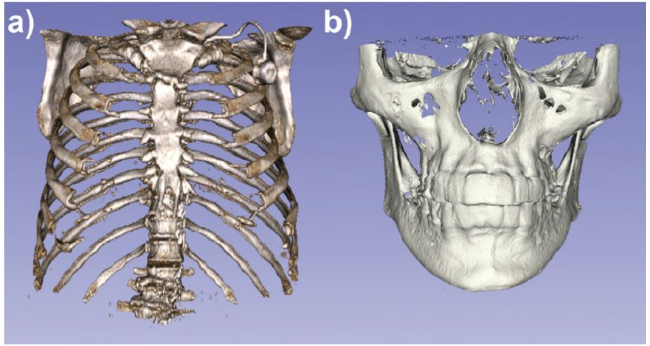
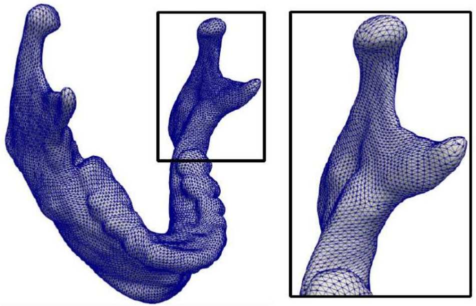
Estimation of shape correspondence for population of objects with complex topology



Limitation of SPHARM-PDM: The method is only applicable on spherical topology objects which excludes a great number of anatomical structures (vertebrae, pelvicbones or skulls)

Description: Research of a method to estimate a corresponding model population of non-spherical topology objects where each generated model will have the same numbers of points at corresponding positions

Example: Existing shape analysis methods such as SPHARM-PDM or s-reps have not been able to properly densely represent mandibular shapes, due to its highly concave and thin shape.



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Method 1 using Advanced Normalization Tools (ANTs):

Step 1	Step 2	Step 3
Estimation of a diffeomorphic non-rigid registration between each binary segmentation inputs to a template by using ANTs.	Computation of the 3D geometry objects from the binary segmentation inputs (using ModelMarker).	Apply of the diffeomorphic non-rigid registration to the segmentation-derived 3D geometry objects (thanks to two binary executables ITKTransformTools and PolydataTransform).

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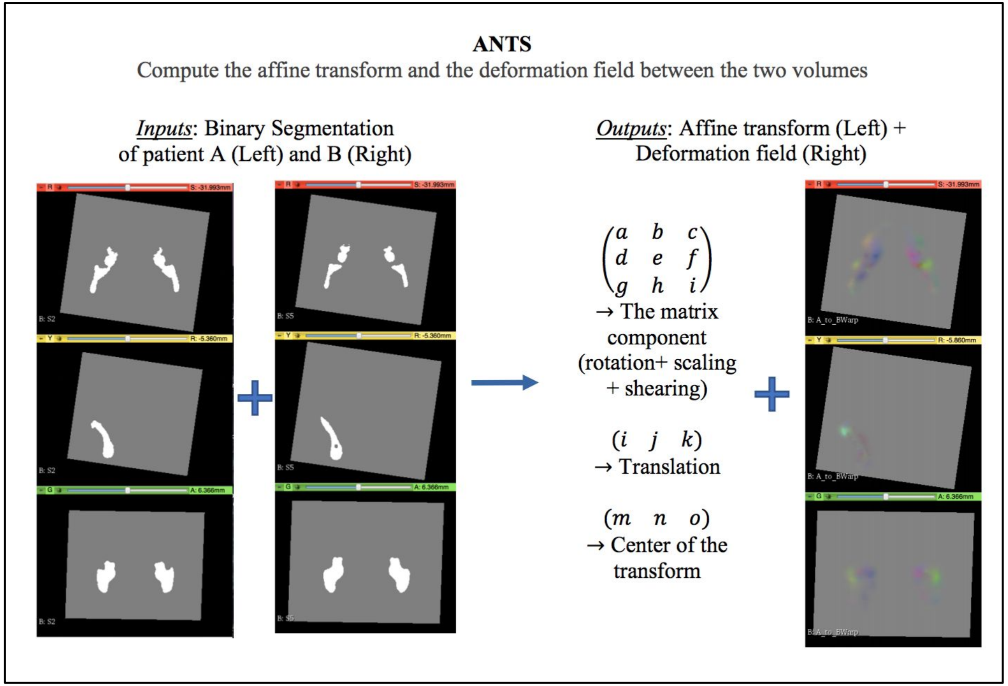
Test on two mandible data:



Method 1 using Advanced Normalization Tools (ANTs):

Step 1. Estimation of a diffeomorphic non-rigid registration between each binary segmentation inputs to a template by using ANTs

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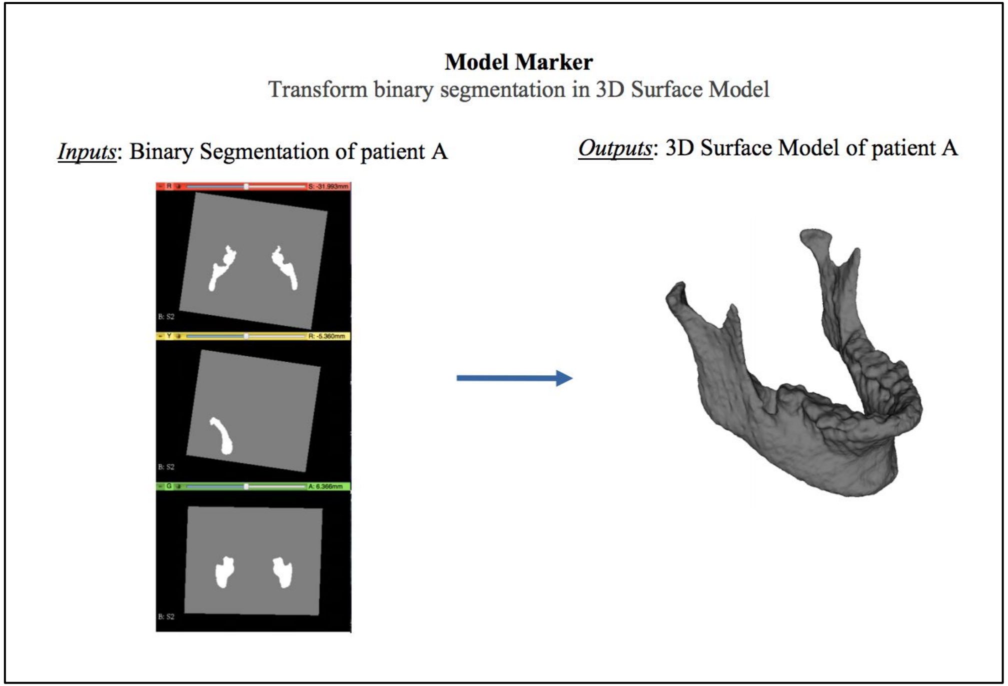
Test on two mandible data:



Method 1 using Advanced Normalization Tools (ANTs):

Step 2. Computation of the 3D geometry objects from the binary segmentation inputs (using ModelMarker)

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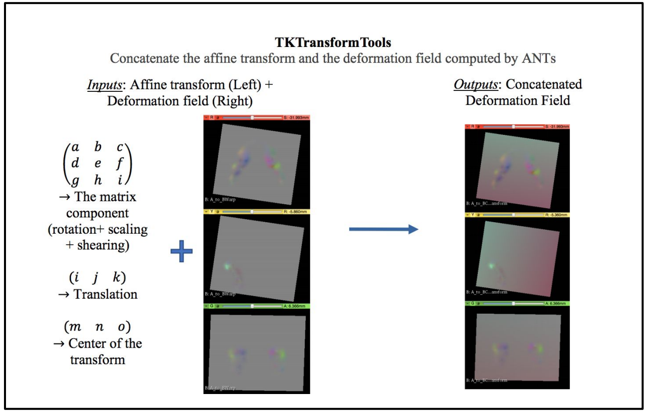
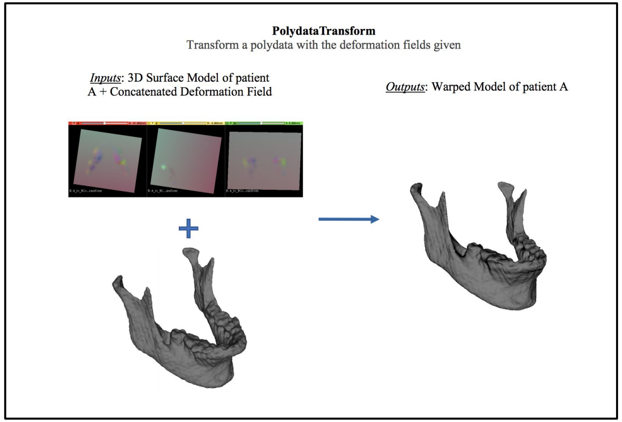
Method 1 using Advanced Normalization Tools (ANTs):

Step 3. Apply of the diffeomorphic non-rigid registration to the segmentation-derived 3D geometry objects (thanks to two binary executables ITKTransformTools and PolydataTransform)

Test on two mandible data:





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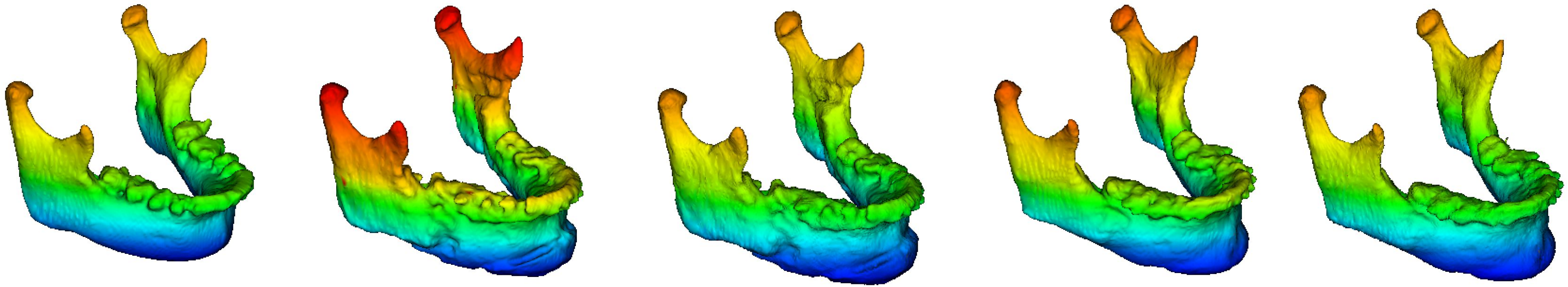
Results for the method 1 using Advanced Normalization Tools (ANTs):



Time-Point 01
Number of points: 65032

Time-Point 02
Number of points: 76568

Estimated Time-Point 02
Number of points: 65032

Time-Point 03
Number of points: 69031

Estimated Time-Point 03
Number of points: 65032

Figure. Surfaces colored by vertex index

→ The obtained results are encouraging as the estimated time-point generated shapes have the same number of points at geometrically correspondence of the time-point 01 shape

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Limit of the method 1 using Advanced Normalization Tools (ANTs):

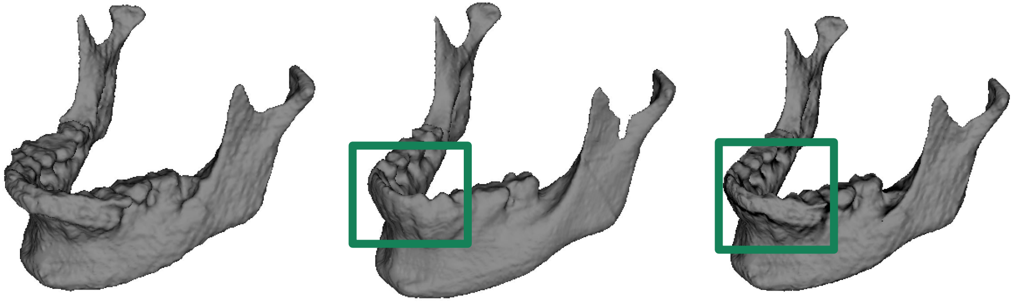

Figure. Visualization of original models and the warped model generated
Left: Model of patient A - Middle: Original model of patient B - Right: Estimated Model of patient B

→ The obtained results for this example are visually not really good: the estimated shape of patient B is not enough similar to the original shape of patient B → method not enough accurate due to the computation of the diffeomorphic non-rigid registration between the binary segmentations and then the application of this deformation field on the segmentation-derived 3D models

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Method 2 using Deformetrica:

Step 1	Step 2	Step 3
Creation of the 3D Models from the binary segmentations: Extraction of the surface meshes from the binary segmentation by using marching cubes algorithm, and use of meshlab for smoothing, decimation and remeshing the 3D models	Estimate an average shape for initialization: computation of a prototype shape configuration by unbiased atlas building of the binary label maps.	Creation of the estimate shape models: Compute the deformation field from the source to the target model and apply it on the source.

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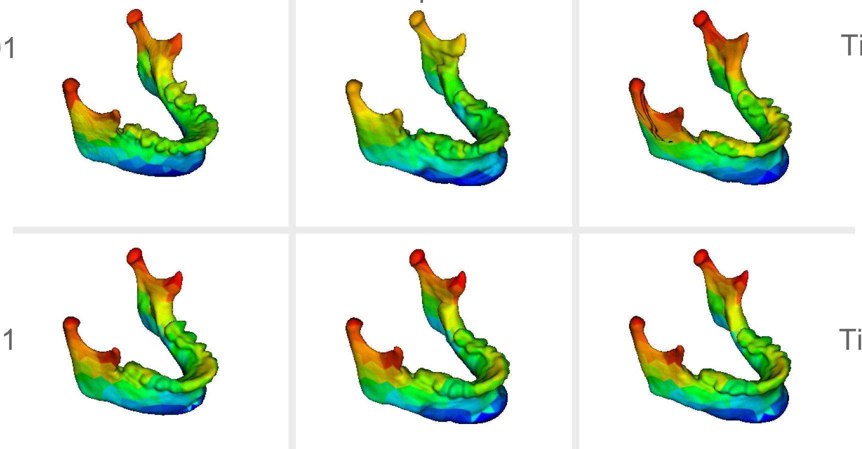
Result of the Method 2 using Deformetrica:

Time-Point 02
Number of points: 11174

Time-Point 01
Number of points: 12644



Time-Point 03
Number of points: 12935

Estimated Time-Point 01
Number of points: 13232

Estimated Time-Point 02
Number of points: 13232

Estimated Time-Point 03
Number of points: 13232

→ The obtained results are encouraging and accurate enough to pursue the next step of shape analysis. But this method used Cuda as parallel computing platform to accelerate the computation which is not supporting for all the platforms (method really slow without cuda) → method not universal for each GPU (cuda is NVIDIA specific platform)

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Method 3 using ThinShellDemon algorithm:

ThinShellDemon is a surface registration algorithm that augments the standard Demons algorithm by including additional information about the physical properties of the surfaces being registered.

Step 1	Step 2
Creation of the 3D Models from the binary segmentations: Extraction of the surface meshes from the binary segmentation by using marching cubes algorithm, and use of meshlab for smoothing, decimation and remeshing the 3D models	Creation of the estimate shape models: Compute the deformation field from the source to the target model and apply it on the source.

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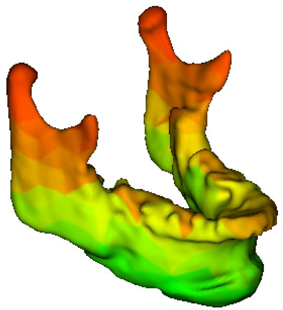
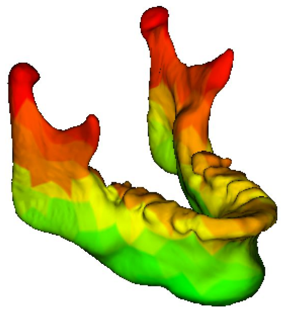
Result of method 3 using ThinShellDemon tool:

Time-Point 01
Number of points:
12644



Time-Point 02
Number of points:
11174



Estimated Time-Point 02
Number of points:
12644

Although, the estimated time-point 02 shape has the same number of points than the time-point 01 shape, visually the estimated time-point 02 shape is not enough similar to the original time-point 02 shape → method not accurate enough

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Analysis of the methods:

Methods 1 using Advanced Normalization Tools (ANTs): The obtained results are not accurate enough due to the computation of the diffeomorphic non-rigid registration between the binary segmentations and then the application of this deformation field on the segmentation-derived 3D models

Methods 2 using Deformetrica: Really good results but the method used Cuda and without it, it is a really slow → Doesn't work with every GPU (cuda is NVIDIA specific platform)

Methods 3 using ThinShellDemon: The obtained results are not enough accurate

Kitware