Project Details

Geometry Description and Mesh Construction from Medical Imaging

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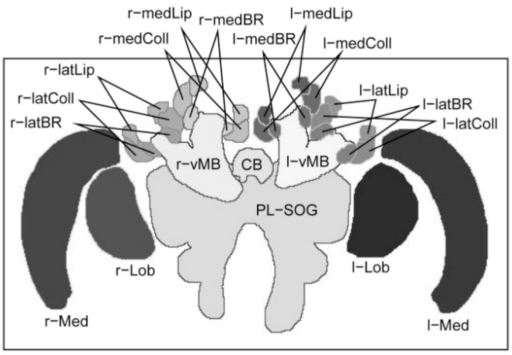
Outline

- Image & atlas-based segmentation
- Atlas selection
  - Single, variable, and multiple individual atlas
  - Single average atlas
- Image registration & trasformations
  - Non-rigid transformations
  - Parametric transformations
- Registration error: distance
- 2D examples

Image segmentation

- Segment an image = tag each pixel/voxel with a semantic label



- From the paper “Quo vadis, Atlas based segmentation” di T. Rohlfing, R. Brand, R. Menzel, D.B. Russakoff, C.R. Maurer jr

Image segmentation

- Intensity based classification
  – Group the gray level space in clusters
  – Each cluster is identified with a label
  – Each pixel is tagged with the label of the corresponding cluster

- Ok for classifying tissue types
- Bad when classifying anatomical structures

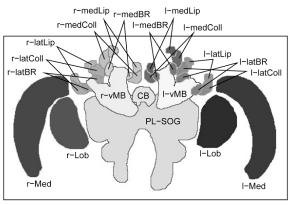
Image segmentation

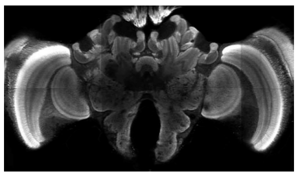
- Force the geometry of the image to evolve using
  - Image properties (gradient)
  - Constraints (smoothness of the segmented curves)

- Examples
  - Active contours (snakes) [Kass, Witkin & Terzopoulos ’87]
  - Level set method [Osher & Sethian ’88,Sethian ’99]
  - …

Image segmentation

- Atlas-based segmentation: template image T, already segmented





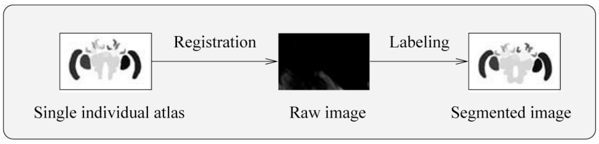
- Find a map transforming the template image in the image R to be segmented
- “Tranfer” on R the segmentation of T

Atlas Selection

Atlas selection

- Choice of atlas has substantial impact on the result of the segmentation algorithm
- Four strategies
  - *Single atlas* for all images to be segmented
  - *Choice of best atlas* for each given image into an atlas set
  - *Average atlas* for all the images to be segmented
  - *Simultaneous use of multiple atlases*

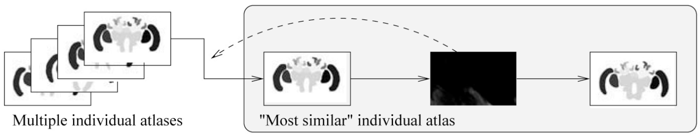
Single individual atlas



IND: Segmentation using a single individual atlas.

- Selection of an individual atlas
- Registration of all the raw images with the selected atlas
- (individual atlas = obtained by a single raw image)

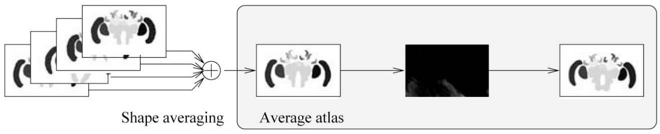
Variable individual atlas



SIM: Segmentation using the "most similar" individual atlas.

- Set of atlases
- Segment R using all atlases
- Select the atlas that gives the best risult
  - Maximum similarity
  - Minimum deformation

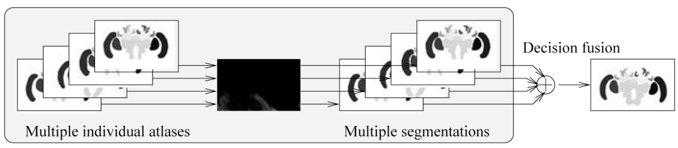
Single average atlas



AVG: Segmentation using an average shape atlas.

- Construct an artificial “tipical image” T from a set of images
- Construct corresponding atlas
- Register all images with T

Multiple individual atlas



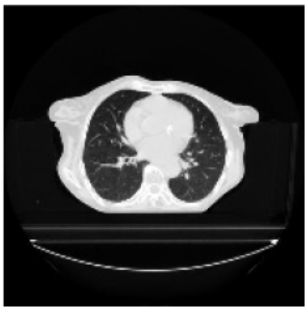
MUL: Independent segmentation using multiple individual atlases with decision

- Set of atlases
- Register R using each atlas
- Tag pixels with labels usin all information
  - Ex: voting strategy <-> tag with label chosen by highest number of atlases

Image Registration

Image registration

REFERENCE IMAGE



TEMPLATE IMAGE

CT studies, of the same patient by different CT machines

Image registration

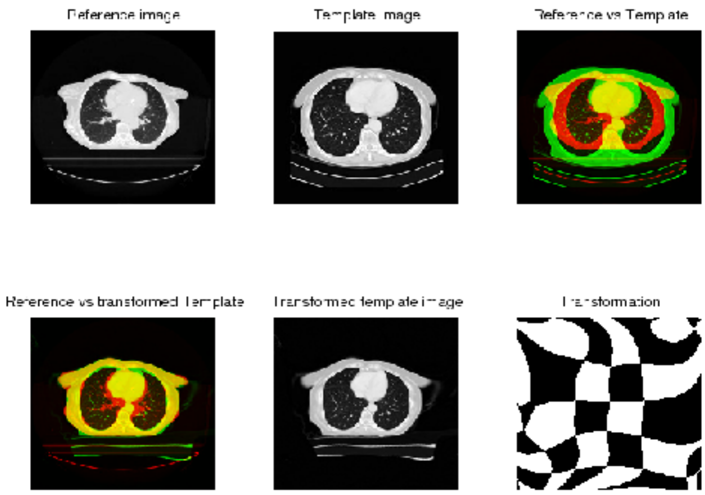


Image registration

- Grey scale images <-> real valued functions
- R: Ω_R -> $\mathbf{R}^+$, T: Ω -> $\mathbf{R}^+$

- Find mapping θ: Ω_R -> Ω such that $T \circ \theta$ and R are as “close” as possible

- Huge number of approaches
- Huge number of algorithms

See [Brown ’92; Zitova,Flusser ’03]

Image registration

- Huge number of algorithms obtained by combining
  - Different “distance” functionals
  - Different transformation classes
  - Different image models
  - Different optimization algorithms

- Huge number of possible combination

The transformations

- Rigid transformations (translations, rotations)
- Affine transformation

- Non rigid transformations
  - Splines, B-splines [Thevenaz, Unser ’98]
  - Thin plate splines [Bookstein, ’89]
  - Interpolating wavelets [S.B., G. Maggi ’13]
  - ...
  - Parametric transformations

Parametric transformations

- N-dimensional parameter space
- Parameter α -> mapping θ_α
- (Ex: $\theta_\alpha = \sum \alpha_i e_i$)
- $\theta_\alpha = \Theta(x;\alpha)$
  - x : spatial coordinate (in $\mathbf{R}^2$)
  - α : parameter (in $\mathbf{R}^N$)
  - Θ : $\mathbf{R}^2$ x $\mathbf{R}^N$ function (represents the selected class of transformations)

The "distance"

- **Im**: space of images
- d: **Im** x **Im** -> **R** functional measuring the discrepancy between the two images
- δ: **Im** -> **R** defined as $\delta(X) = d(X,R)$
- c : $\mathbf{R}^N$ -> **R** cost functional
- $c(\alpha) = d(T \circ \theta_\alpha, R) = \delta(T \circ \theta_\alpha)$

The “distance”

- Many different possibilities
  - Least square error
  - Human Visual System model distance [Mannos, ’74]
  - Structural similarity index SSI [Wang et al, ’04, Brunet, Vrscay, Wang ’11]
  - Besov functional norm
  - Besov norm + divisive renormalization (generalised SSI) [S.B., G. Maggi, ’14]
  - Mutual information [Viola, Wells ’97; Thevenaz, Unser ’98]
  - ...

The optimization problem

- Find α_0 in $\mathbf{R}^N$

$$\alpha_0 = \arg\min_\alpha c(\alpha)$$

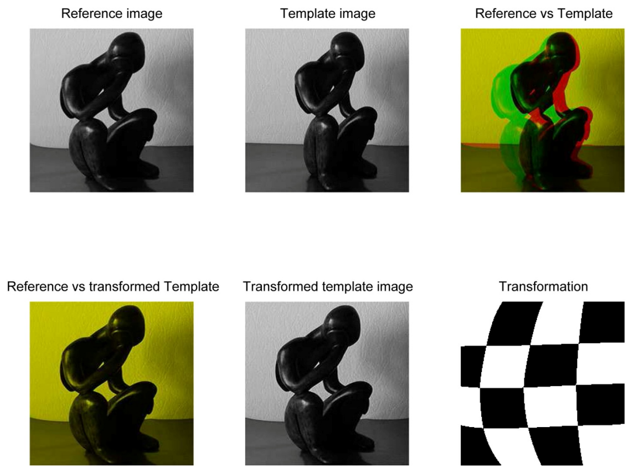
- Unconstrained optimization problem

- Several possible optimization algorithms
- Choice depends on the characteristics of
  - Transformation
  - Distance functional

Image model

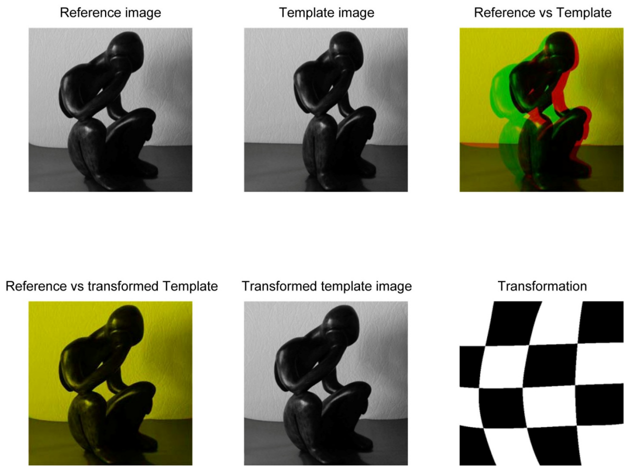
- Need rules to
  - Evaluate images out of their domain of definition (*extrapolation*)
  - Compute values of (deformed) images at pixels (*interpolation*)
  - Compute the values of derivative of images at pixels (*numerical differentiation*)
- Many different possibilities

Results



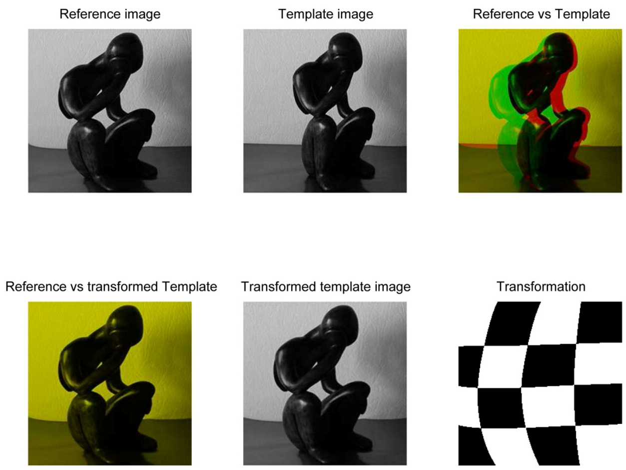
<u>**No noise**</u>
Distance: LS

Results



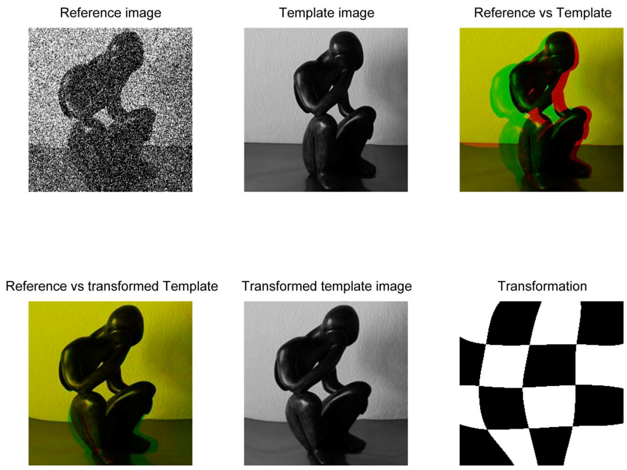
<u>No noise</u>
Distance: SSIM
p=2

Results



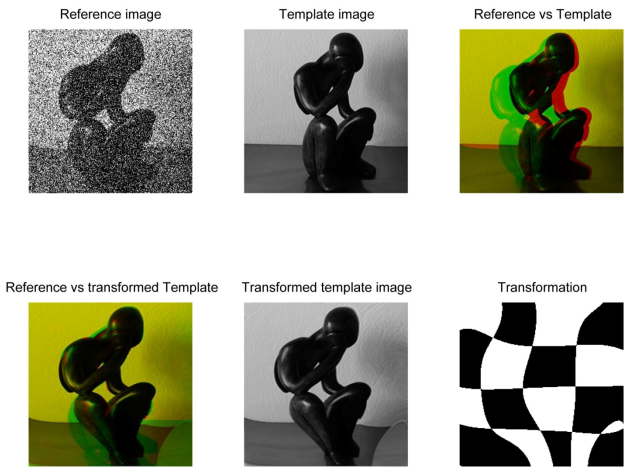
<u>No noise</u>
Distance: GSSIM
p=2

Results



<u>Gaussian noise</u>
Distance: LS

Results



<u>Gaussian noise</u>
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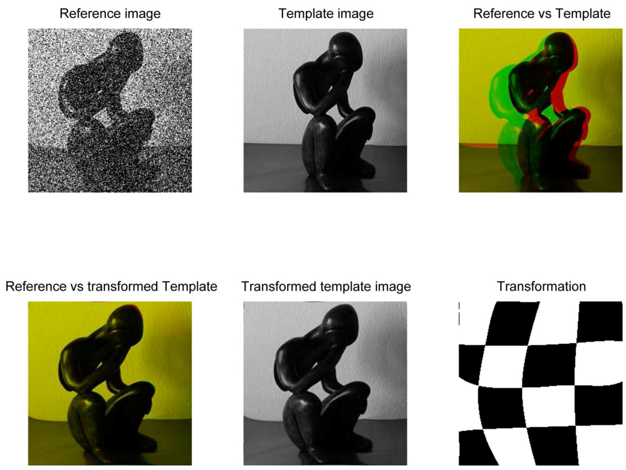
p=2

Results



<u>Gaussian noise</u>
Distance: GSSIM
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