Morphological analysis on structural MRI for the early diagnosis of neurodegenerative diseases

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On behalf of MAGIC-5 collaboration

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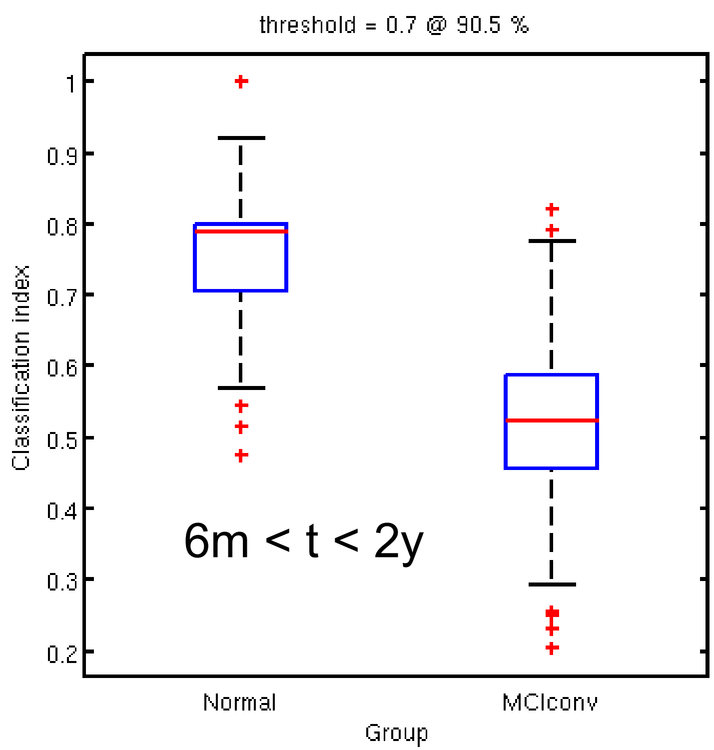
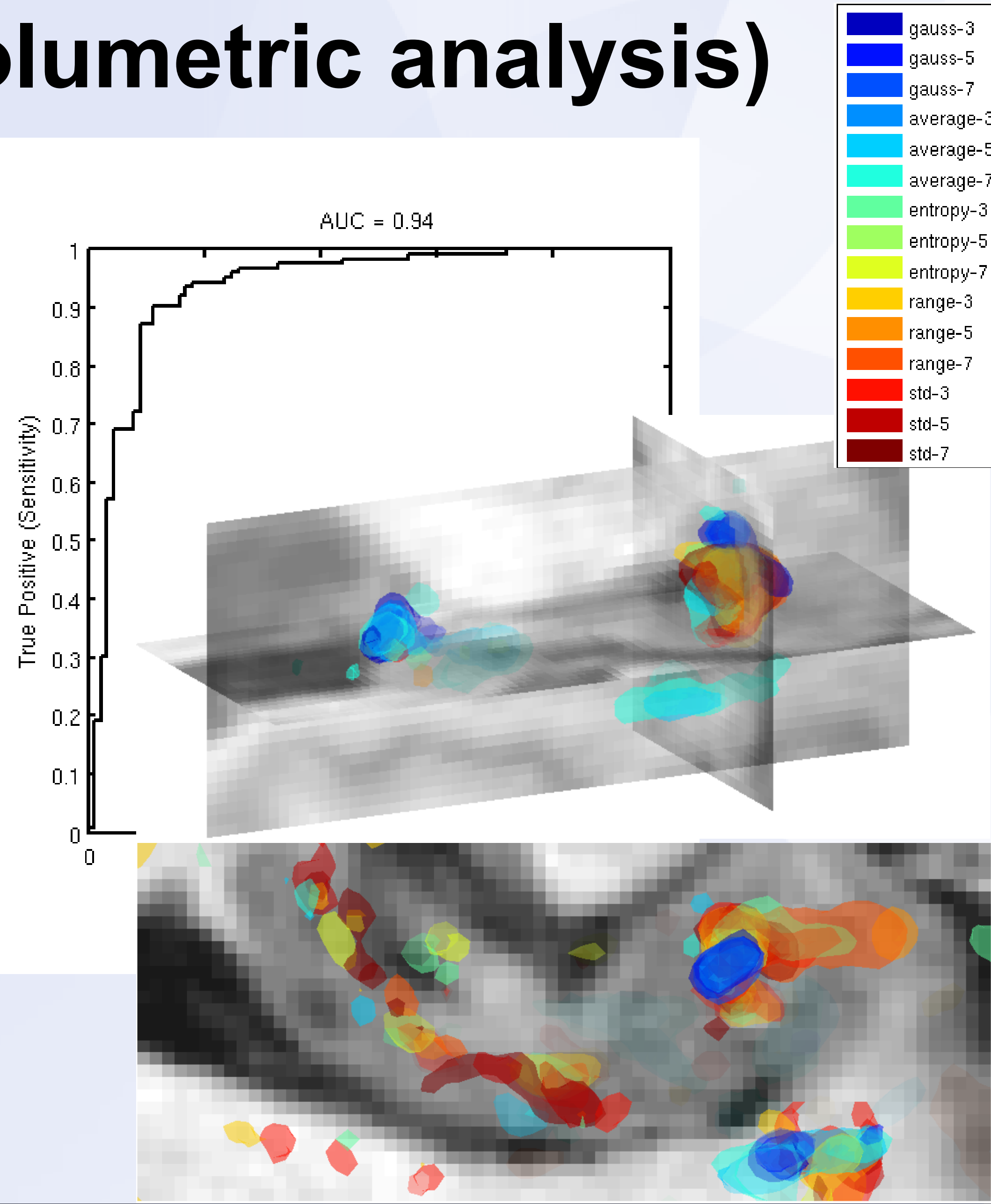
- Motivations of morphological analysis
- Segmentation of hippocampal region
- Template-based segmentation
- Voxel-based segmentation
- Shape analysis
- Conclusions and future works

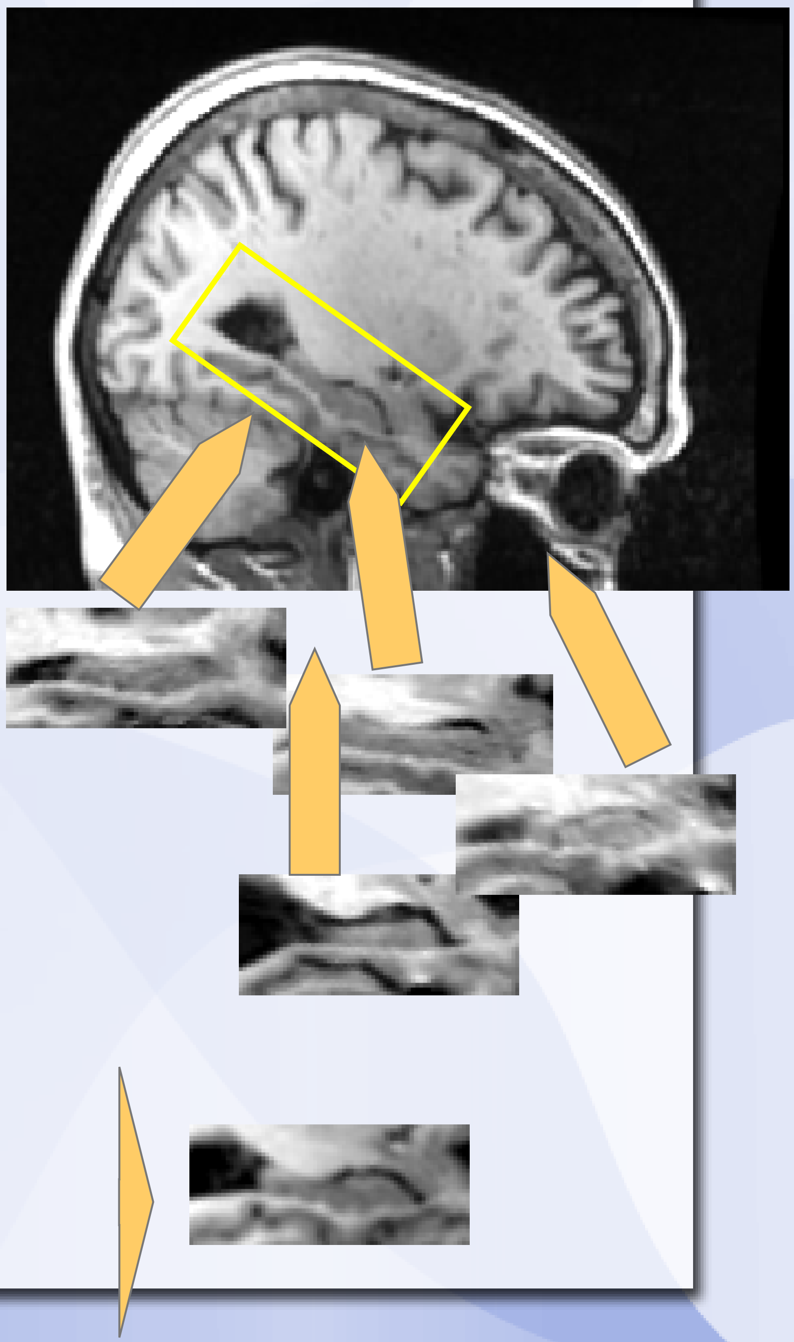
Key result (volumetric analysis)





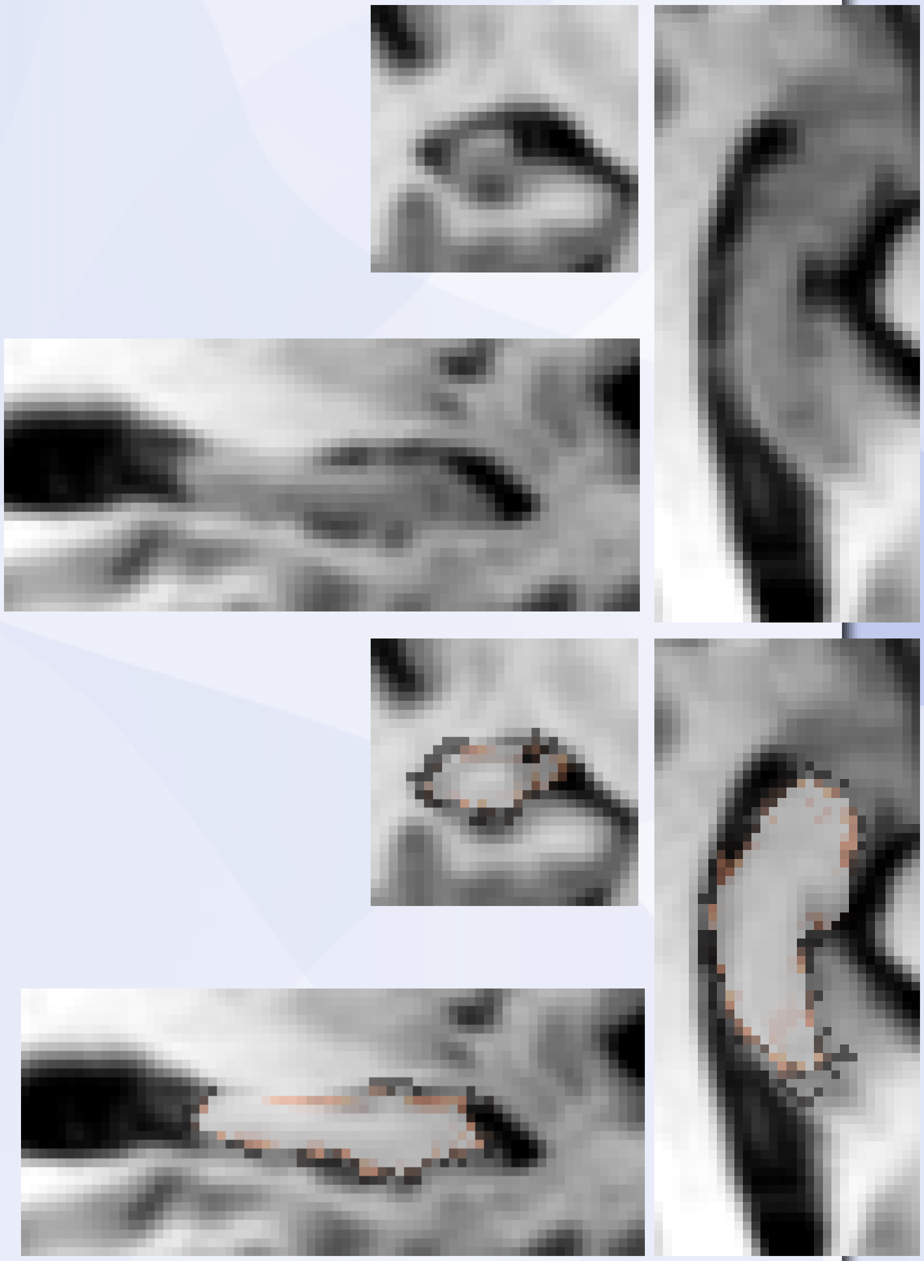
Segmentation

- From the boxes generated such as the volumetric analysis, we want to find the hippocampal structure



Segmentation goal

- Retrieve automatically the hippocampus shape



<u>Difficulties:</u>

- Gray matter structure near to some gray matter structures
- Low contrast and no well-defined contours

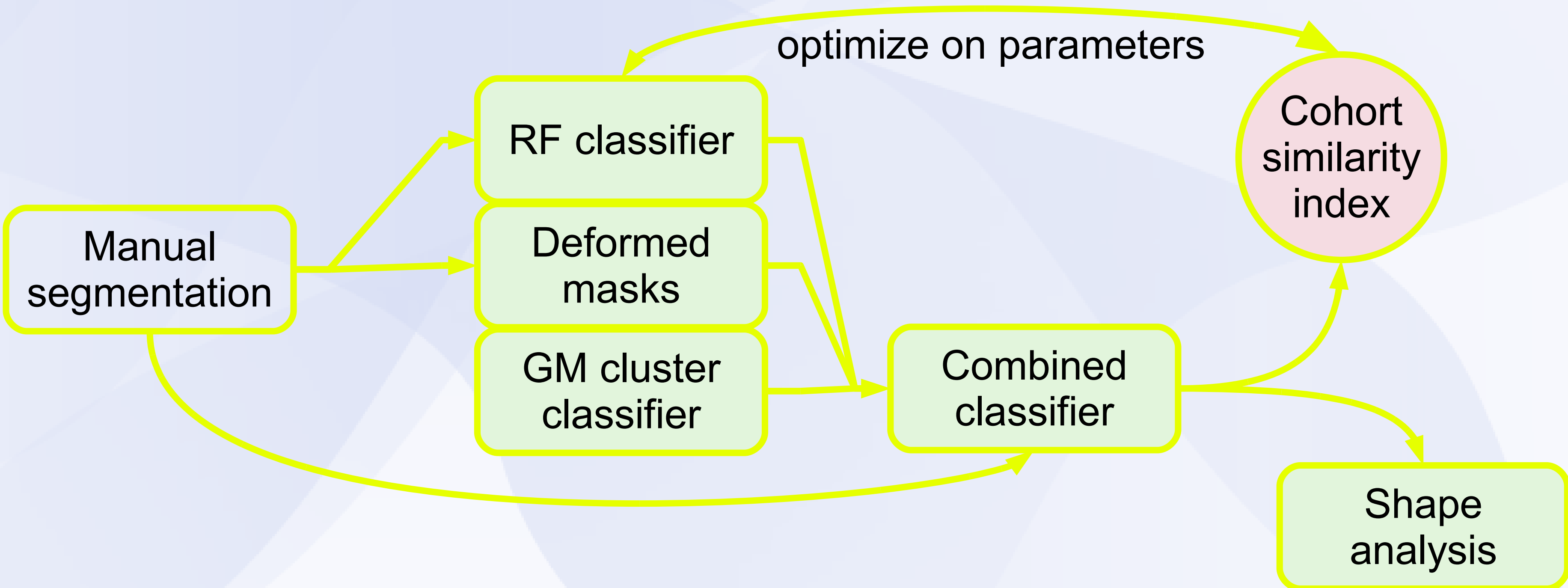
Segmentation methods

- Snakes, Watershade, Region Growing...
- Voxel-based approach (Clustering and supervised classification)

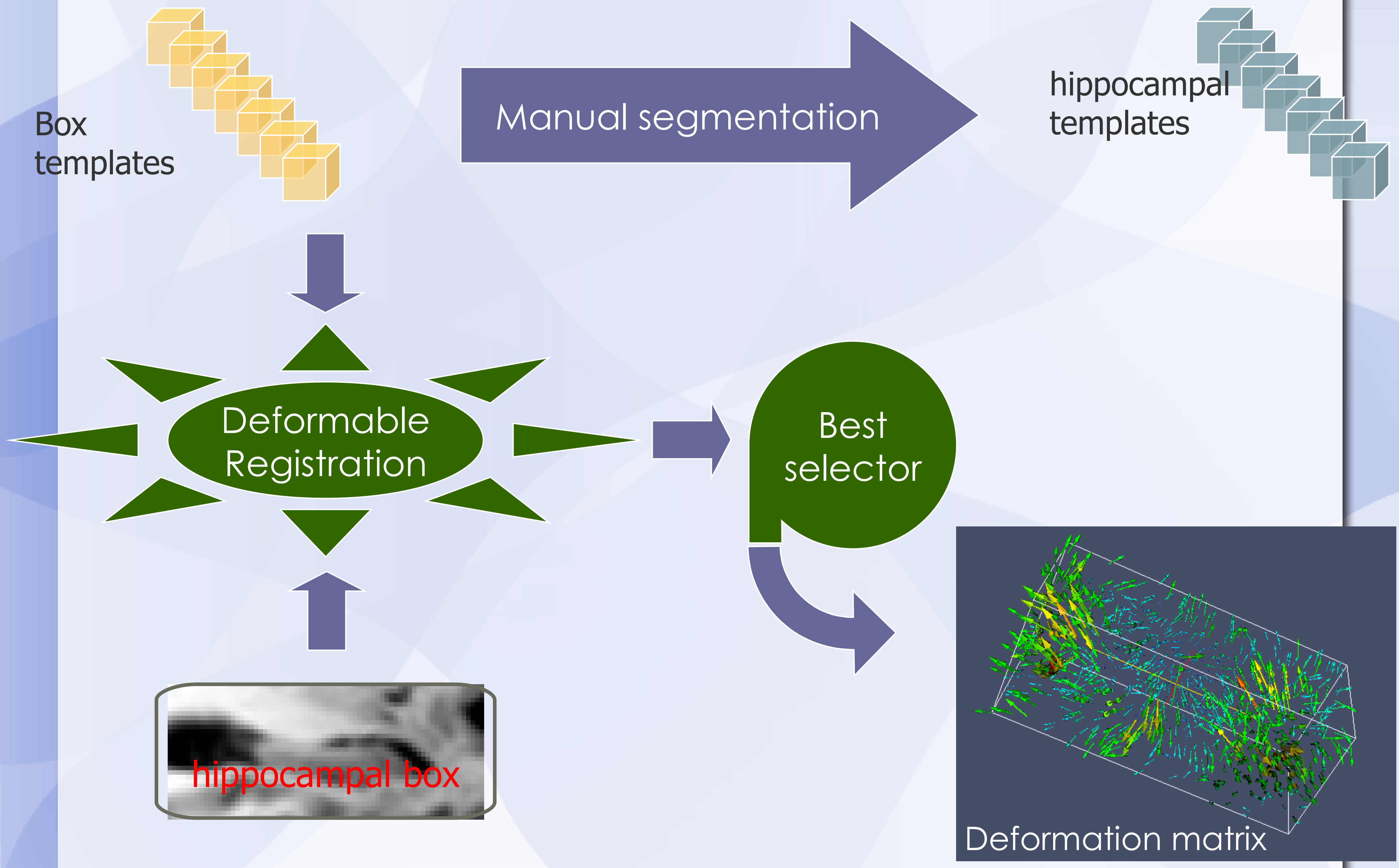
- Template-based approach (deformable masks)

Our Segmentation approach

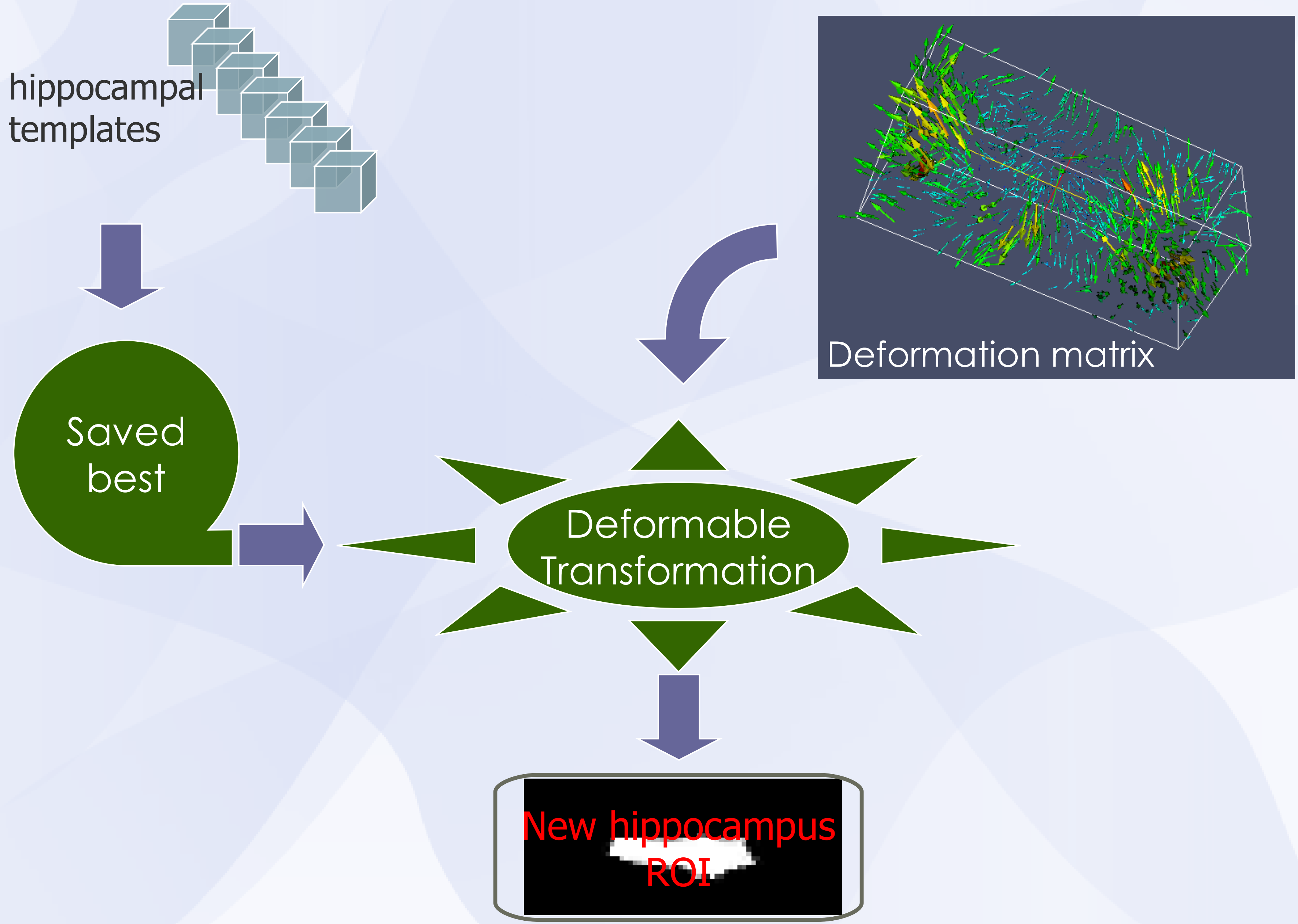
- Integration of multiple segmentation methods
- Shape consistency check (similarity index)
- Multiple approach path



Deformable masks



Deformable masks (2)



Deformable Registration

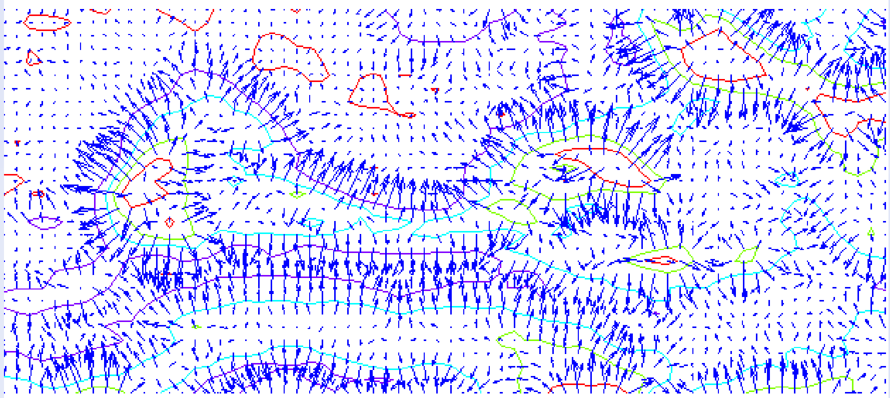
- Physical continuum model, viscous fluid mechanics (Thirion's algorithm)
  - In this scheme each image is viewed as a set of iso-intensity contours
  - The main idea is that a regular grid of forces deform an image by pushing the contours in the normal direction
  - The orientation and magnitude of the displacement is derived from the instantaneous optical flow equation
- Maintains topology and connectivity of deforming template

$$D(x) \cdot \nabla f(x) = -(m(x) - f(x))$$

Warping

Mean square metric

$$MS(A,B) = \frac{1}{N}\sum_{i=1}^{N}\left(\boxed{A_i} - \boxed{B_i}\right)^2$$



Voxel of the moving image

Voxel of the fixed image

$$D(x)\cdot\nabla f(x) = -\left(\boxed{m}(x) - \boxed{f}(x)\right)$$

- Simple to compute
- Large capture range

- Restricted to mono-modality applications
- Linear differences in intensity results in poor similarity measure

- We need that *similar gray values correspond to similar tissues*! histogram normalization is required!

Supervised classification

Box and masks (training/validation data)

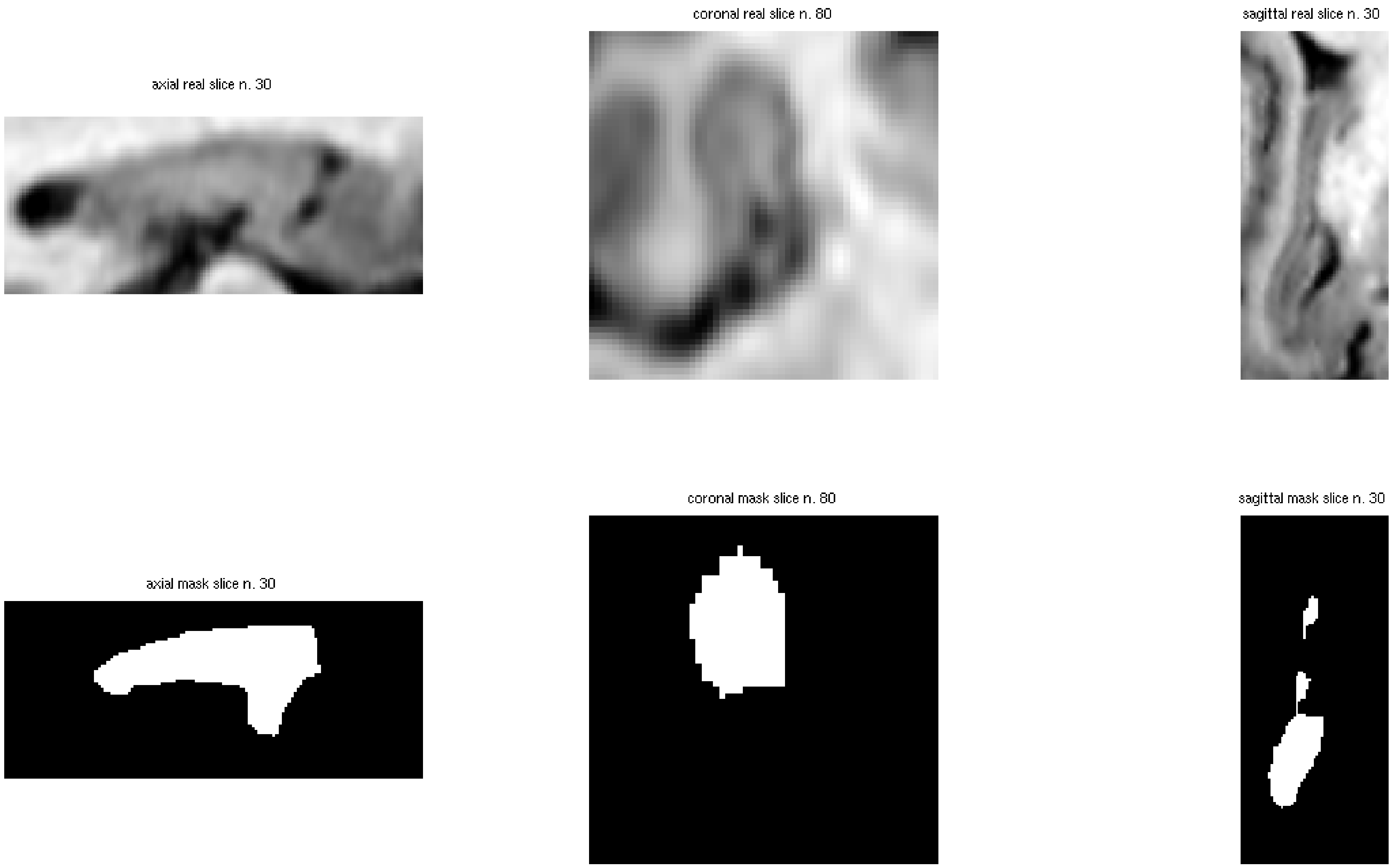
Extraction:
Haar-like features
Gradients
Moments

RANDOM FOREST classification

bootstrap

Fuzzy hippocampal mask

Training set



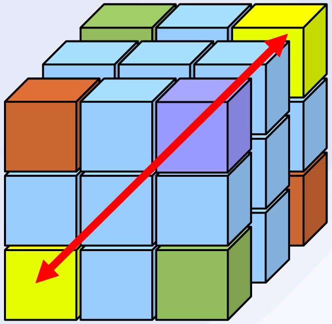
Features extraction

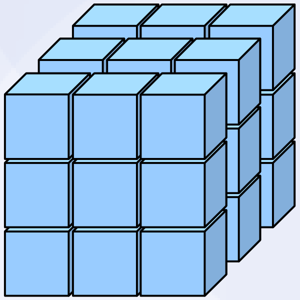
•3D texture analysis

•Our features are derived from gradients and first order statistic (*mean, std, skewness, entropy..)*

The haar-like features are calculated on masks of different dimensions (3x3x3 up to 9x9x9) centered on the voxel of interest.

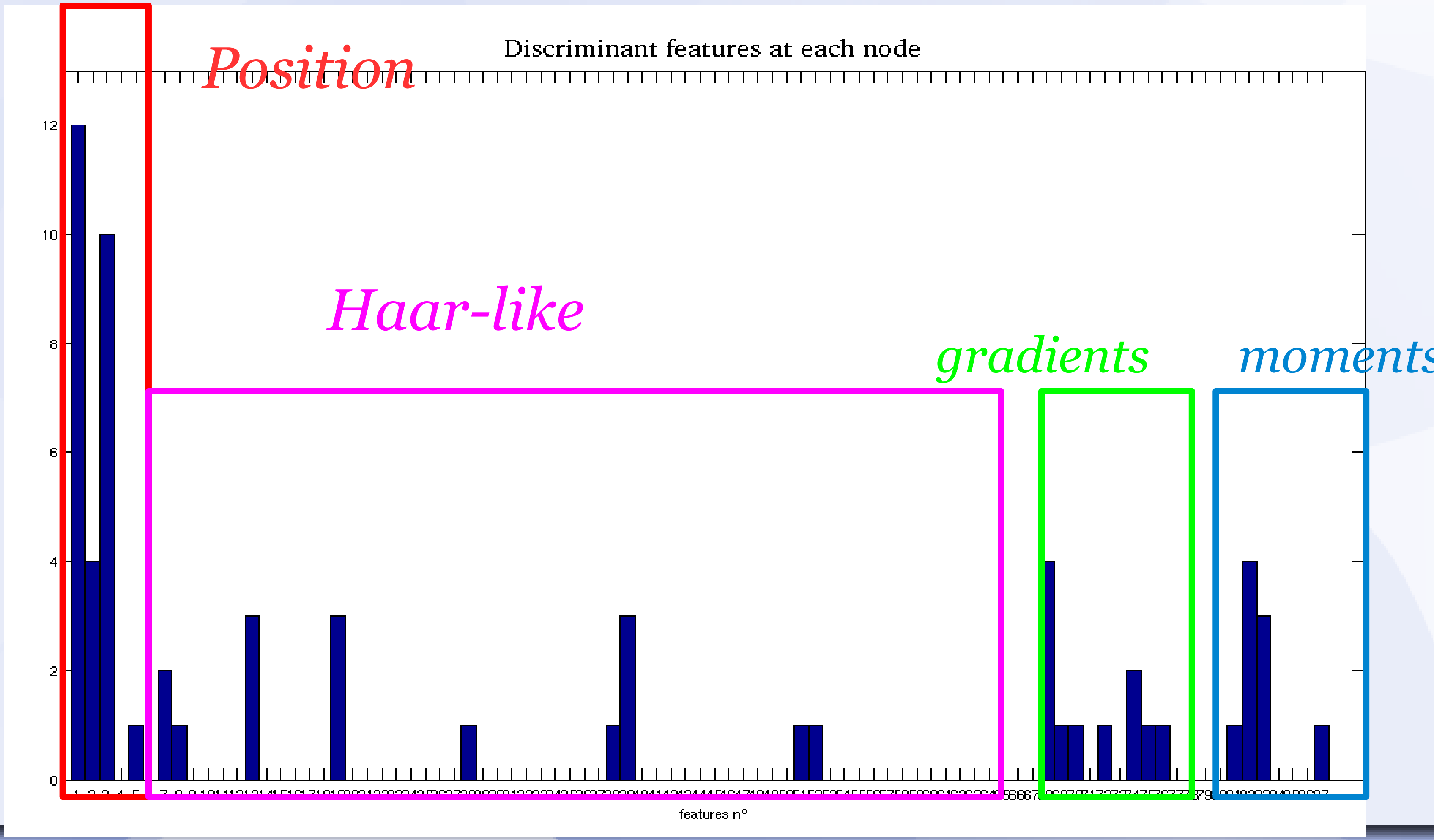
We obtain almost ***3000 features for each voxel.***



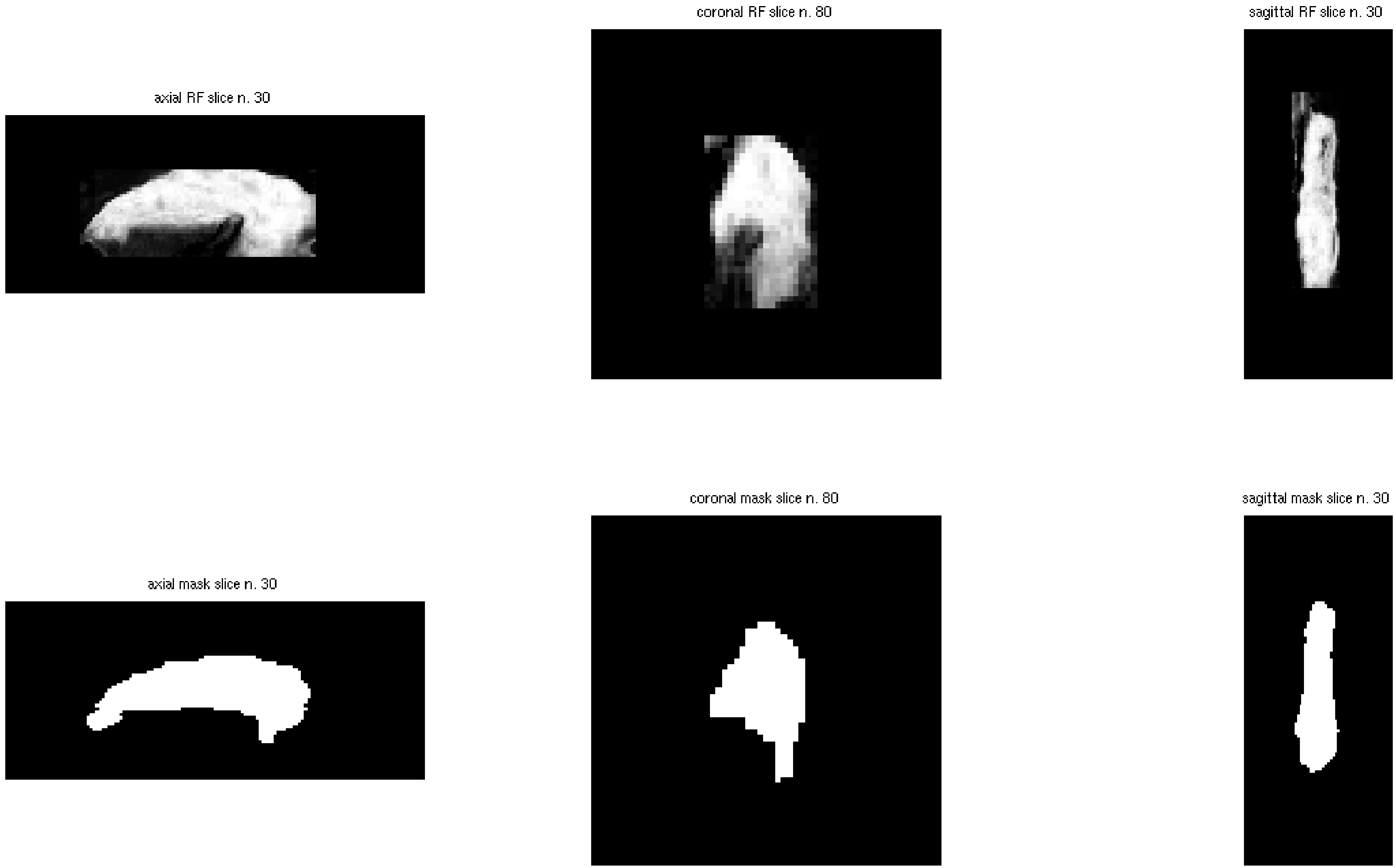


Features selection

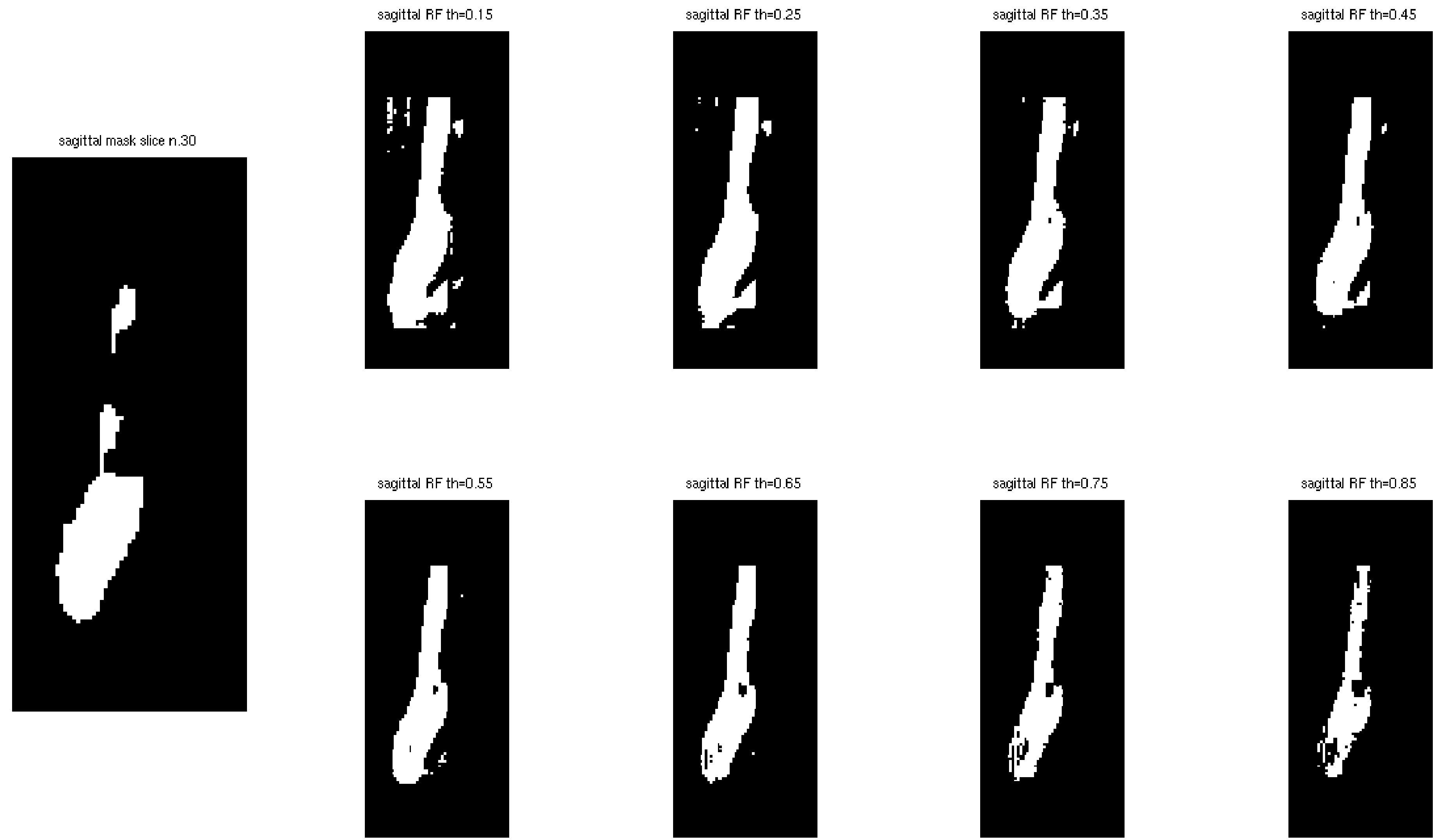
- Bootstrap for data selection
- Most relevent features discrimination



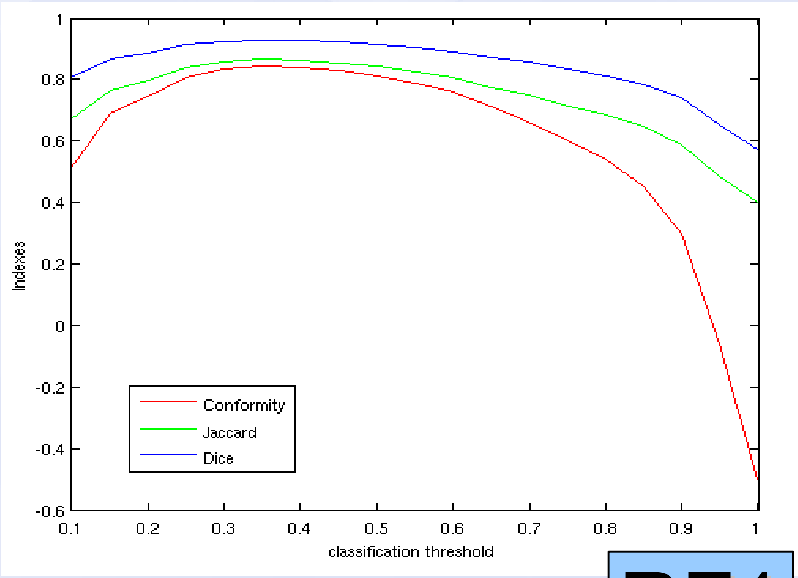
Results


axial RF slice n. 30
coronal RF slice n. 80
sagittal RF slice n. 30
axial mask slice n. 30
coronal mask slice n. 80
sagittal mask slice n. 30

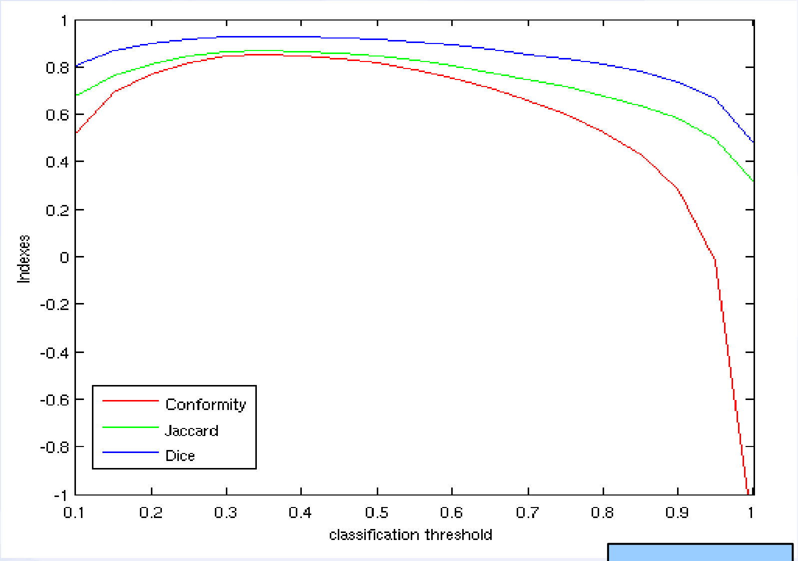
Fuzzy hippocampal mask



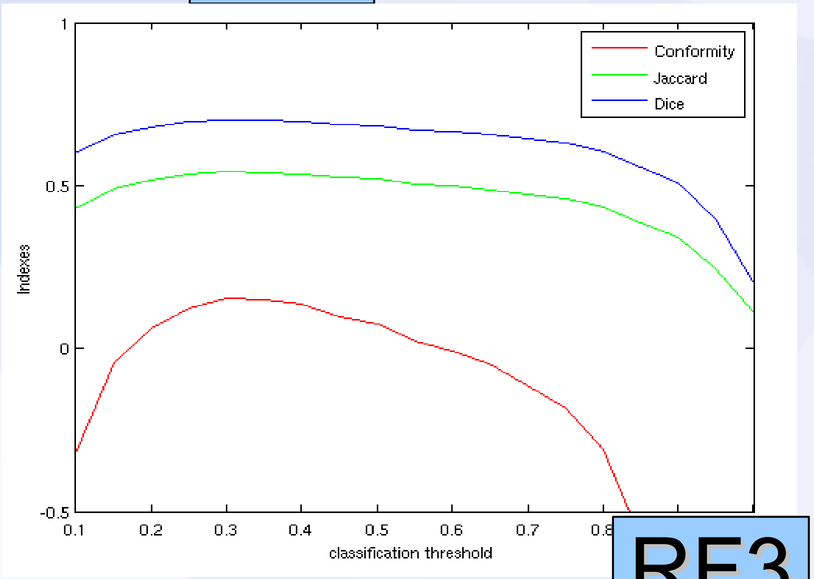
Results



RF1



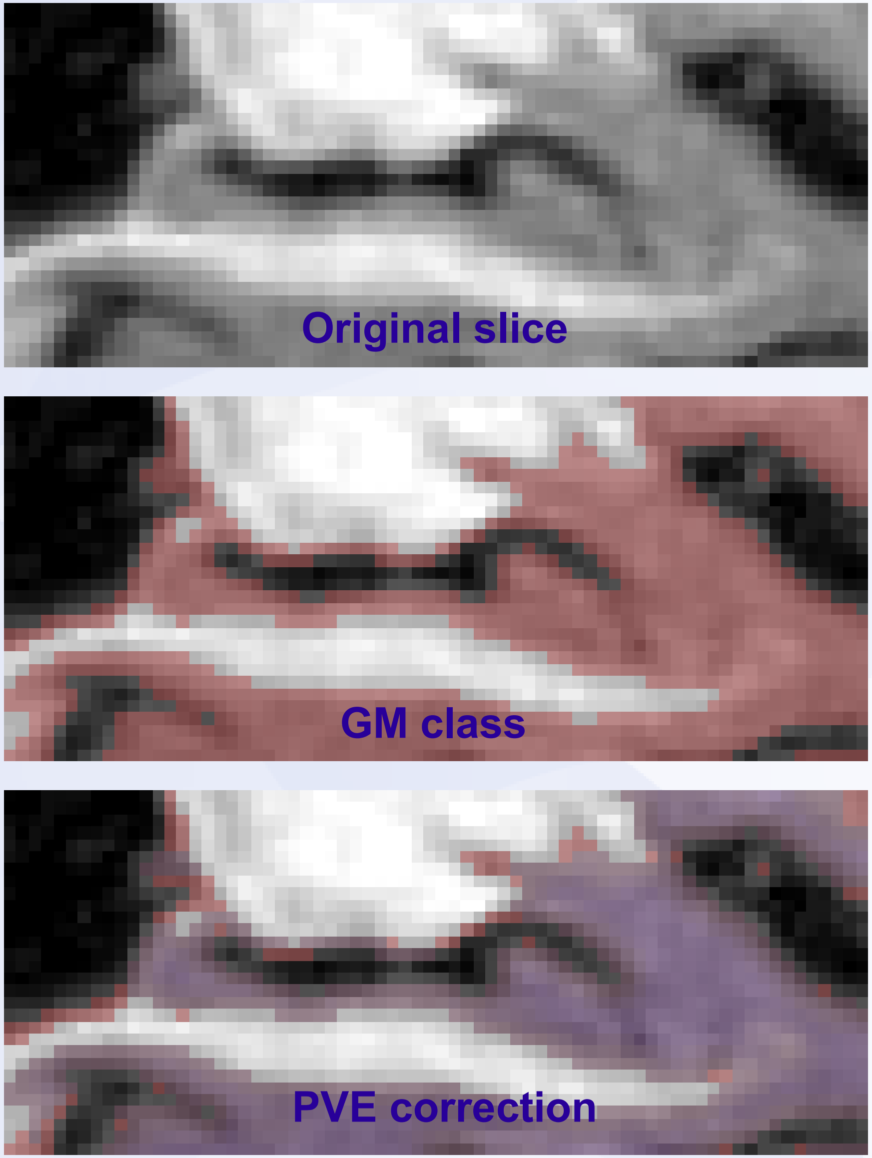
RF2



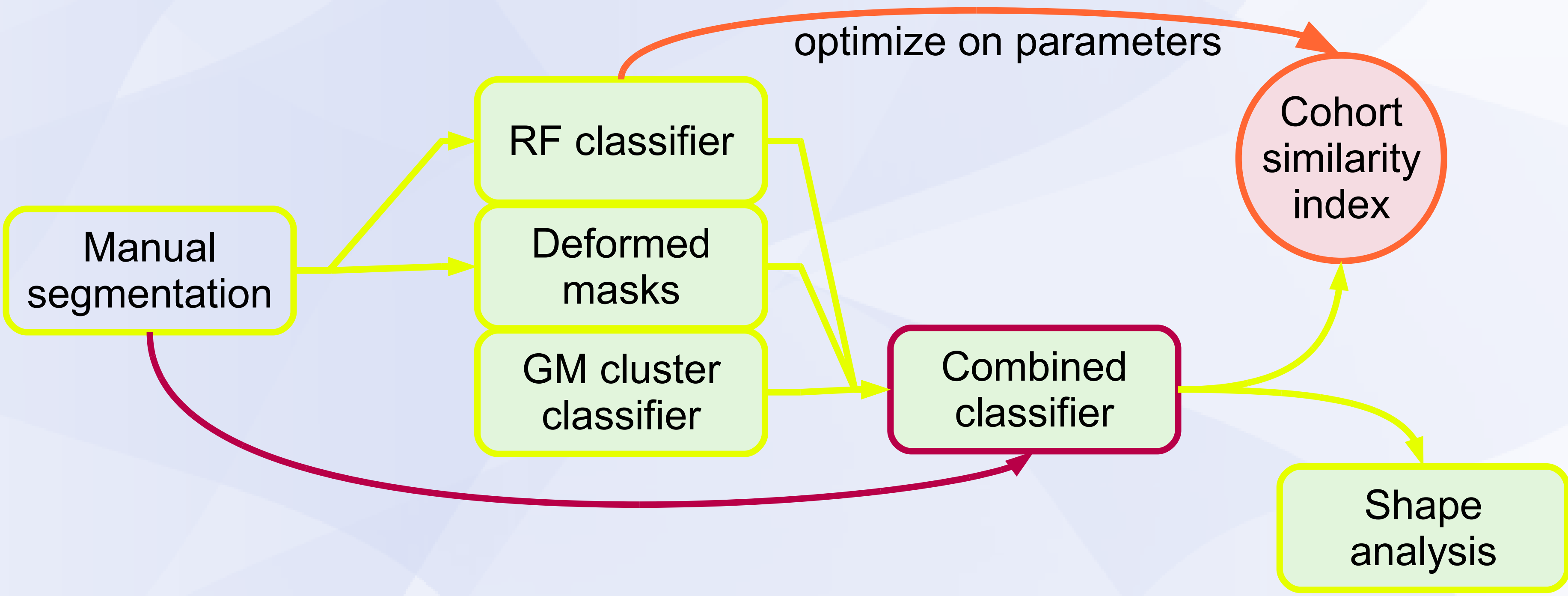
RF3

Unsupervised classification (k-means)

- 3-classes (GM,WM,CSF) intensity-based clustering
- Rough segmentation
- PVE correction by erosion/dilation



Pipeline reminder



Combined classifier

- We have different hippocampal masks derived from differents segmentation methods
- We want to combine this information into a single meaningful mask
- STAPLE (Simultaneous Truth and Performance Level Estimation)
- Algorithm for the performance estimation of raters when no ground truth exists.

EM instance:

The raters segmentation is observable.

The true segmentation is a "hidden" binary variable

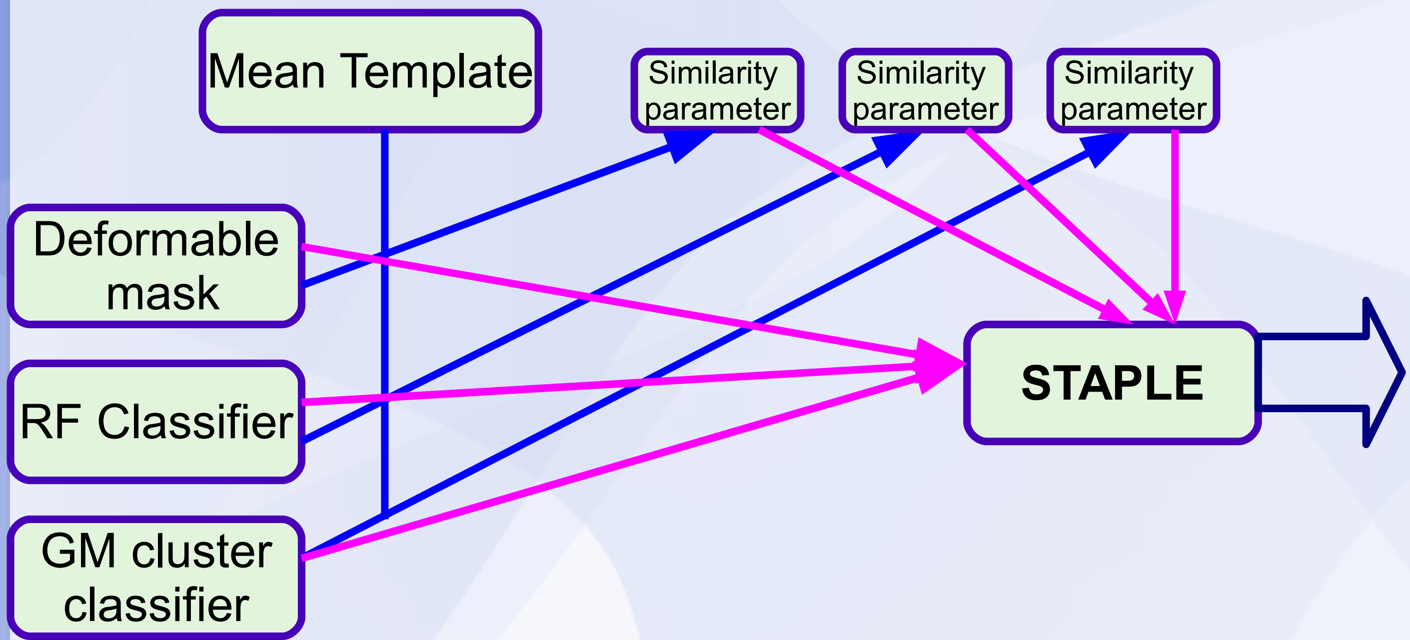
The raters performance level is defined by:

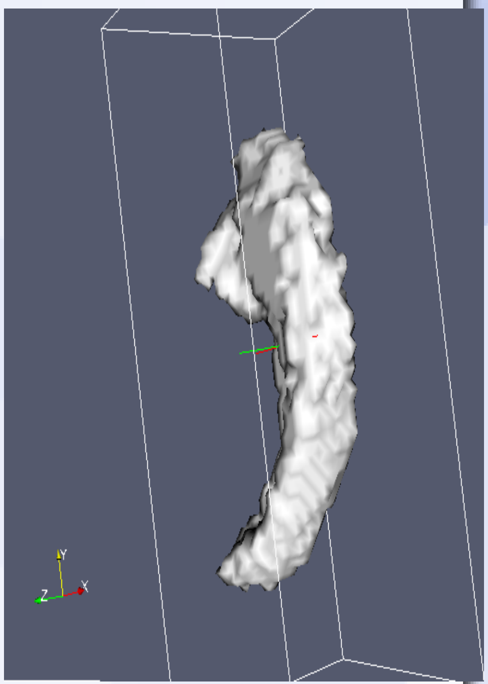
Sensibility p : true positives rate.

Specificity q : true negatives rate.

STAPLE (parameters)

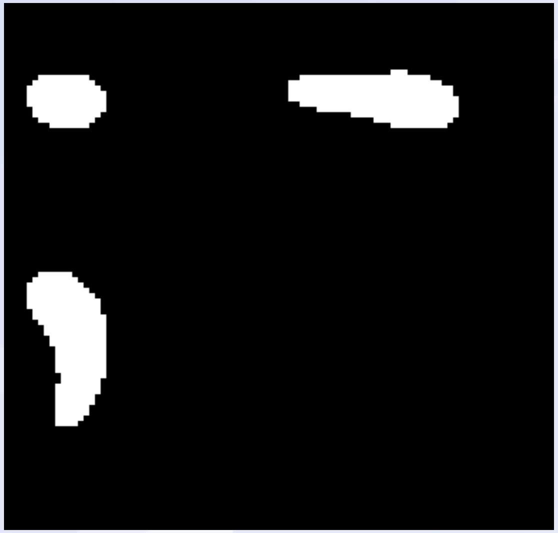
- STAPLEs starting parameters to weigh the raters segmentation





Consistency check

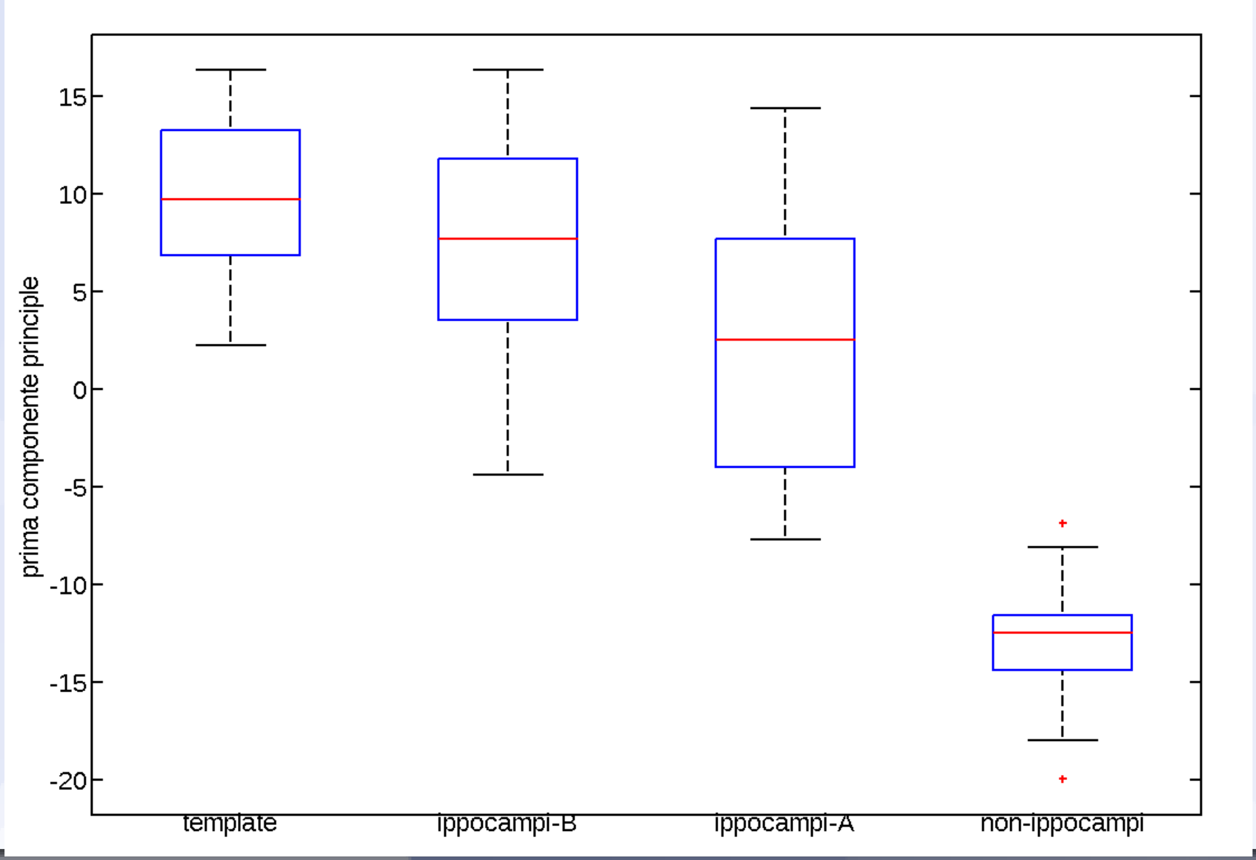
- Unambiguos hippocampi are similar to template masks



Ippocampo ambiguo **Ippocampo non ambiguo**

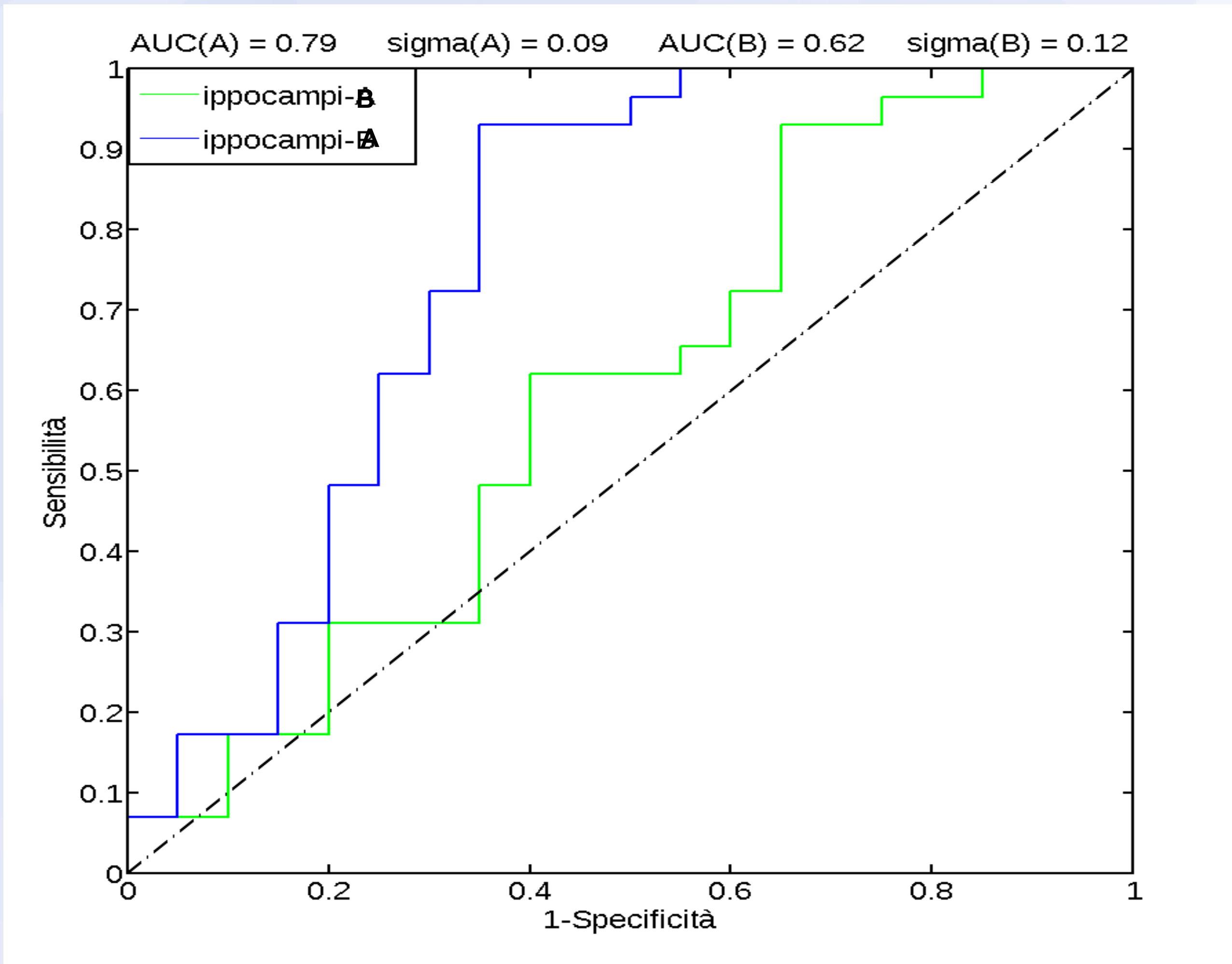
Consistency check (2)

- Two sets of results: hippocampi-A and hippocampi-B
- PCA-based comparison between *h-A*, *h-B, templates* and *non-hippocampi*



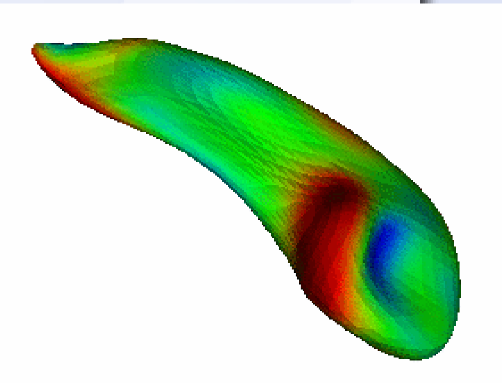
Consistency check (3)

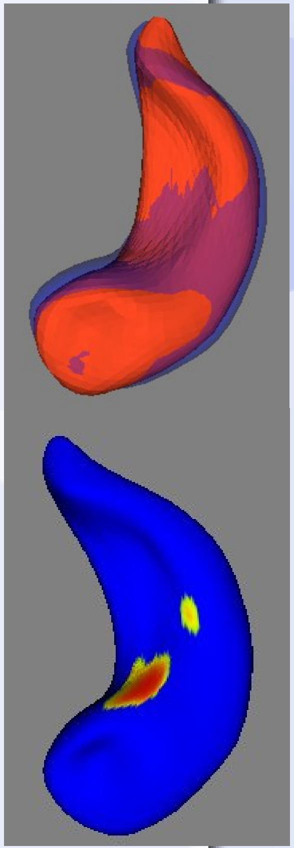
- Comparison with templates family

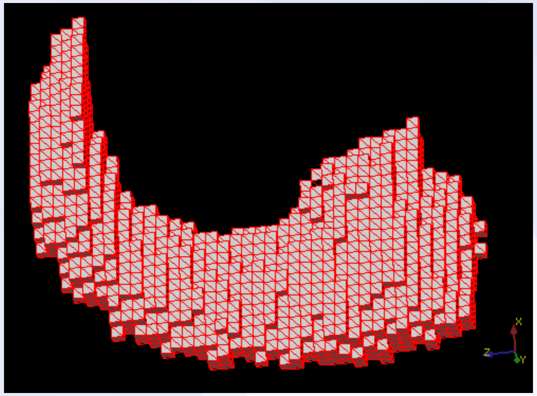


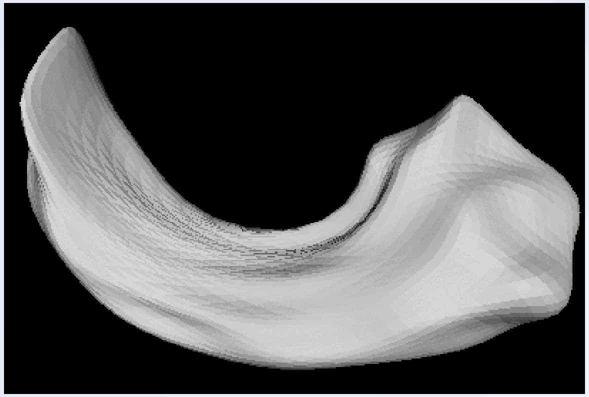
Shape analysis

- Hippocampus shape should be analyzed to find atrophy characteristics
  - Possible method: spherical harmonics analysis using *SPHARM*
  - Metric analysis (diffeomorphism...)
  - All this methods discover the global variability of the shape....SPARSE PCA can measure local variability such atrophy







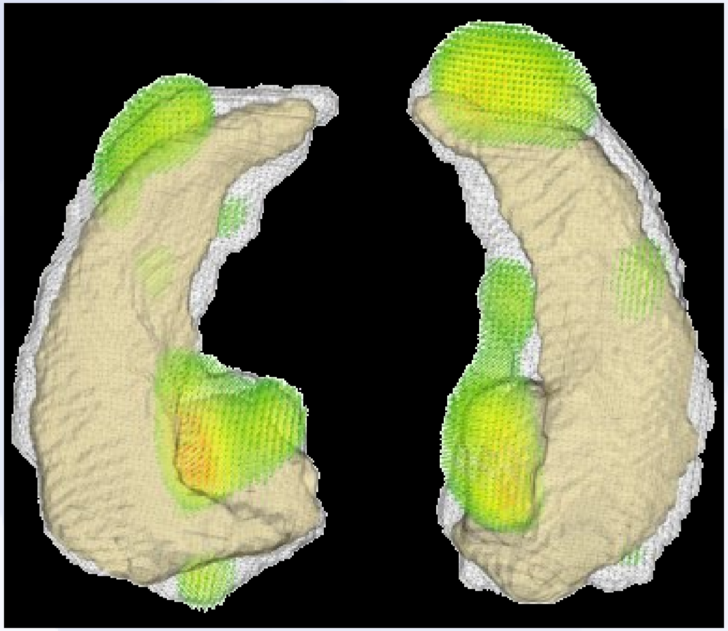


Sparsity

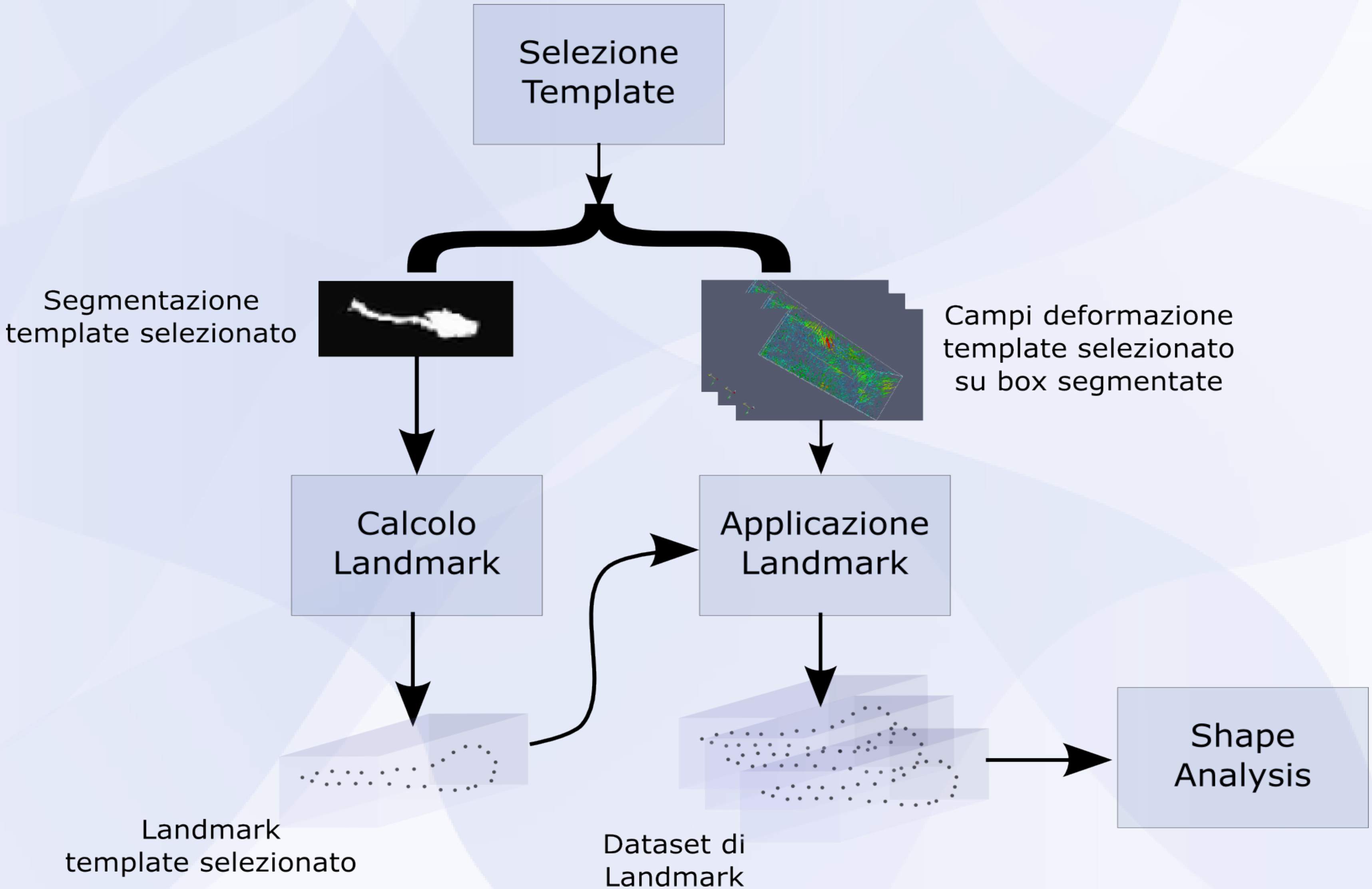
- Sparsity constrains to find localized spatial variability

Null components in the vector of the model parameters (*feature selection*)

- Statistical correlation between variables

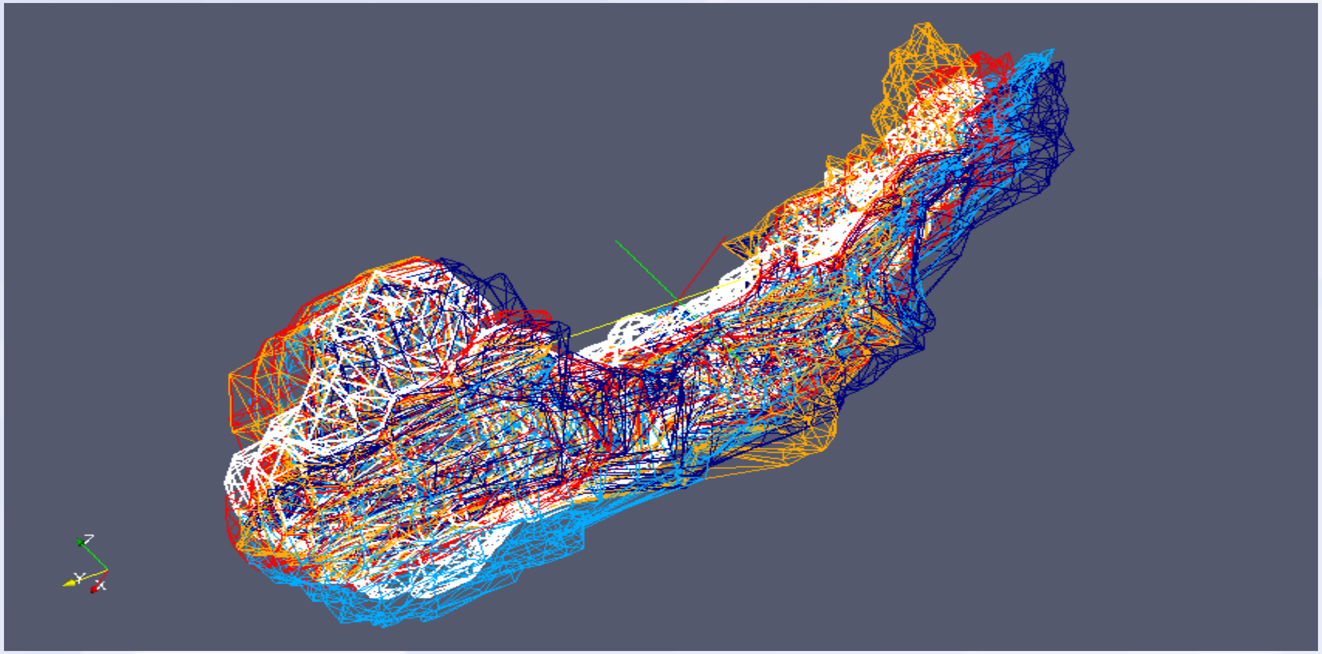


Sparse PCA

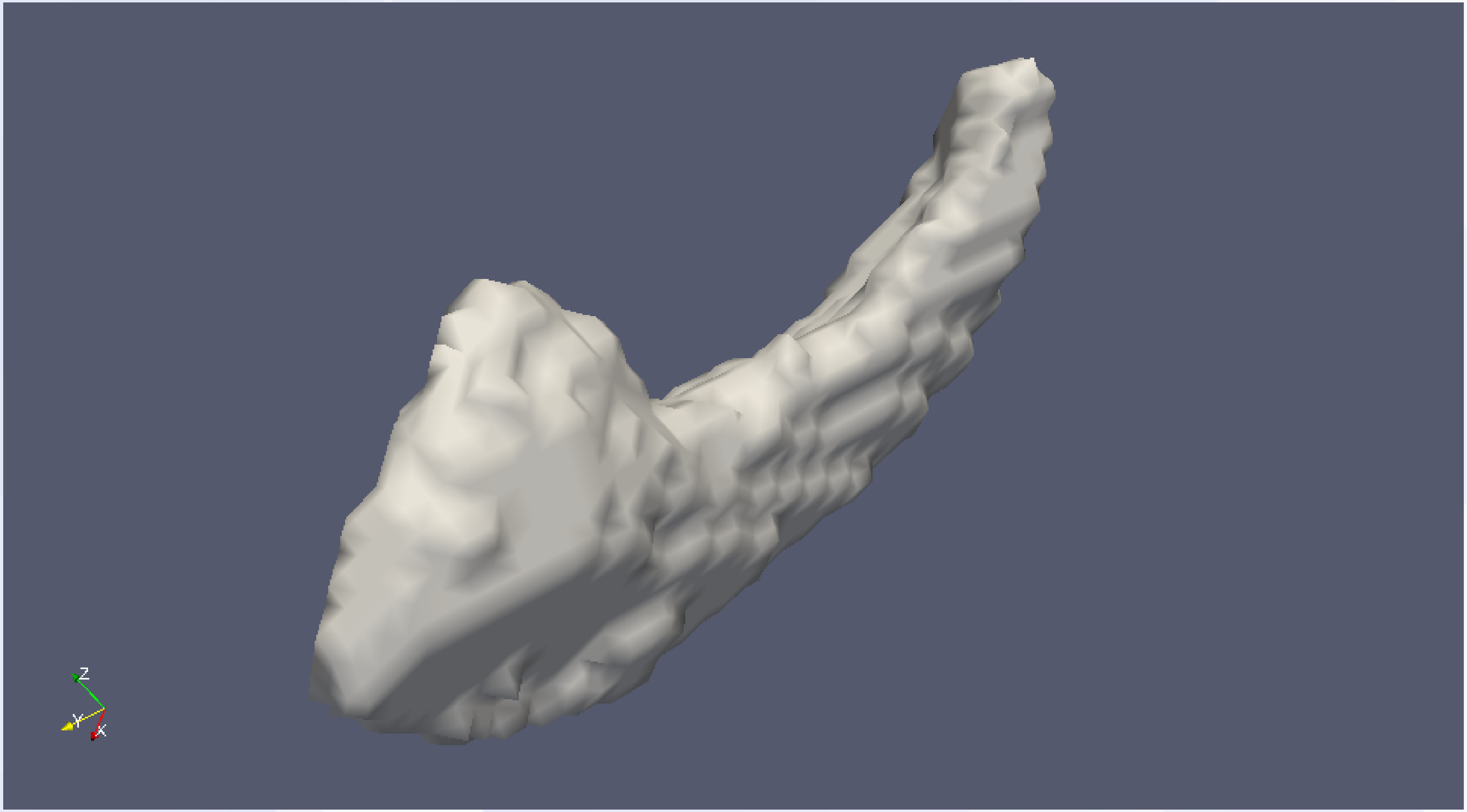

Selezione
Template
Segmentazione
template selezionato
Campi deformazione
template selezionato
su box segmentate
Calcolo
Landmark
Applicazione
Landmark
Shape
Analysis
Landmark
template selezionato
Dataset di
Landmark

Dataset

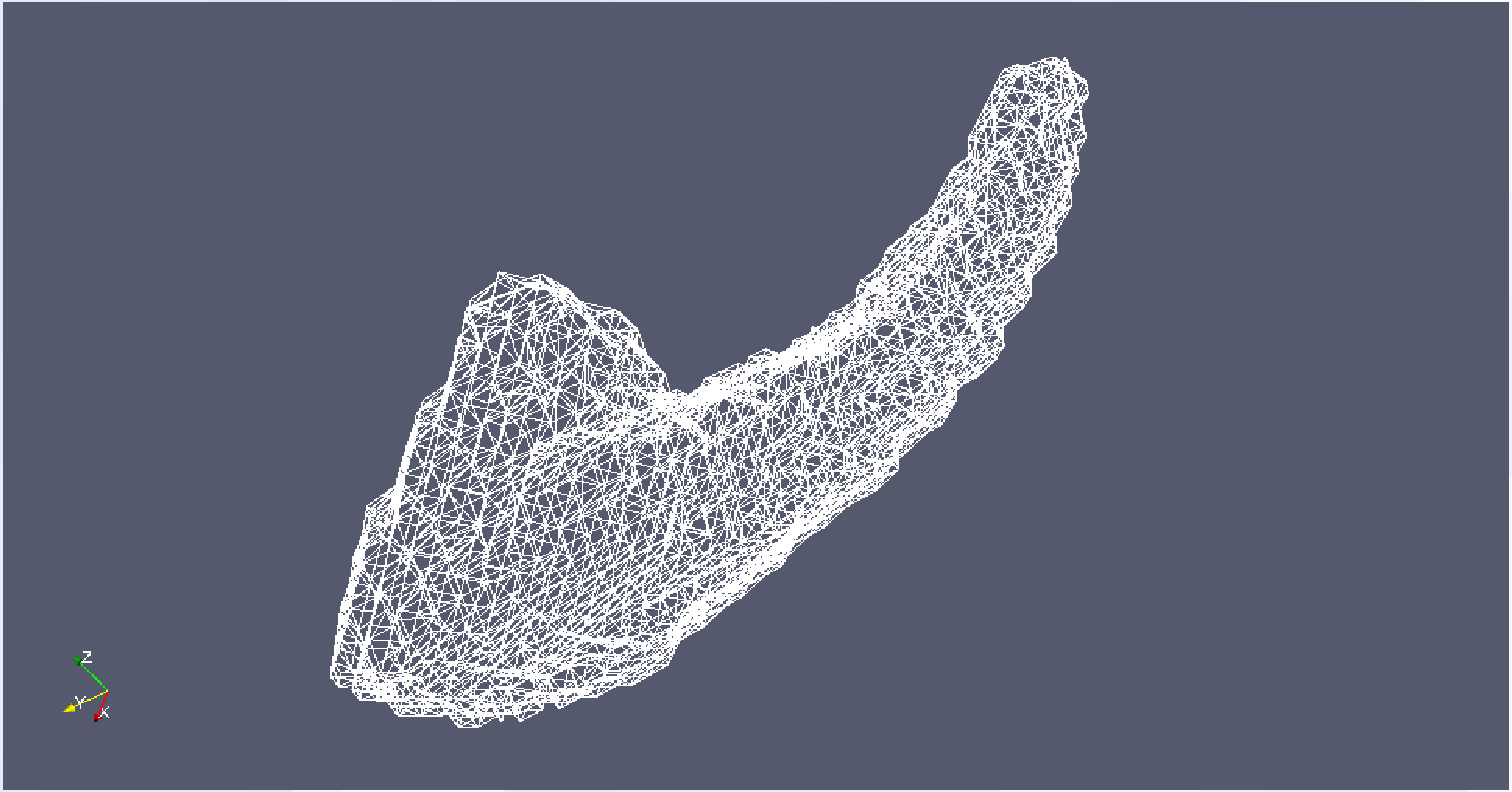
- Mesh on template (2348 landmark)
- Mesh decimation (1644 landmark)
- Deformation fields selection
- Warping of the template on reference hippocampus



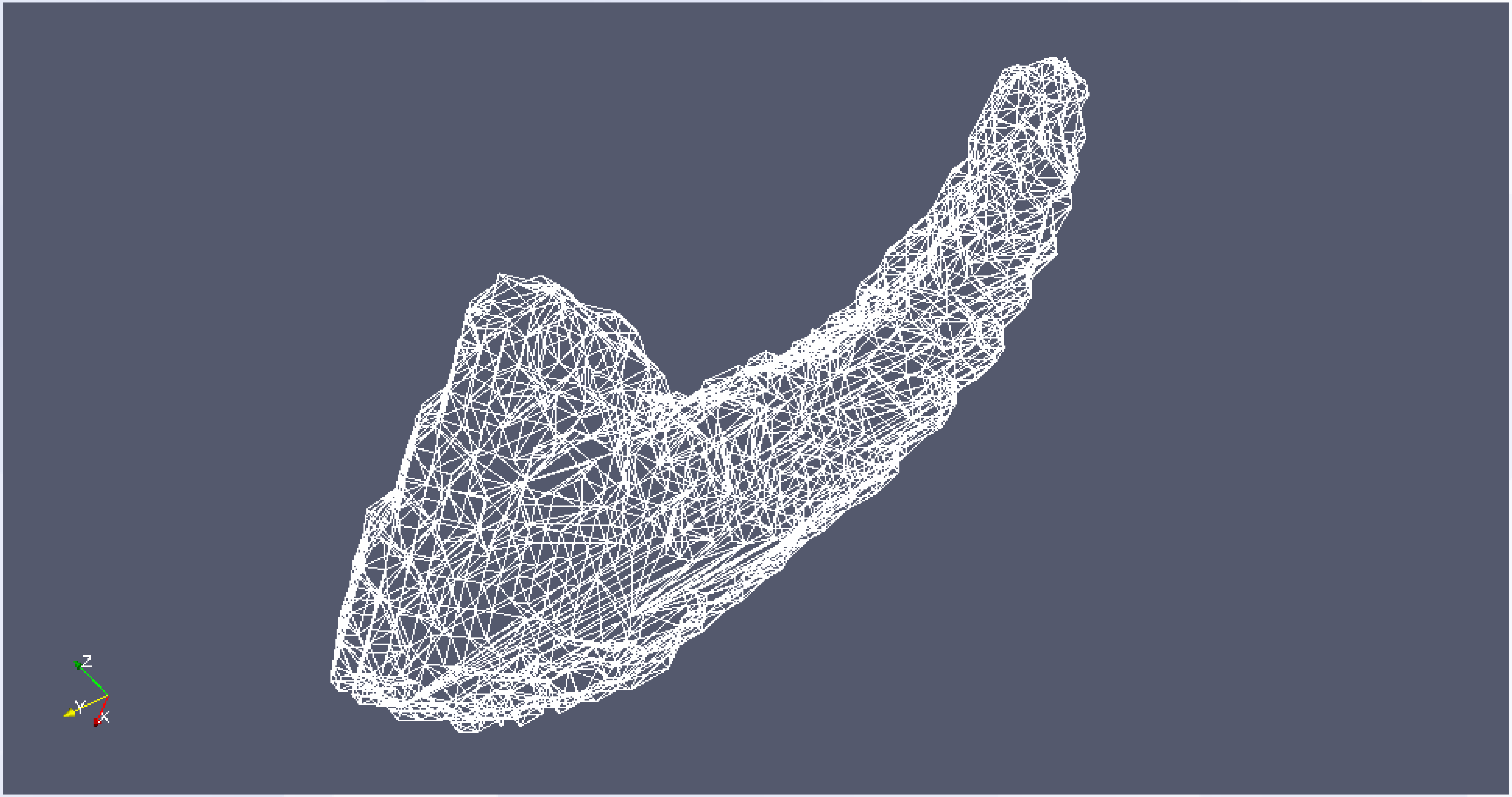
Reference hippocampus



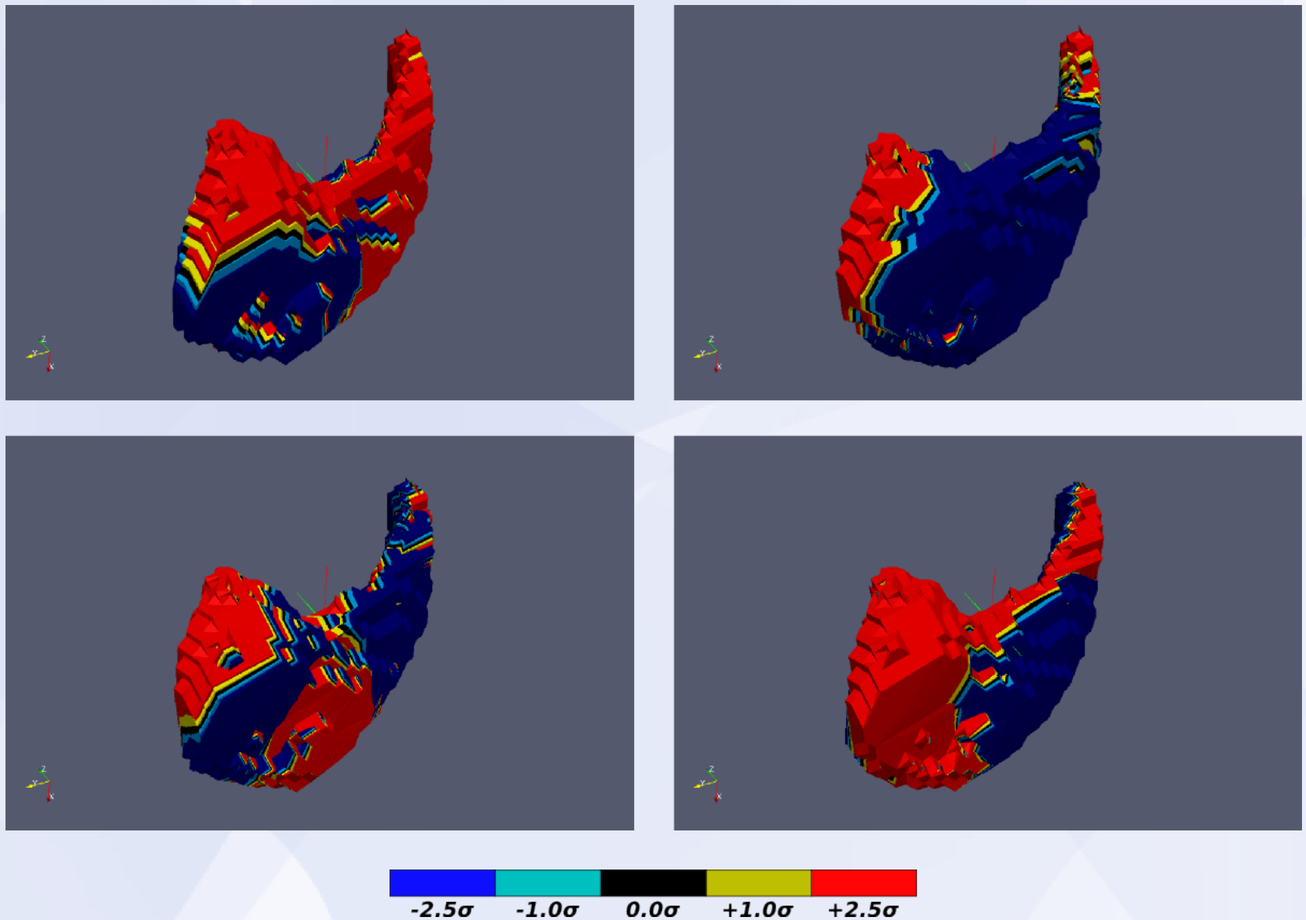
Reference mesh (2348 landmark)



Decimated mesh (1644 landmark)



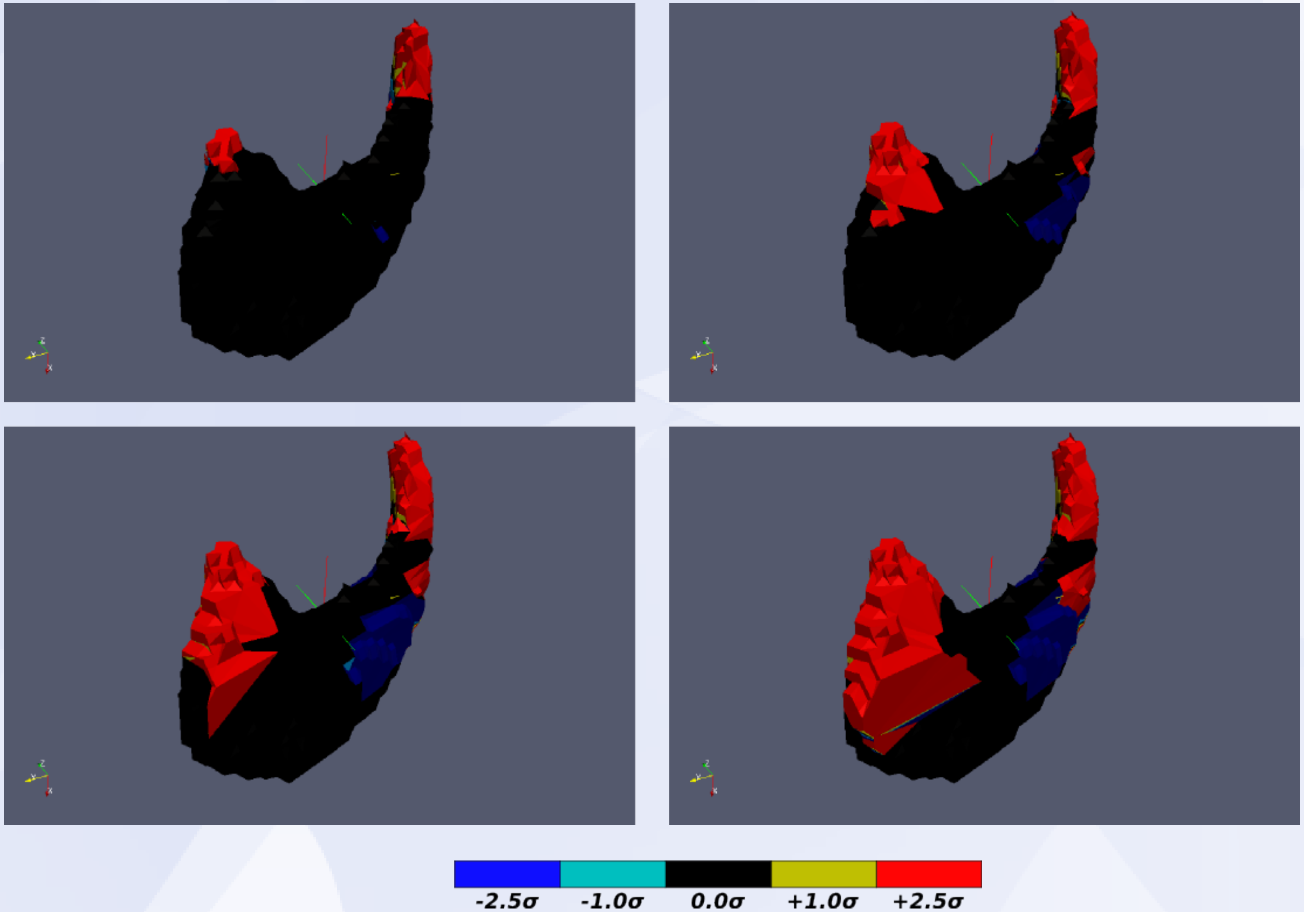
Principal component analysis (PCA)



95 segmentations dataset

1644 3D landmarks (4932 variables) for each shape

Sparse Principal Component (SPCA)



First principal component
5% up to 20% of the variables (5% step)

Conclusions and future works

- A **fully automatic** segmentation pipeline of the hippocampal region
- The **integration** of various, complementary approach can provide a finer segmentation
- The **consistency check** improve the robustness of the pipeline
- Our shape analysis can provide a **local variations** information

In progress:

- Validation: gold standard to evaluate our results (EADC protocol)
- Relation between shape analysis parameters and clinical score

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Thanks!