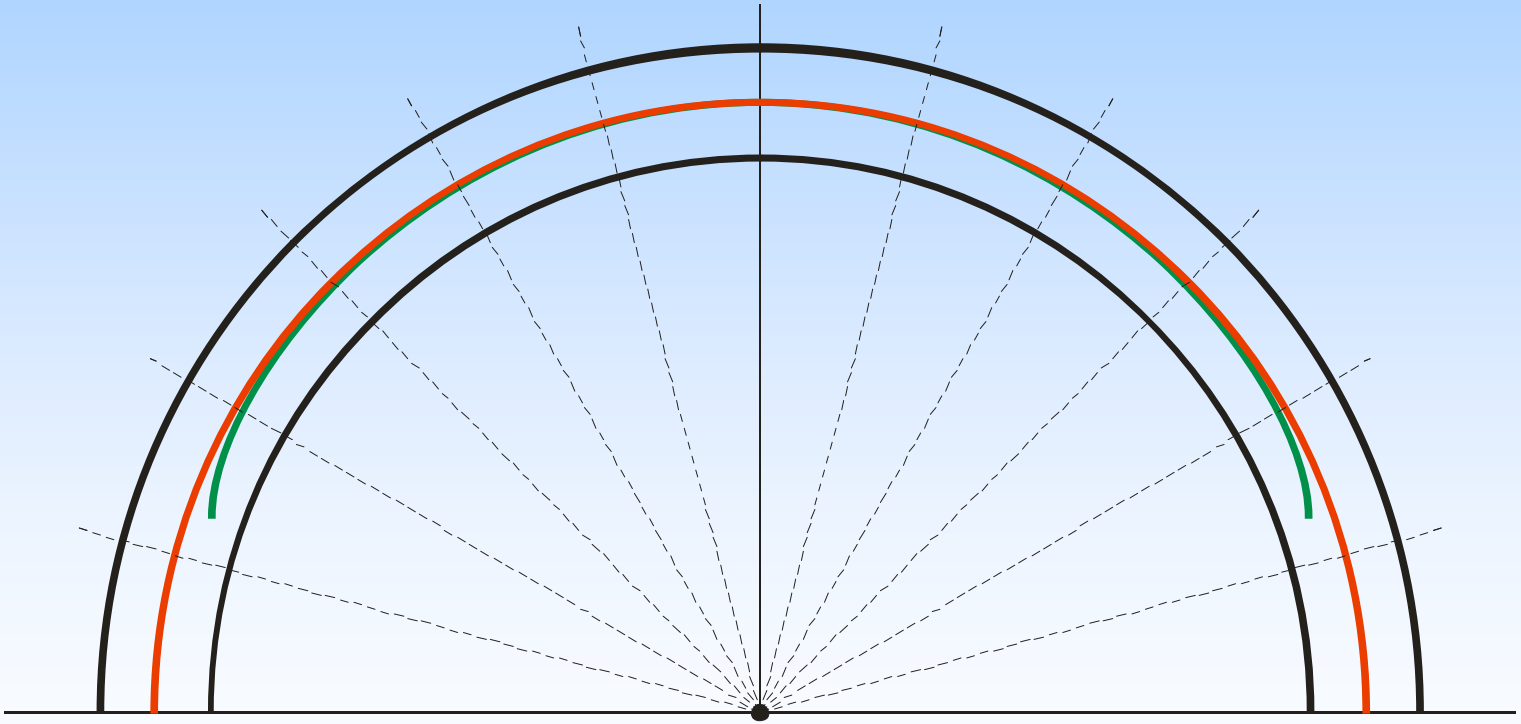
Example: Averaging of semicircles

- Intuitively this is not right



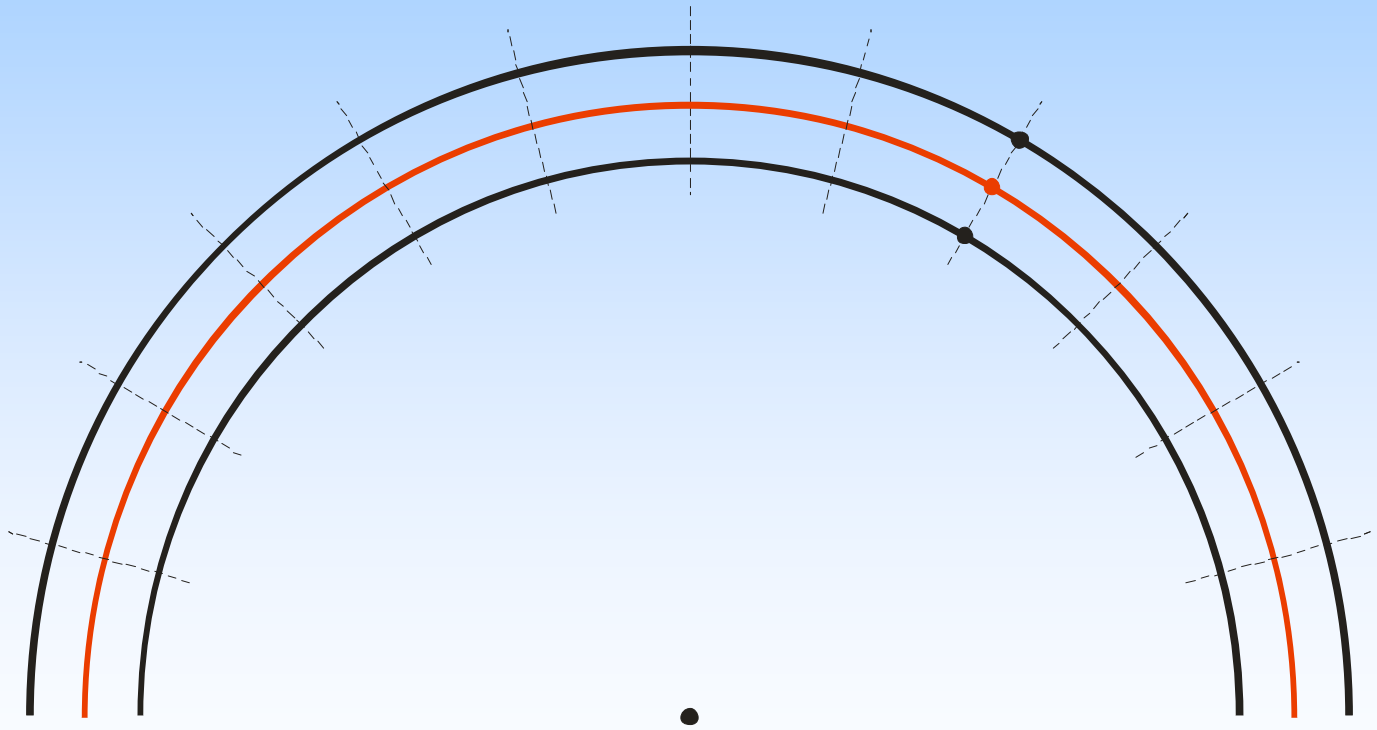
Example: Averaging of semicircles

- Averaging should be made in radial direction



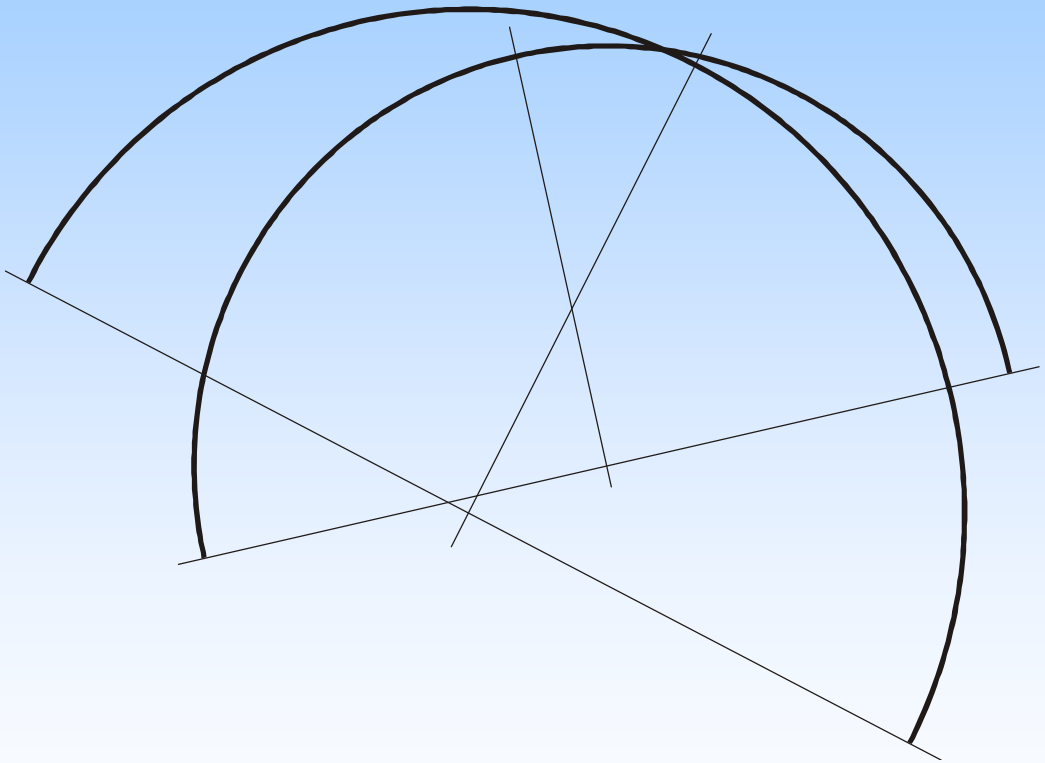
Example: Averaging of semicircles

- More generally, averaging should be made in normal direction



Example: Averaging of semicircles

- How to average if the figures are unaligned?



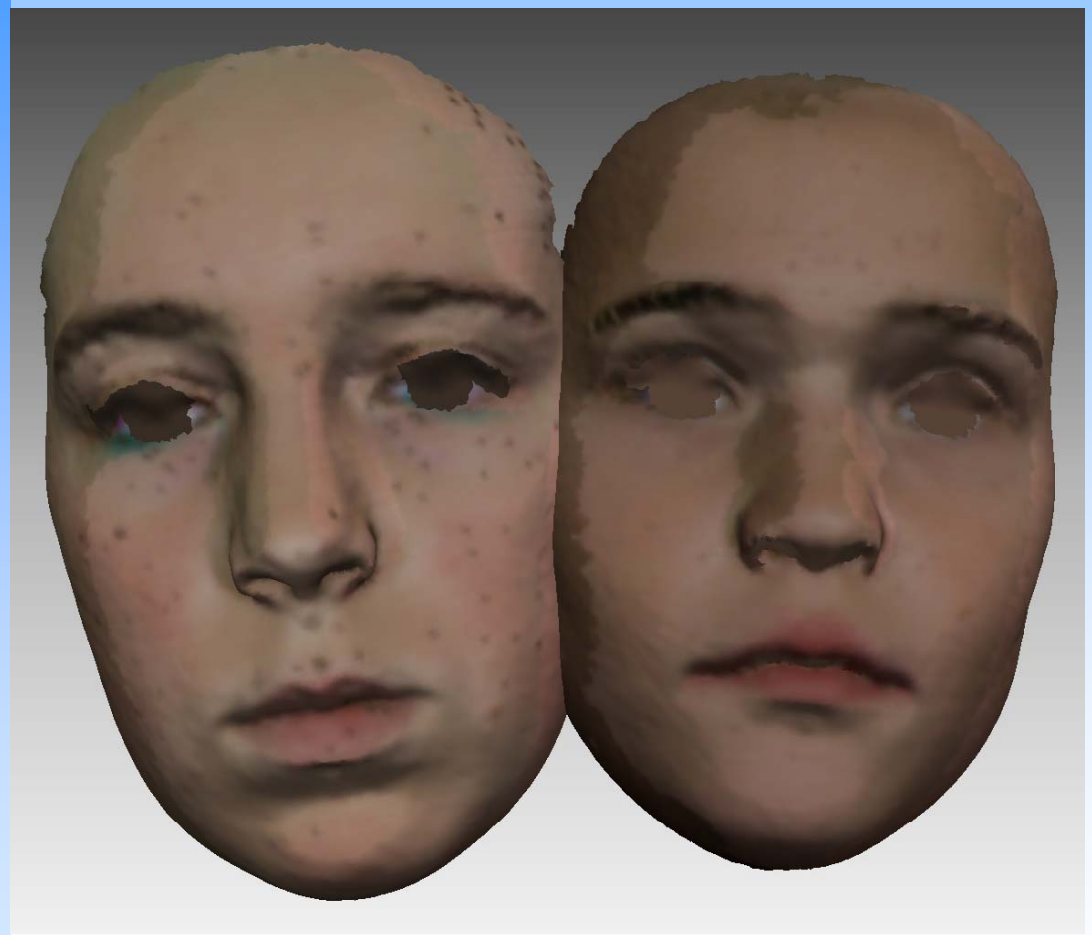
- Align them first by removing translation and rotation

Objects must be aligned

Unaligned

Best-fit aligned

Objects should have same size



Unscaled and unaligned

Scaled and aligned

What is 3D averaging?

3D facial average is a face that:

- Has average size
- Has average shape

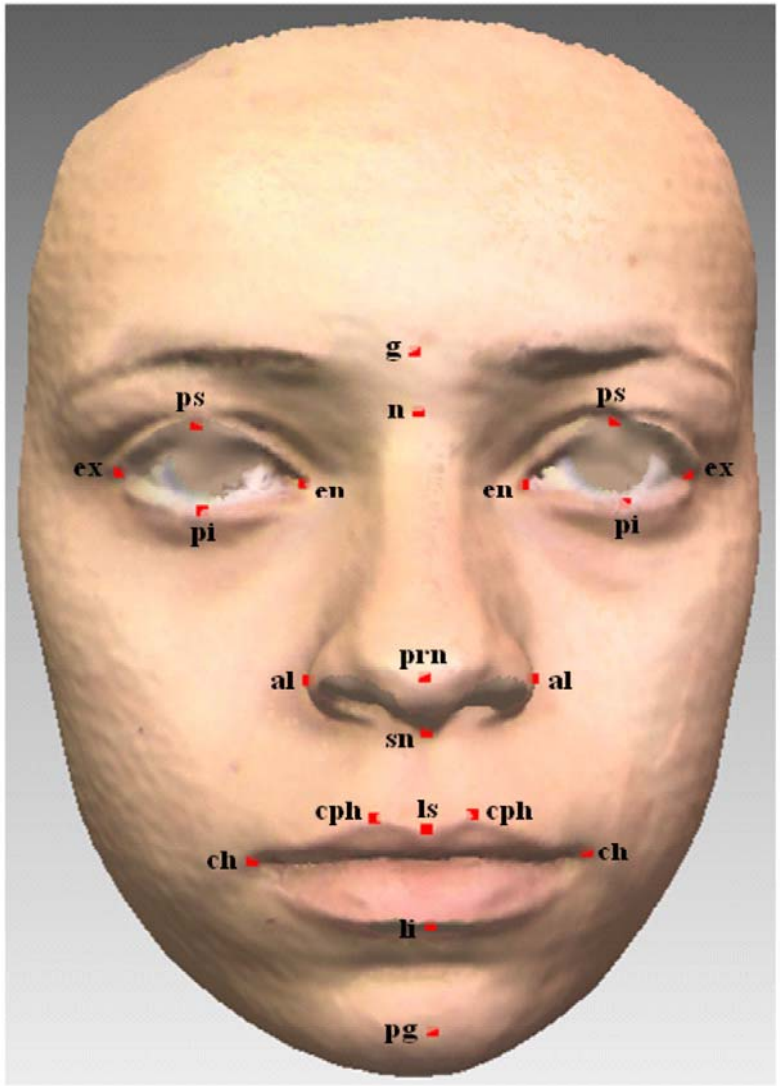
Averaging involves:

- Removal of translation
- Removal of rotation
- Removal of size differences
- Averaging method

Problem:

- How to do all of these?

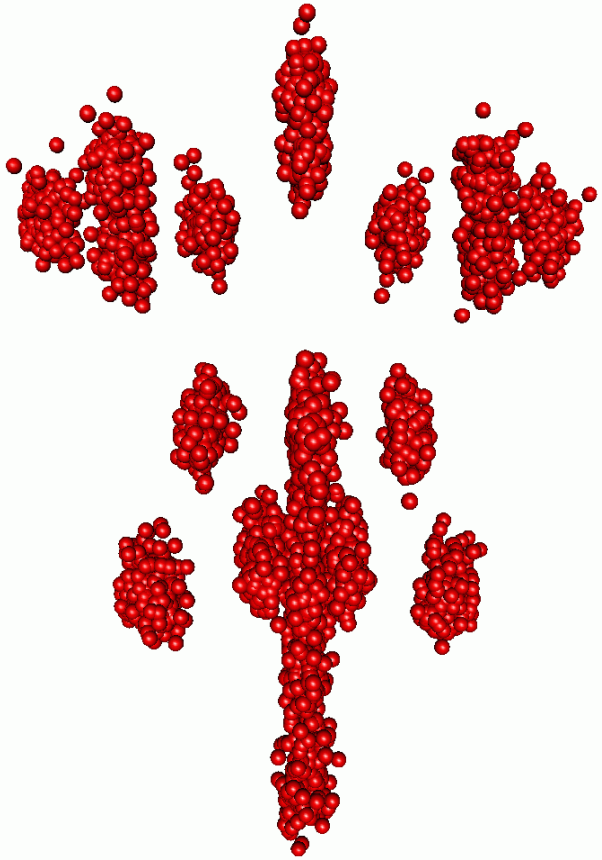
Facial landmarks

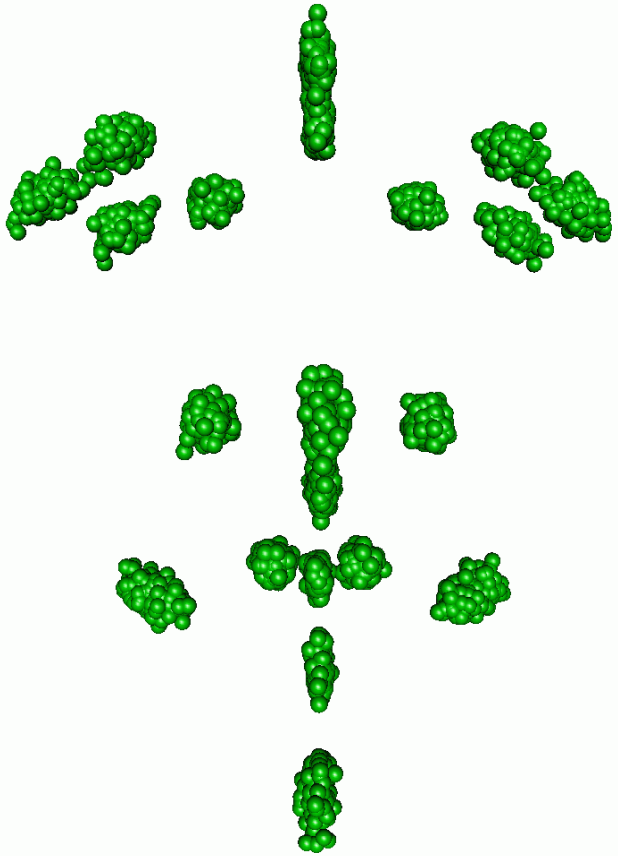


Landmarks

- Glabella (g)
- Nasion (n)
- Endocanthion (en) L/R
- Exocanthion (ex) L/R
- Palpebrale superius (ps) L/R
- Palpebrale inferius (pi) L/R
- Pronasale (prn)
- Subnasale (sn)
- Alare (al) L/R
- Labiale superius (ls)
- Labiale inferius (li)
- Crista philtri (cph) L/R
- Cheilion (ch) L/R
- Pogonion (pg)

Choosing the origin





Standard deviations for landmarks

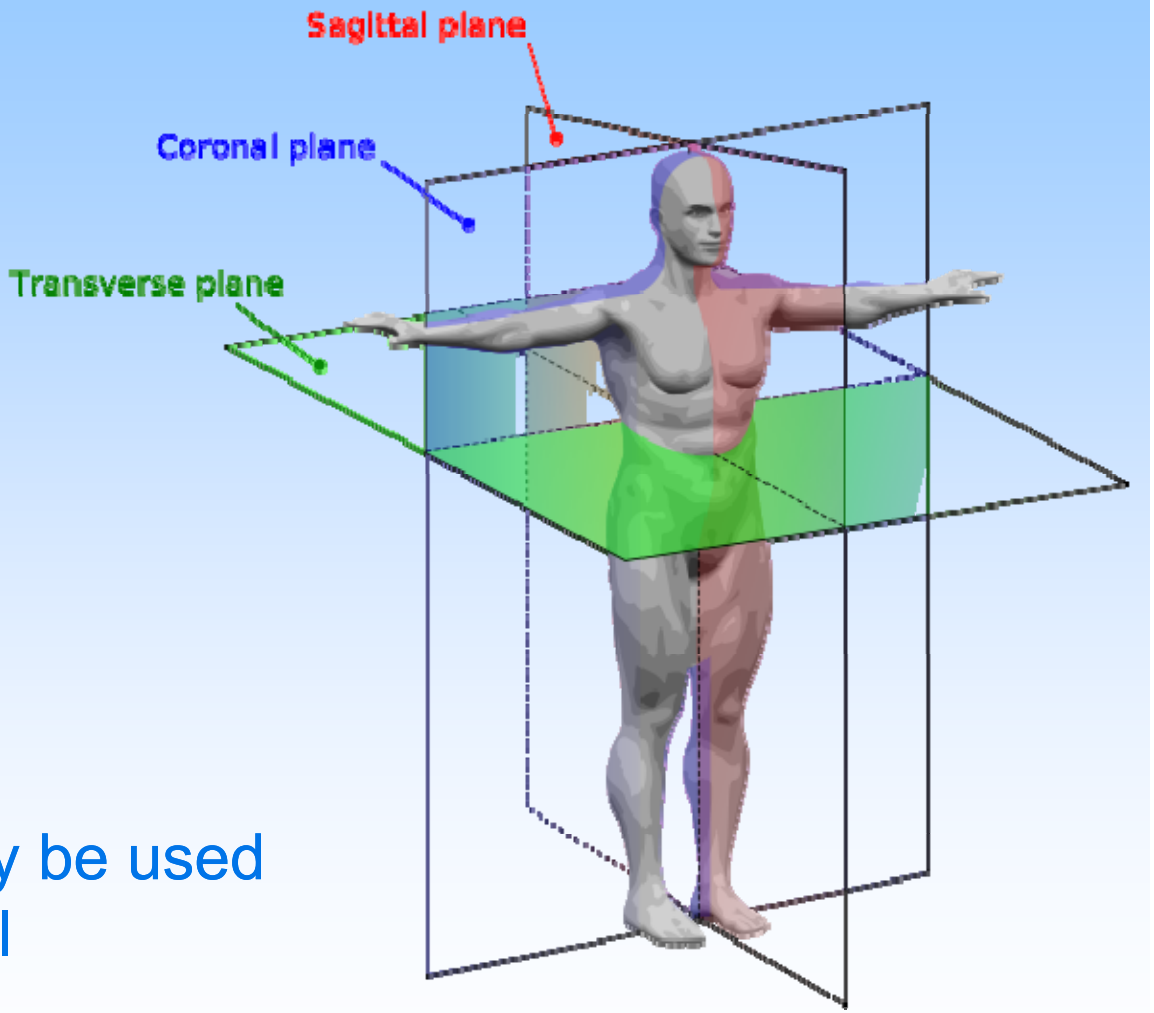
	Initial data, best-fit registration				GPA registration with scaling				GPA registration without scaling			
	X	Y	Z	Dist	X	Y	Z	Dist	X	Y	Z	Dist
g	1.177	3.164	1.811	3.831	0.562	1.827	1.899	2.695	0.560	2.540	1.921	3.234
n	1.015	2.749	2.151	3.635	0.508	1.761	1.707	2.505	0.506	2.439	1.717	3.025
enL	1.617	2.767	2.686	4.181	1.329	1.075	1.468	2.253	1.415	1.725	1.664	2.783
enR	1.616	2.786	2.430	4.035	1.308	1.089	1.334	2.162	1.411	1.770	1.524	2.728
exL	2.229	3.103	3.066	4.899	2.107	1.481	1.493	2.977	2.064	1.853	1.813	3.314
exR	2.331	3.029	2.619	4.633	2.141	1.486	1.407	2.962	2.204	1.982	1.722	3.428
psL	1.900	3.063	2.390	4.325	1.597	1.346	1.452	2.544	1.622	1.916	1.615	2.985
psR	1.912	3.021	2.145	4.169	1.541	1.321	1.509	2.529	1.607	1.972	1.659	3.037
piL	1.809	2.940	2.751	4.414	1.645	1.259	1.447	2.527	1.634	1.787	1.651	2.931
piR	1.831	2.912	2.492	4.247	1.552	1.232	1.498	2.484	1.640	1.827	1.669	2.969
prn	1.122	3.167	3.330	4.730	0.905	2.062	2.300	3.219	0.903	2.064	2.627	3.460
sn	0.895	3.134	2.917	4.374	0.580	1.657	1.775	2.496	0.579	1.736	1.942	2.669
alL	1.404	2.766	2.723	4.128	1.237	1.263	1.641	2.412	1.407	1.304	1.707	2.568
alR	1.501	2.664	2.674	4.062	1.286	1.280	1.781	2.542	1.455	1.307	1.884	2.716
ls	1.125	3.423	2.654	4.475	0.448	1.127	1.267	1.754	0.447	1.776	1.569	2.411
li	1.298	4.497	2.584	5.346	0.454	1.837	1.578	2.464	0.454	2.974	1.668	3.440
cphL	1.318	3.363	2.544	4.418	0.894	1.095	1.096	1.789	0.932	1.655	1.370	2.341
cphR	1.363	3.304	2.521	4.374	0.889	1.061	1.130	1.787	0.894	1.620	1.445	2.347
chL	2.165	3.608	3.063	5.205	1.991	1.380	1.841	3.043	2.007	2.169	1.841	3.482
chR	2.332	3.669	2.713	5.125	2.099	1.357	1.768	3.062	2.166	2.215	1.782	3.574
pg	1.679	5.553	2.698	6.398	0.819	2.502	2.925	3.935	0.820	4.364	2.822	5.261
men	0.925	2.725	2.477	3.797	0.485	1.011	1.291	1.710	0.487	1.704	1.498	2.321
mex	0.995	2.824	2.672	4.013	0.570	1.314	1.299	1.934	0.575	1.790	1.647	2.500
menex	0.900	2.677	2.403	3.708	0.409	0.919	0.910	1.357	0.410	1.589	1.273	2.077

Most stable point

- The most stable point in the area around the eyes is mid-endocanthion
- It is logical to take it as the origin

Introduction of reference planes

- In human body anatomy three planes are introduced
- Sagittal plane (also known as median or mid-sagittal plane)
- Coronal plane (frontal plane)
- Transverse plane (horizontal plane)

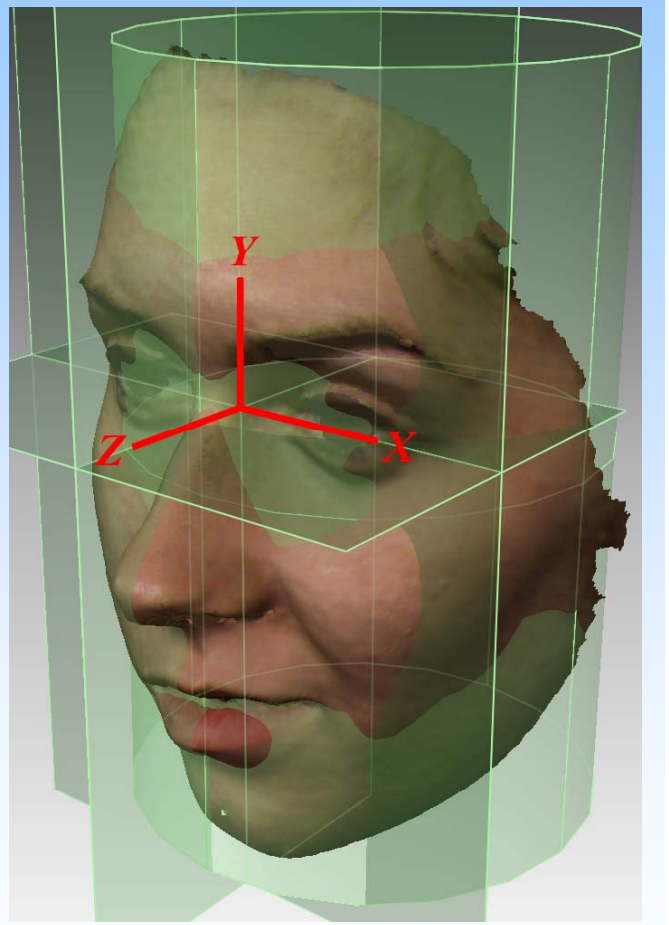


- Similar planes may be used for the face as well

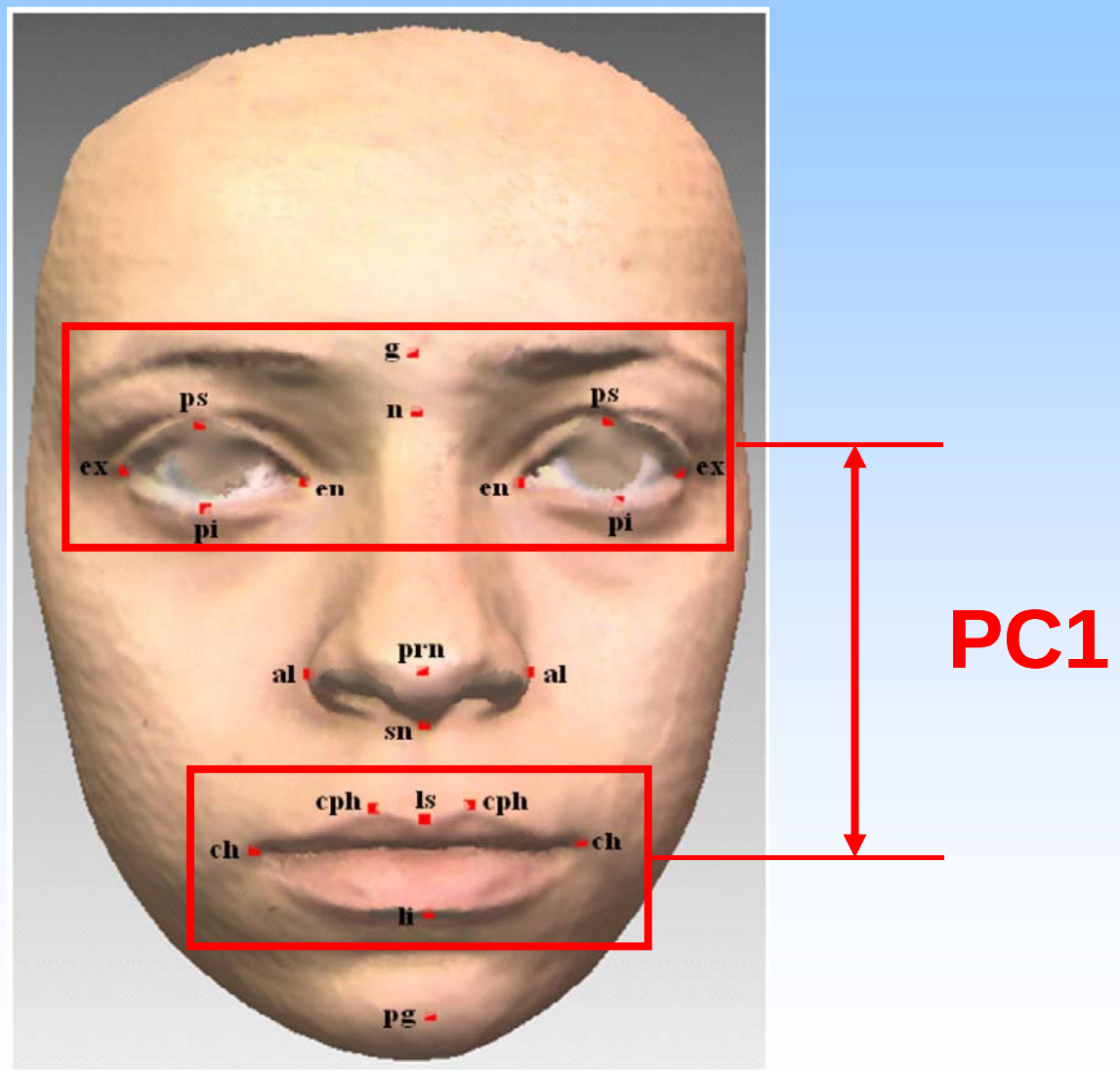
Sagittal plane

- Sagittal plane = symmetry plane
- What is the symmetry plane in the face?
- All faces are asymmetric!

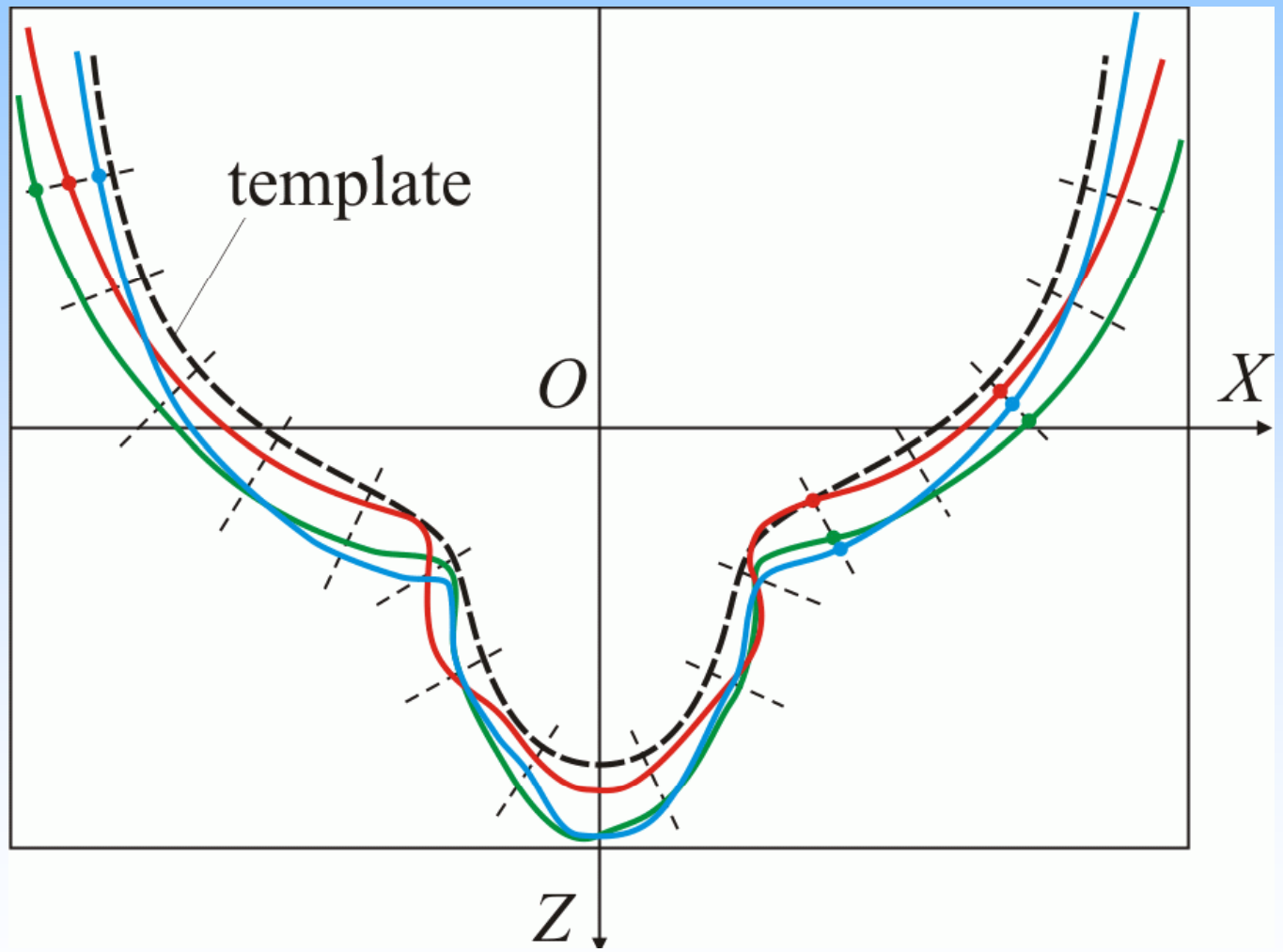
Defining reference frame



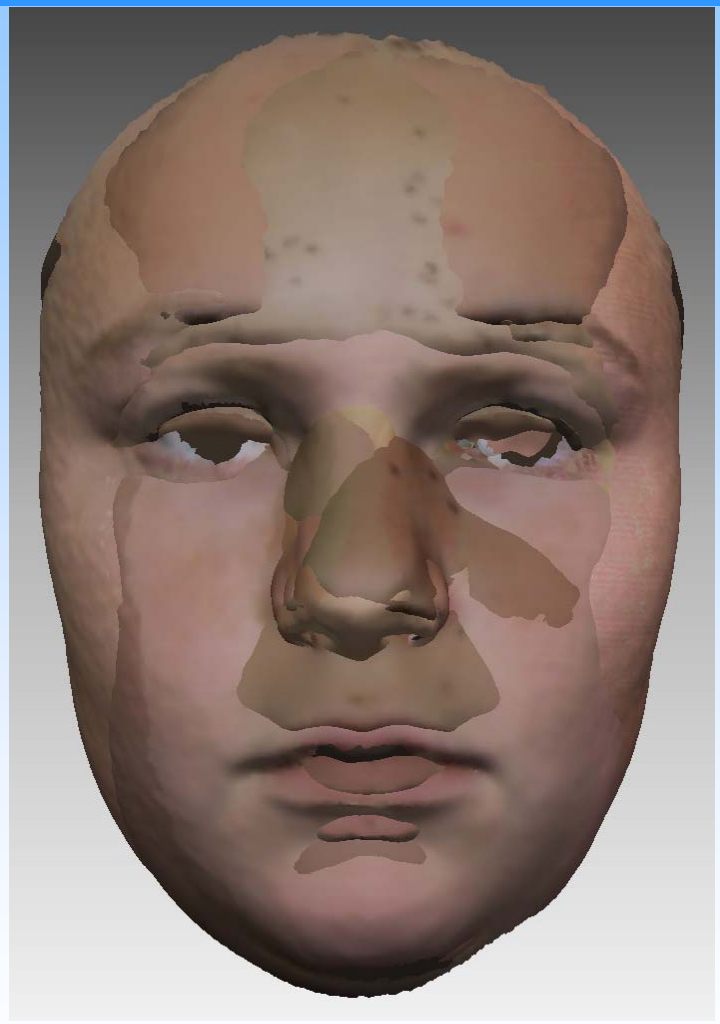
Facial size



Method of averaging



Facial averaging



Unaligned

Aligned on mid-endocanthion

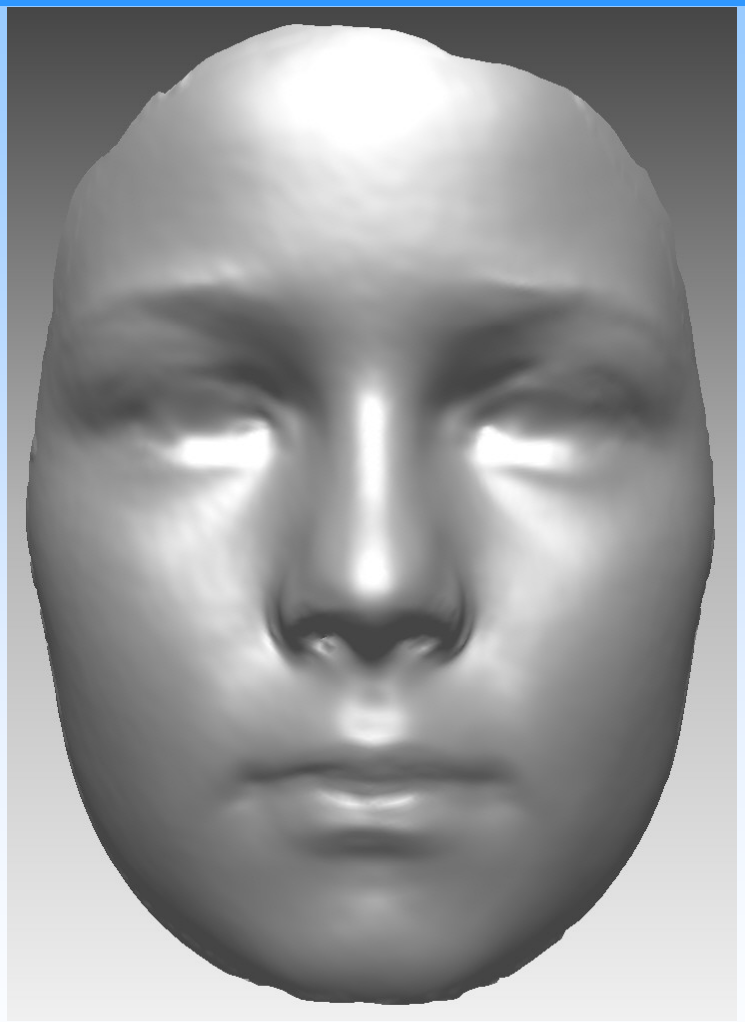
Facial averaging

	A	B	C	D
1	**Shell name**	**PC1 size**	**Rel size**	**Inv rel size**
2	SMC-013-T4-B0B1	69.137	0.9902	1.0099
3	SMC-014-T4-B0B1	68.646	0.9831	1.0171
4	SMC-017-T4-B0B1	78.350	1.1221	0.8912
5	SMC-024-T4A	68.028	0.9743	1.0264
6	SMC-027-T4-B0B1	68.663	0.9834	1.0169
7	SMC-028-T4-B0B1	72.349	1.0362	0.9651
8	SMC-030-T4-B0B1	65.853	0.9431	1.0603
9	SMC-035-T4A	66.696	0.9552	1.0469
10	SMC-040-T4A	71.135	1.0188	0.9816
11	SMC-041-T4-B0B1	69.371	0.9935	1.0065
12	**Mean**	**69.823**	**1.0000**	**1.0000**

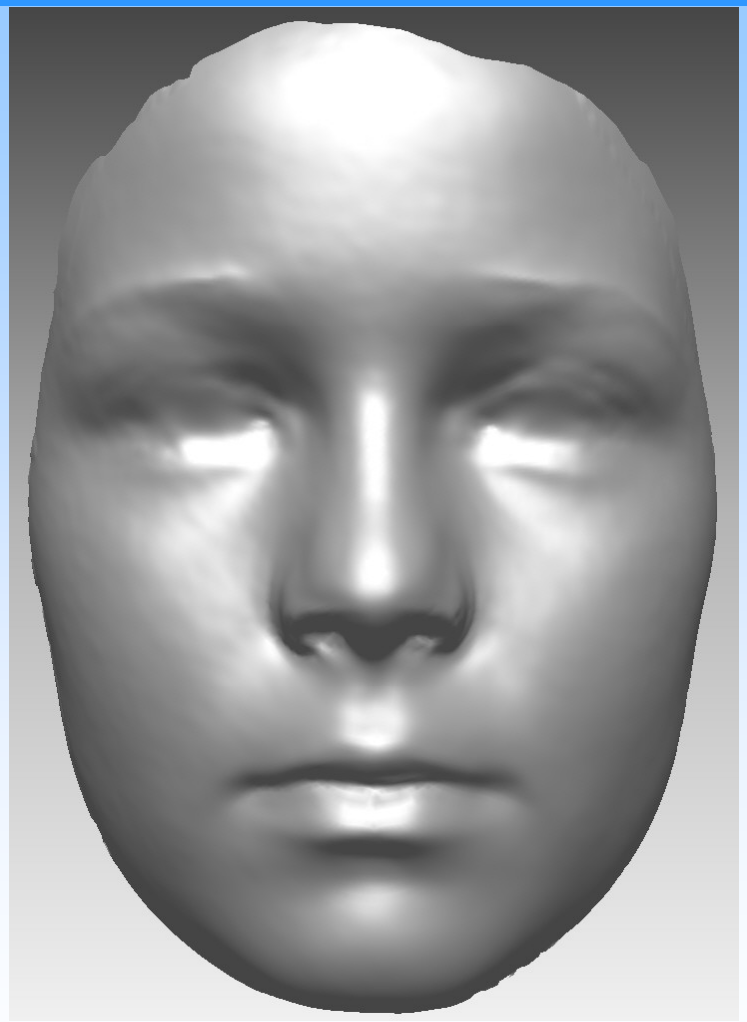
Face sizes: PC1

Aligned and scaled

Scaled vs unscaled average

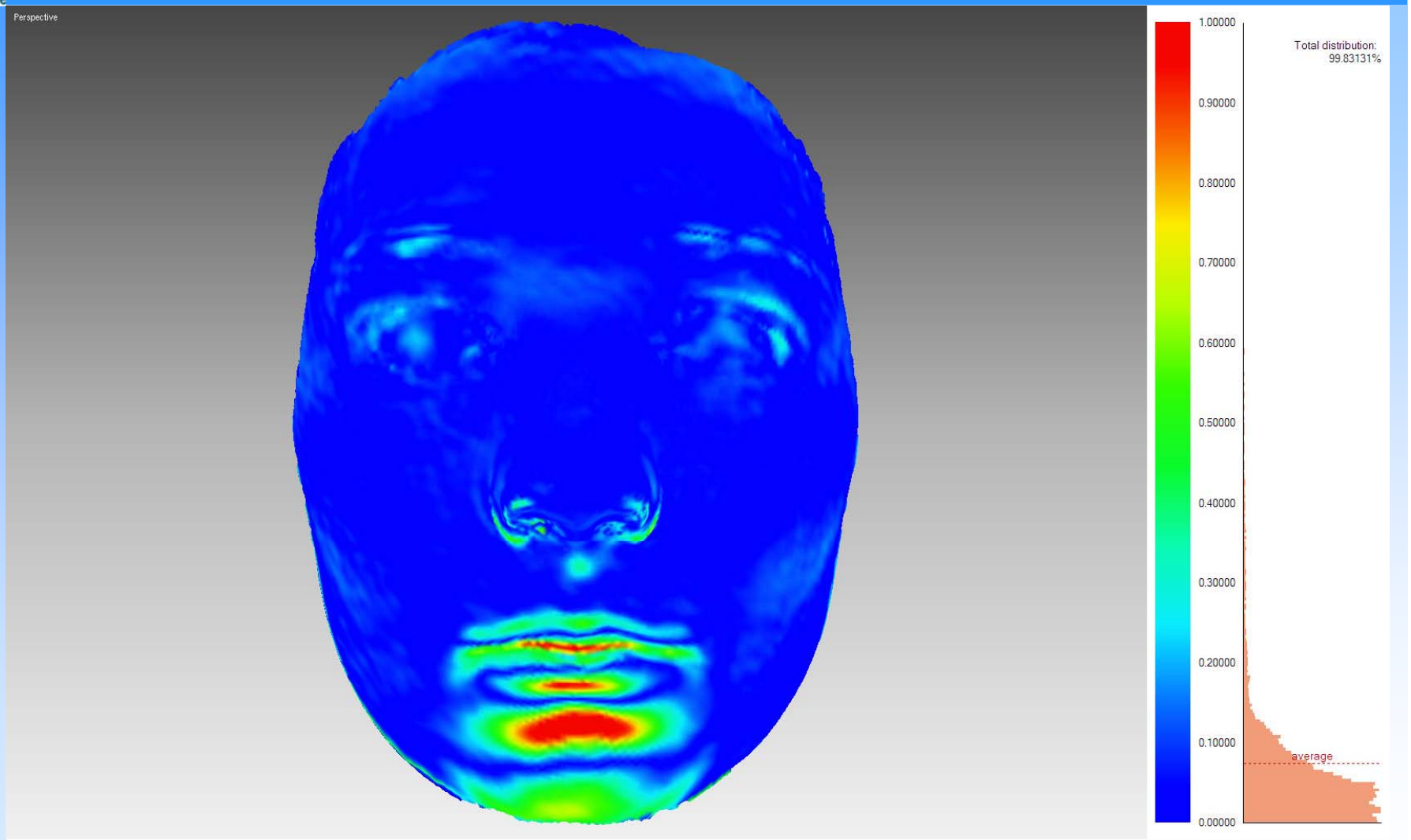


Unscaled average

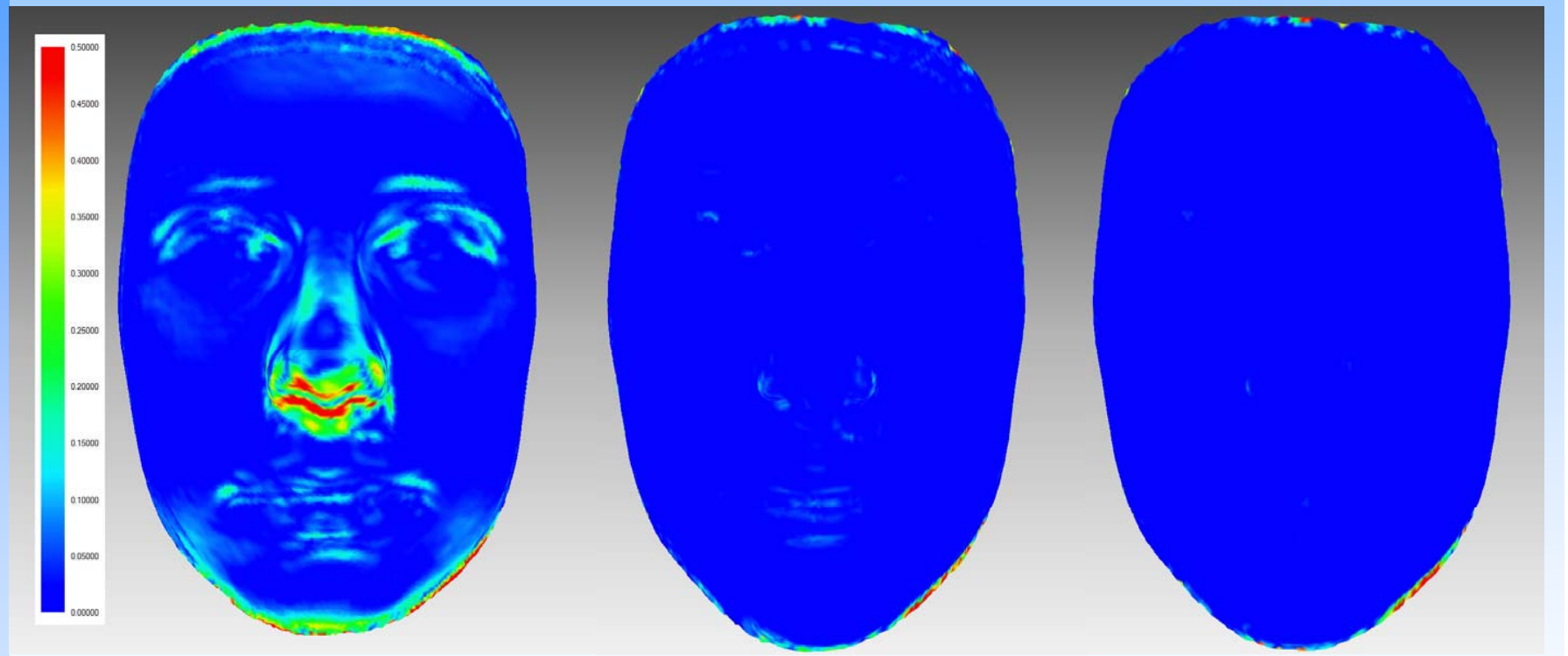


Scaled average

Scaled vs unscaled average



Convergence of averaging iterations



T2 vs T1 **T3 vs T2** **T4 vs T3**

Acknowledgements

- Stephen Richmond
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  Cardiff University, School of Dentistry

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THANK YOU