Improved system of reference for analysis of craniofacial growth

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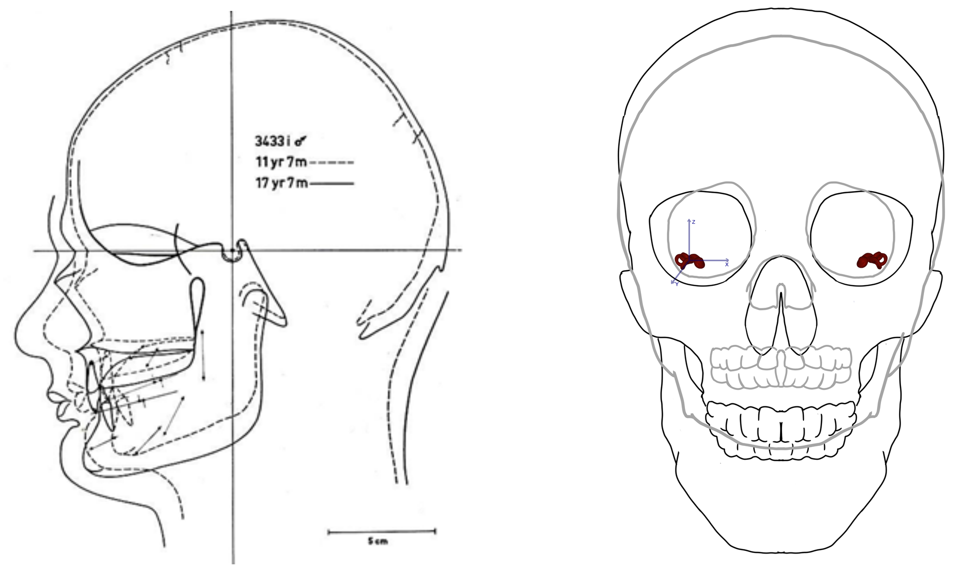
Introduction

Description of how a cranium is growing is important when treating patients with deform craniums. The current superimpositioning method, Fig. 1(a), has the limitations:

- It is only 2-dimensional.
- It is based on unstable anatomical structures.
- It is influenced by craniofacial surgery.



(a) (b)

Figure 1: Current method (a) and objective of this project (b).

Objective

Develop an automatic superimpositioning technique for MRI based on the inner ear since:

- It has a unique 3D shape
- It is fully grown from birth.
- It is not influenced by craniofacial surgery.

The inner ear is completely stable, which makes analysis of craniums at different ages possible, Fig. 1(b).

Used software

- Simple Elastix [1],[2]
- Simple ITK
- Image Registration Toolkit (IRTK) [3], [4]
- 3D slicer [5]
- Landmarker [6]

Data

The data is provided by DRCMR[1] and consists of T_2-weighted craniofacial magnitude MR images of 40 typically developing children aged 7 to 13 scanned up to 11 times with intervals of 6 months.

Image registration

Goal: find the parameters $\boldsymbol{\mu}$ of the transformation $T : \mathcal{S} \rightarrow \mathcal{T}$ that minimizes

$$\hat{\boldsymbol{\mu}} = \arg\min_{\boldsymbol{\mu}} C(T_{\boldsymbol{\mu}}(\mathcal{S}), \mathcal{T})$$

for a given cost function C.

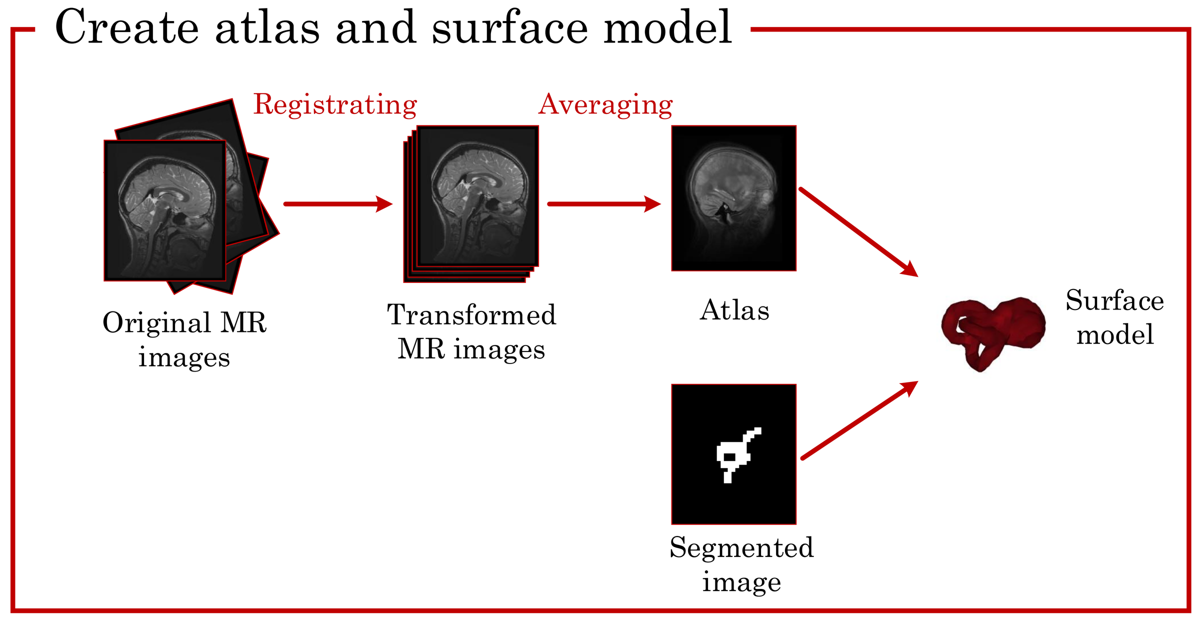
Rigid transformation

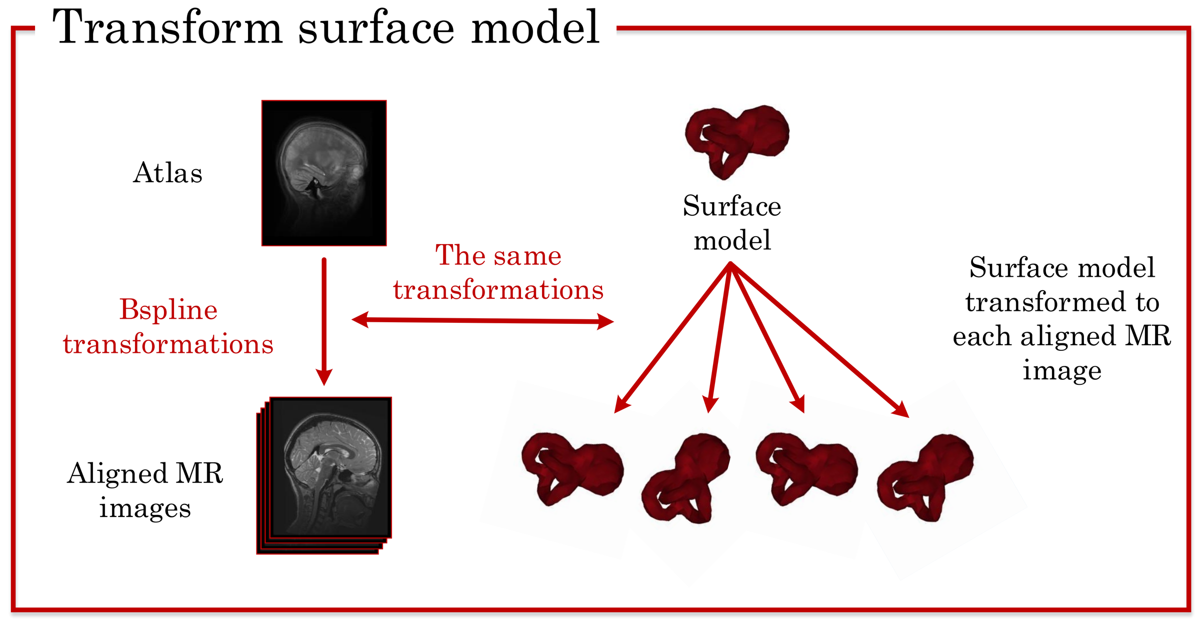
$$T_{\boldsymbol{\mu}}(\boldsymbol{x}) = \boldsymbol{R}\boldsymbol{x} + \boldsymbol{t}$$

Non-rigid transformation

$$T_{\boldsymbol{\mu}}(\boldsymbol{x}) = \boldsymbol{x} + \sum_{\boldsymbol{x} \in N} \boldsymbol{p}_{\boldsymbol{k}} B^3 \left(\frac{\boldsymbol{x} - \boldsymbol{x}_{\boldsymbol{k}}}{\sigma} \right)$$

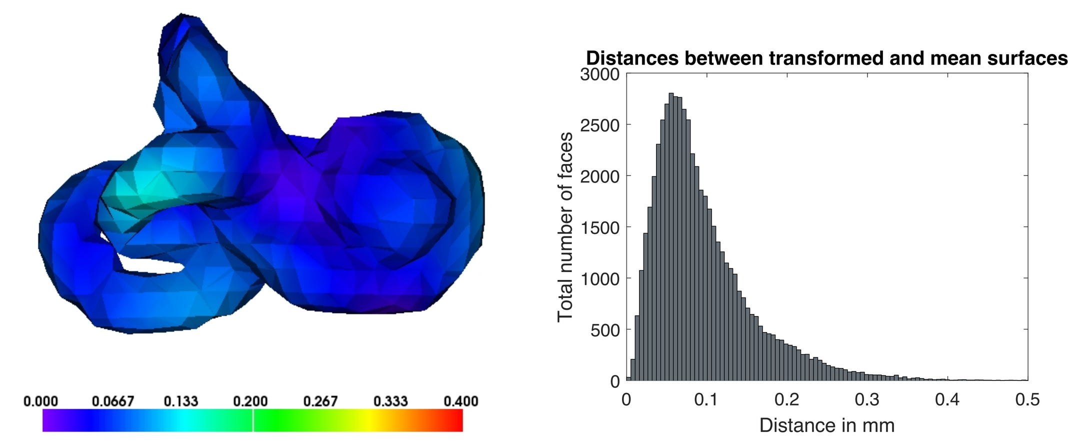
Method





Results

Figure 2 (a) shows an example of how a transformed surface differs from the mean transformed surface. (b) summarizes all the distances from all surfaces for 3 persons in a histogram. Corresponding statistics can be seen in Table 1.



(a) Distances in mm. (b) Distribution of distances.

Figure 2: (a) The distances between a transformed surface and the mean. (b) The distribution of distances from transformed surfaces and their means. The histogram is based on 3 persons.

Table 1: Statistics for the differences between transformed surfaces and the mean surfaces. These are the total of 3 persons.

MR	Median	Interquartile range
1	0.1285	[0.0849, 0.1890]
2	0.1053	[0.0705, 0.1379]
3	0.0848	[0.0544, 0.1254]
4	0.0683	[0.0491, 0.1005]
5	0.0555	[0.0347, 0.0841]
6	0.0477	[0.0301, 0.0732]
7	0.0660	[0.0473, 0.0851]
8	0.0810	[0.0588, 0.1140]
9	0.0758	[0.0524, 0.1079]
10	0.0912	[0.0546, 0.1493]
11	0.1133	[0.0647, 0.1976]

Animations

Scan the QR code to see the stability of:

- The inner ear in registered MRI.
- The transformed surfaces.

Remaining work

The following still needs to be done before a conclusion can be made.

- Register MR images with parameters from a second surface registration. This surface registration removes the movement of the ear caused by a growing cranium.
- Get the deformation fields of the transformed MR images. This will describe how each point in the head has moved in the growing head.
- Use the method on a bigger data set to have enough statistical material for an evaluation of the method.

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1) Danish Research Centre for Magnetic Resonance, Copenhagen University Hospital, Hvidovre, Denmark.