Traitement d'Image avec ITK

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Insight Toolkit (ITK)

- Bibliothèque Open Source
- Ecrite en C++
- Existe depuis 2000
- Environ 267 développeurs
- Plus de 500k téléchargements
- Investissement de la part du NIH: ~$14M
- Algorithmes de traitement d'images seulement
- Pas de UI ou visualisation
- www.itk.org

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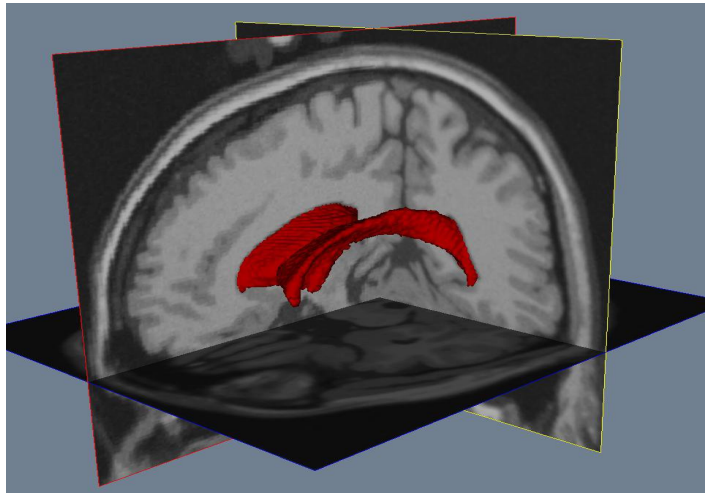
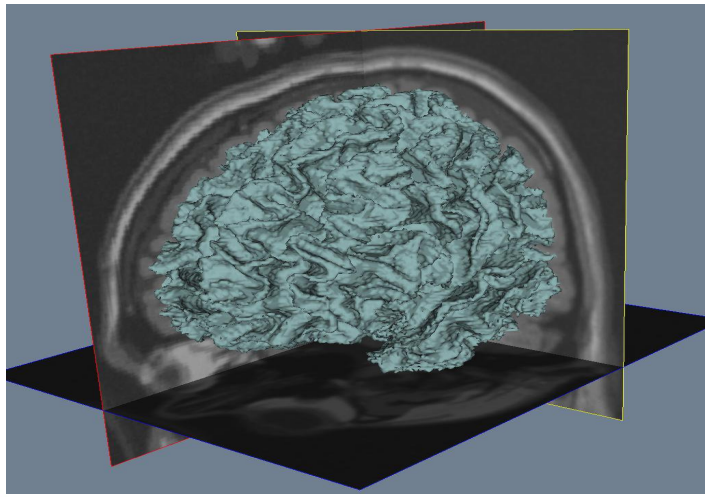
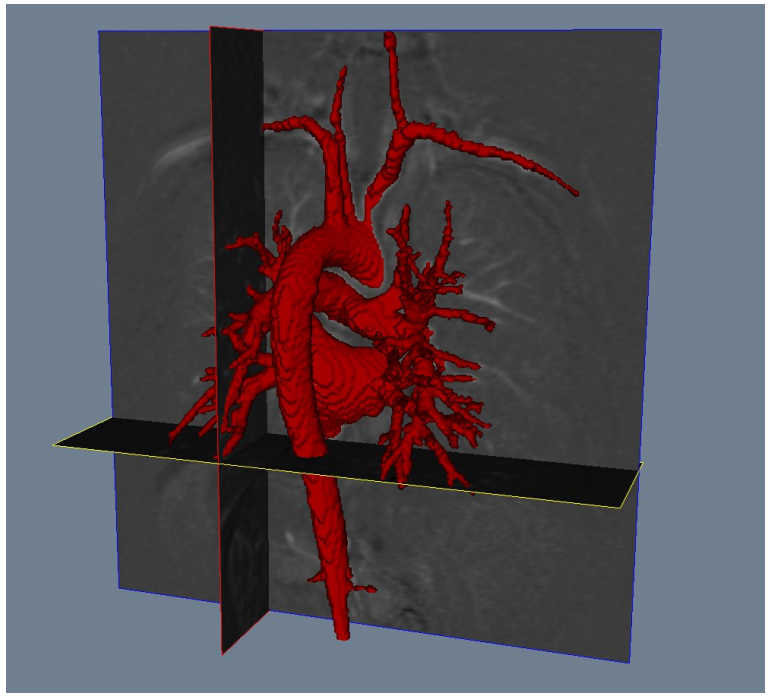
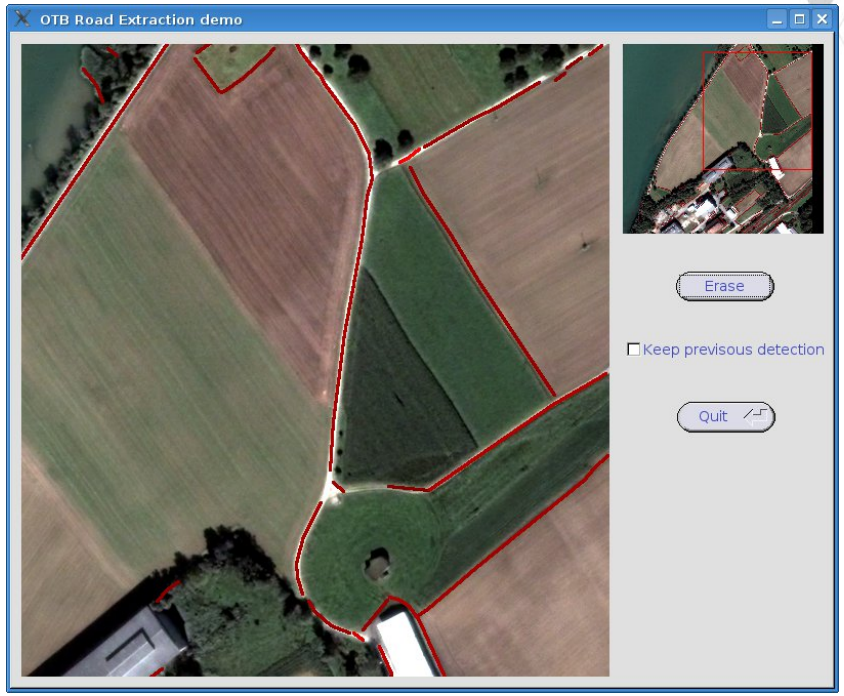
Développeurs initiaux d'ITK

ITK – Segmentation









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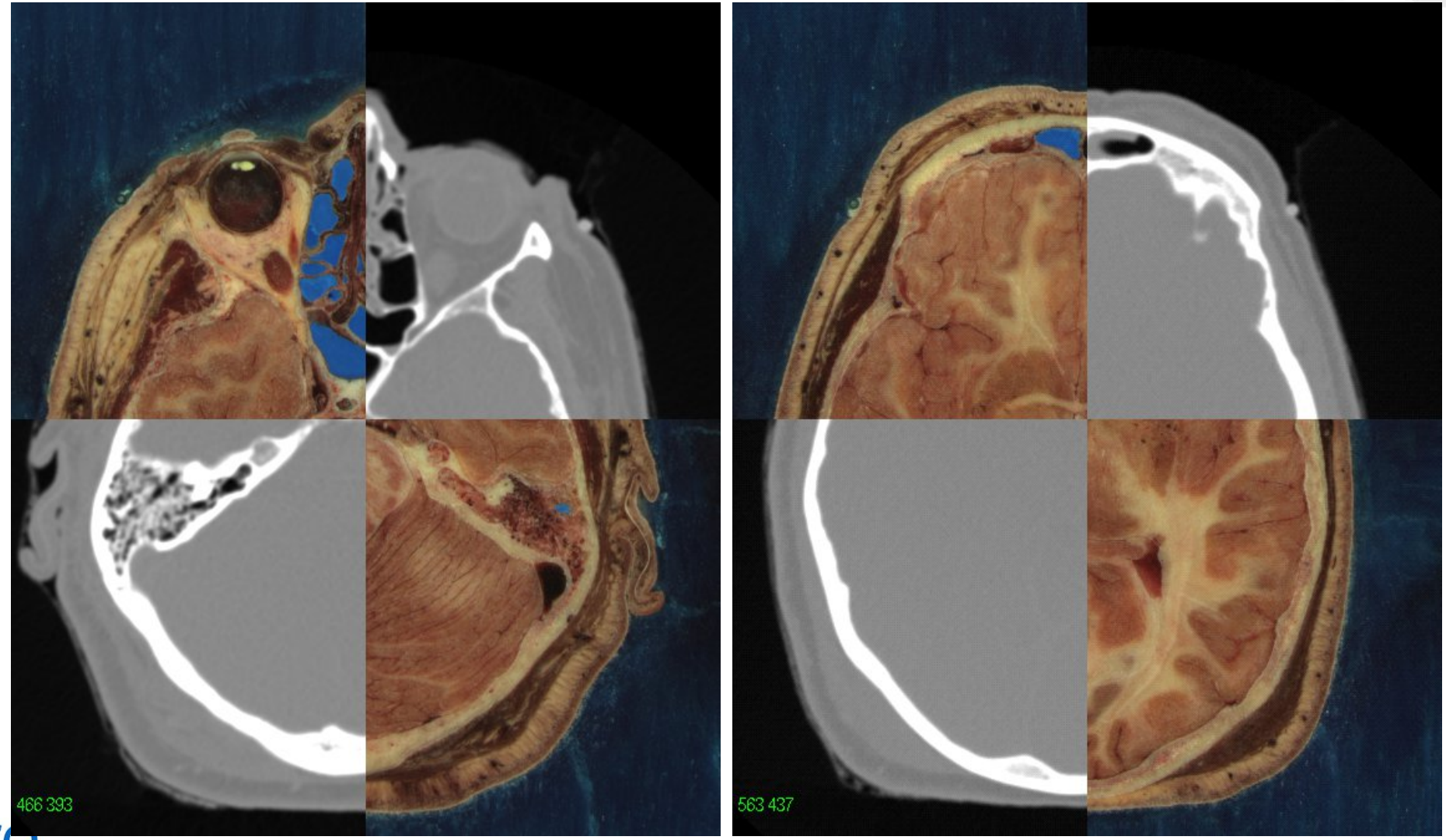
ITK – Recalage



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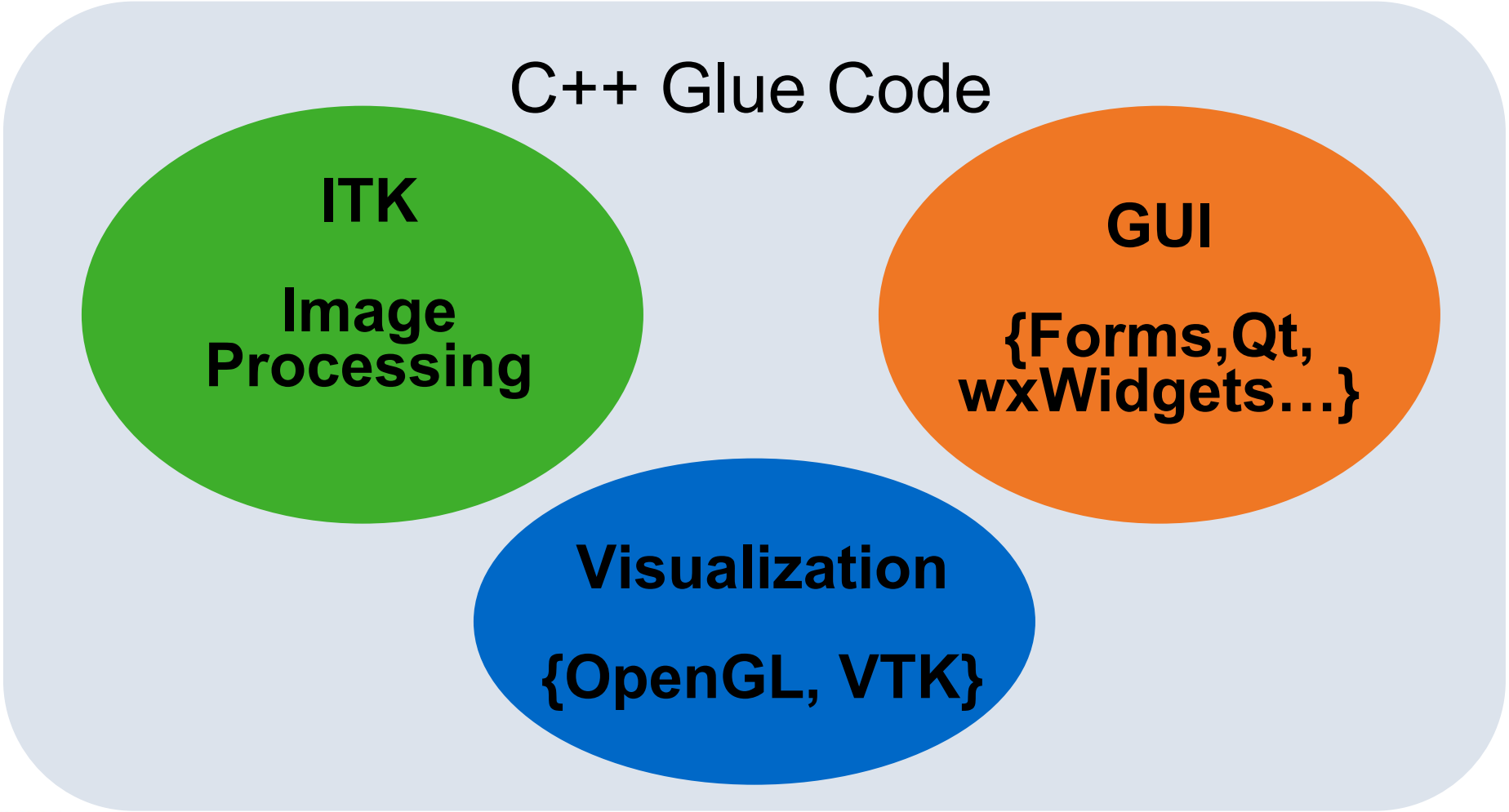
Intégrer ITK dans une application C++



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Apprendre ITK

- http://www.itk.org/Wiki/ITK
- http://www.itk.org/ItkSoftwareGuide.pdf
- http://www.itk.org/Doxygen/html/index.html
- https://itkpythonpackage.readthedocs.io/en/master/Quick_start_guide.html

ITK – Generic Programming

- Par exemple la STL en C++
- Abstraction des types et actions

std::vector< T >

std::vector< int >
std::vector< double >
std::vector< char * >
std::vector< Point >
std::vector< Image >

itk::Image< PixelType , Dimension >

itk::Image< char , 2 >
itk::Image< char , 3 >
itk::Image< RGB , 3 >
itk::Image< unsigned short , 2 >
itk::Image< itk::Vector<float,2> , 2 >

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ITK – C++

- Utilisation de namespaces
- Utilisation de smart pointeurs
- Utilisation de Const correctness
- Gestion des expections

ITK - Python Types

C++ type	Python type
float	itk.F
double	itk.D
unsigned char	itk.UC
signed short	itk.SS
unsigned short	itk.US
int	itk.I
std::complex<float>	itk.complex[itk.F]

```
-> itk.ctype('float')
```

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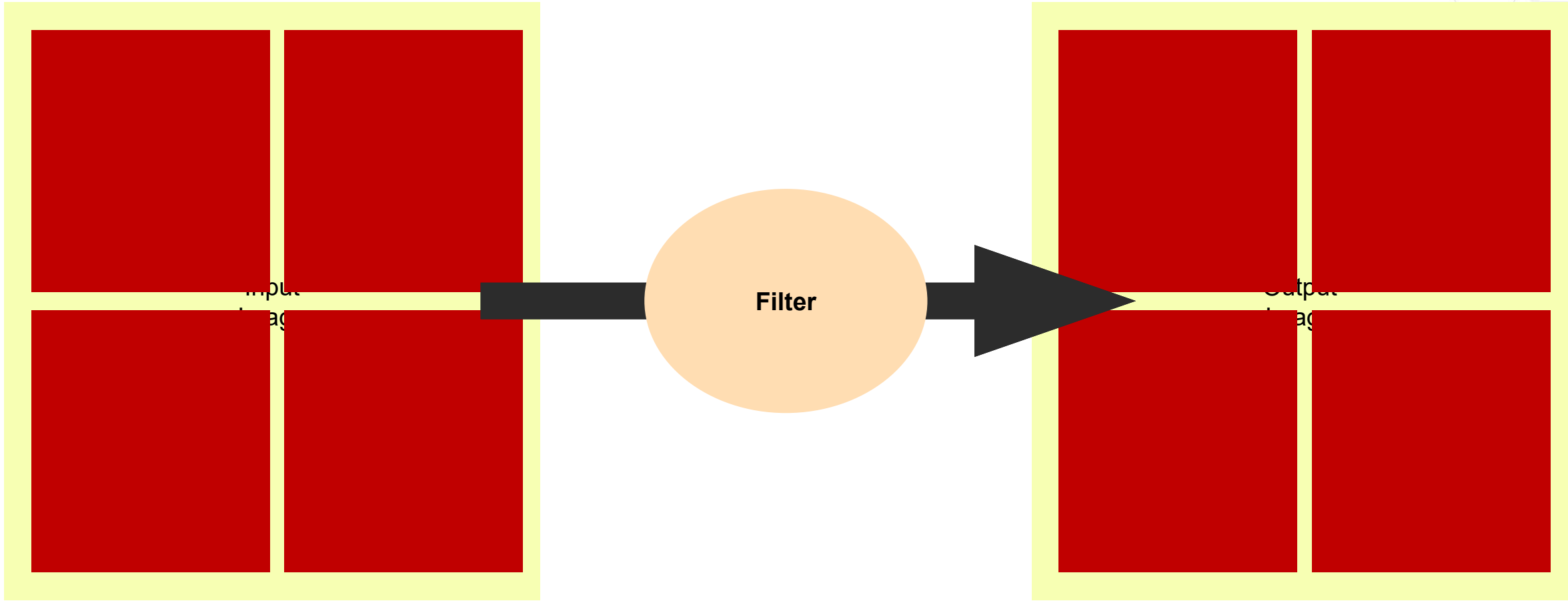
ITK – Streaming



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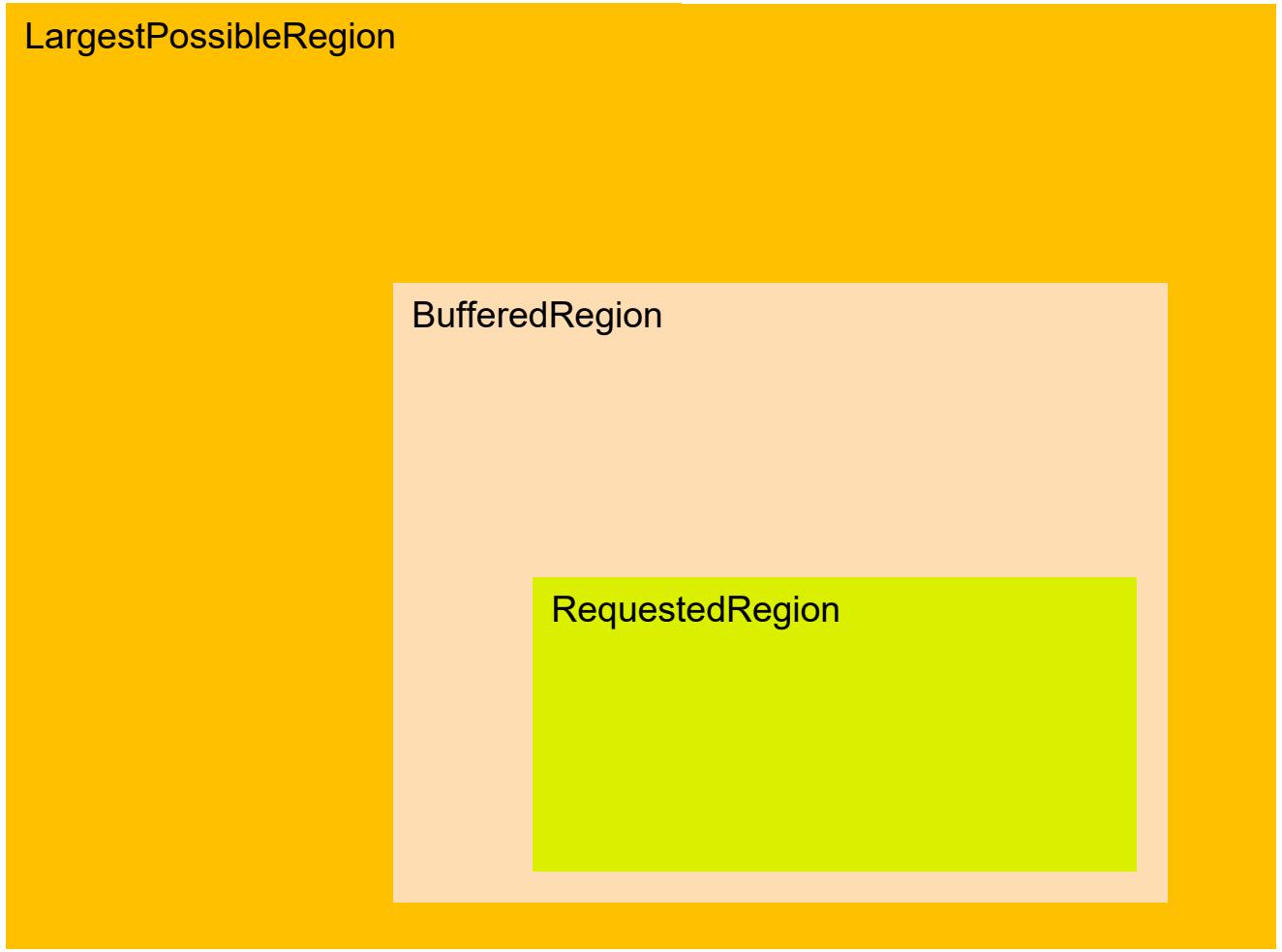
ITK – Gestion de la mémoire



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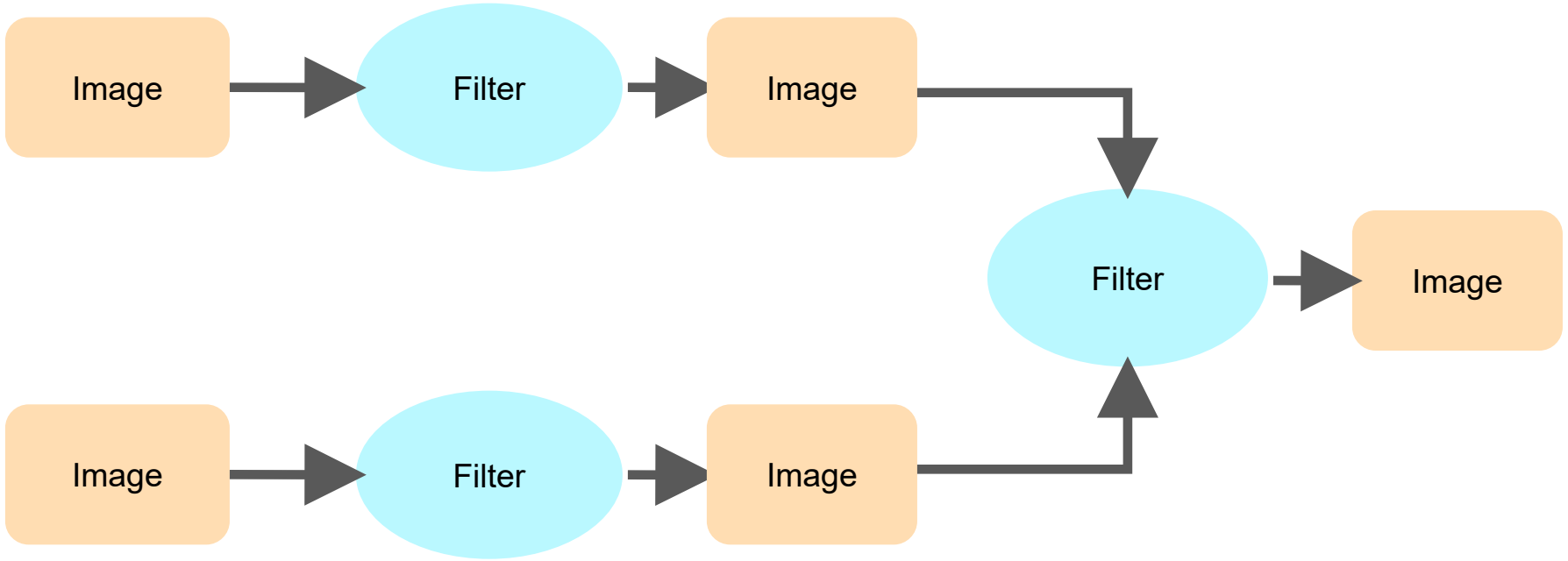
ITK – Pipeline de traitement



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Filter instantiation syntax

```
filter = itk.ImageFilter[InputType, OutputType].New()
filter.SetInput(image)

filter = itk.ImageFilter[image, image].New()
filter.SetInput(image)

filter = itk.ImageFilter.New(image)
filter = itk.ImageFilter.New(filter)

image = itk.ImageFilter(image)
image = itk.ImageFilter(filter)
```

Segmentation

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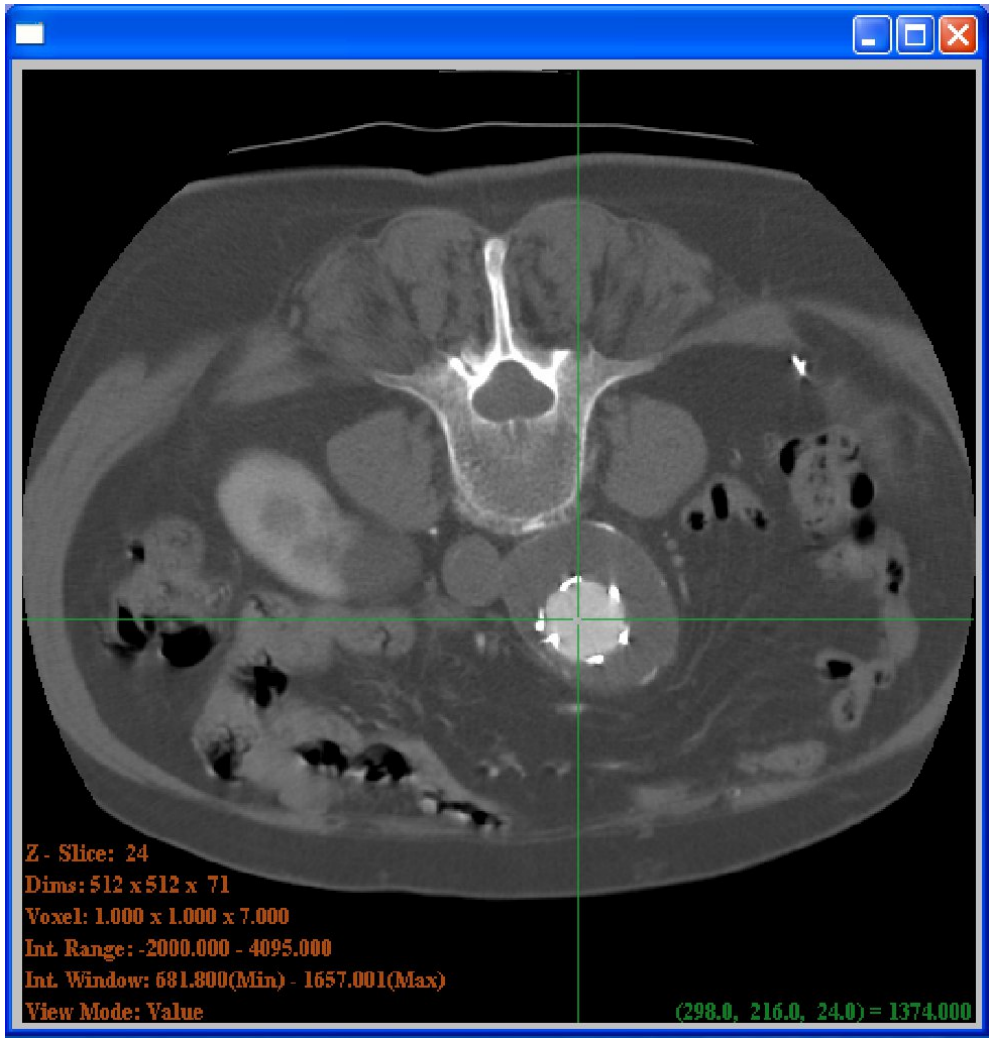
Comment segmenter cette tumeur?



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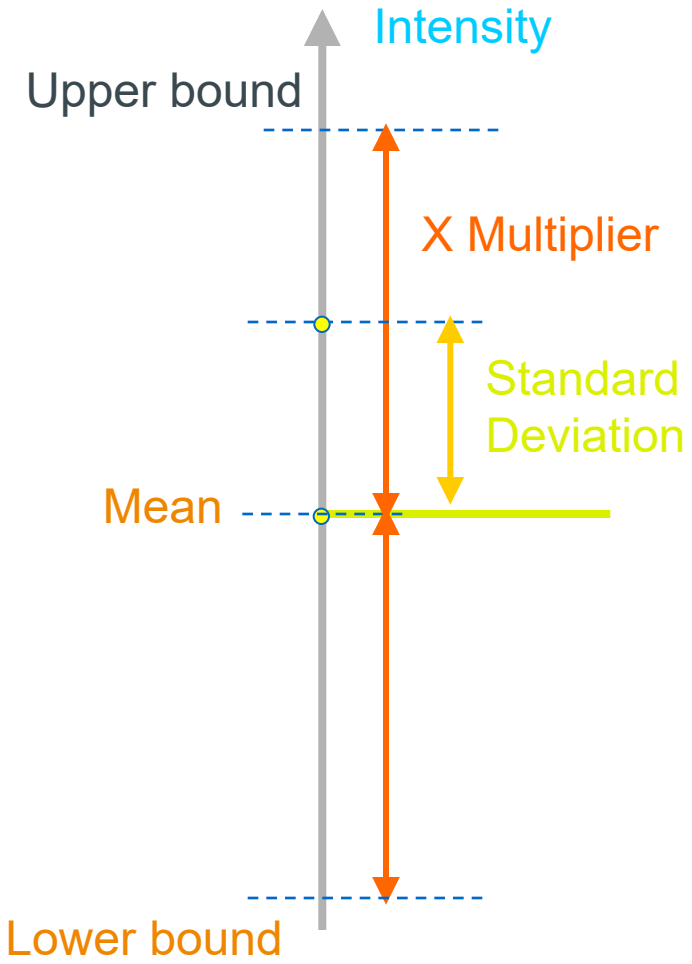
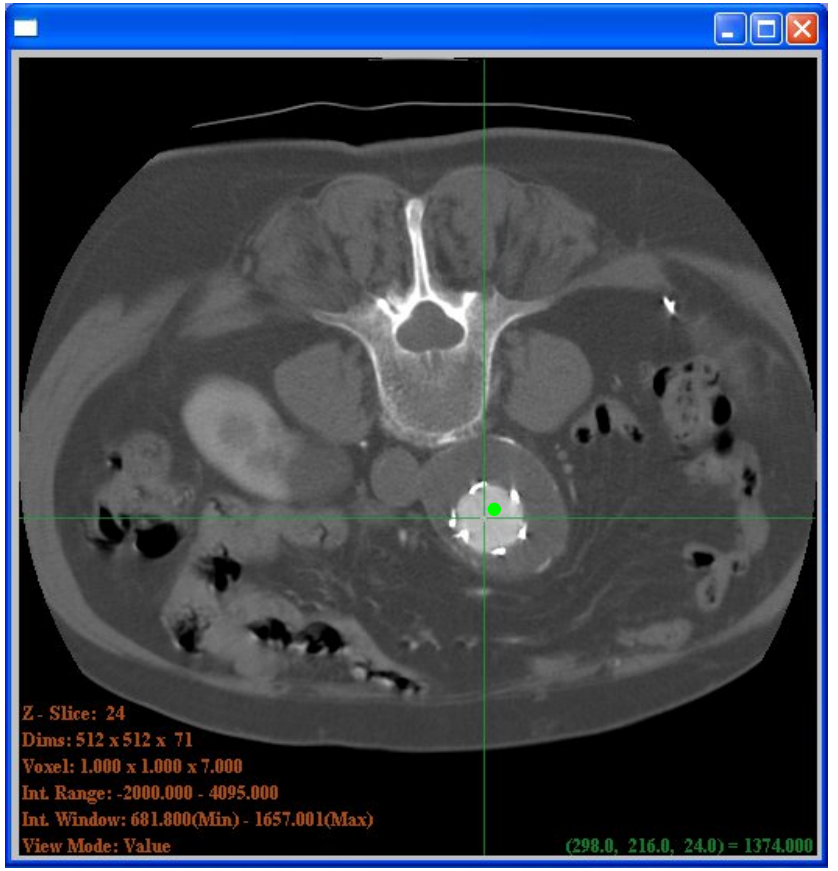
Confidence Connected





Seed Point

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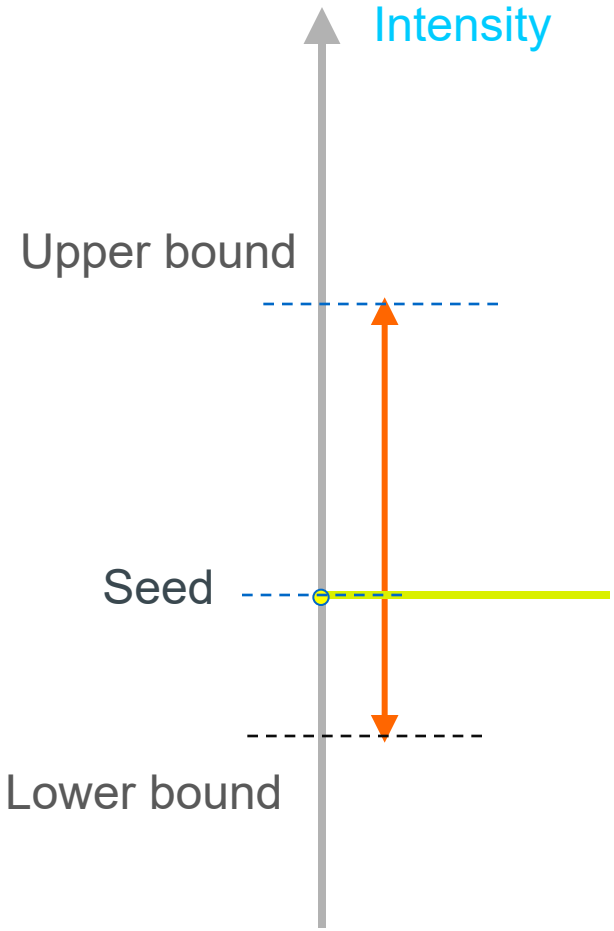
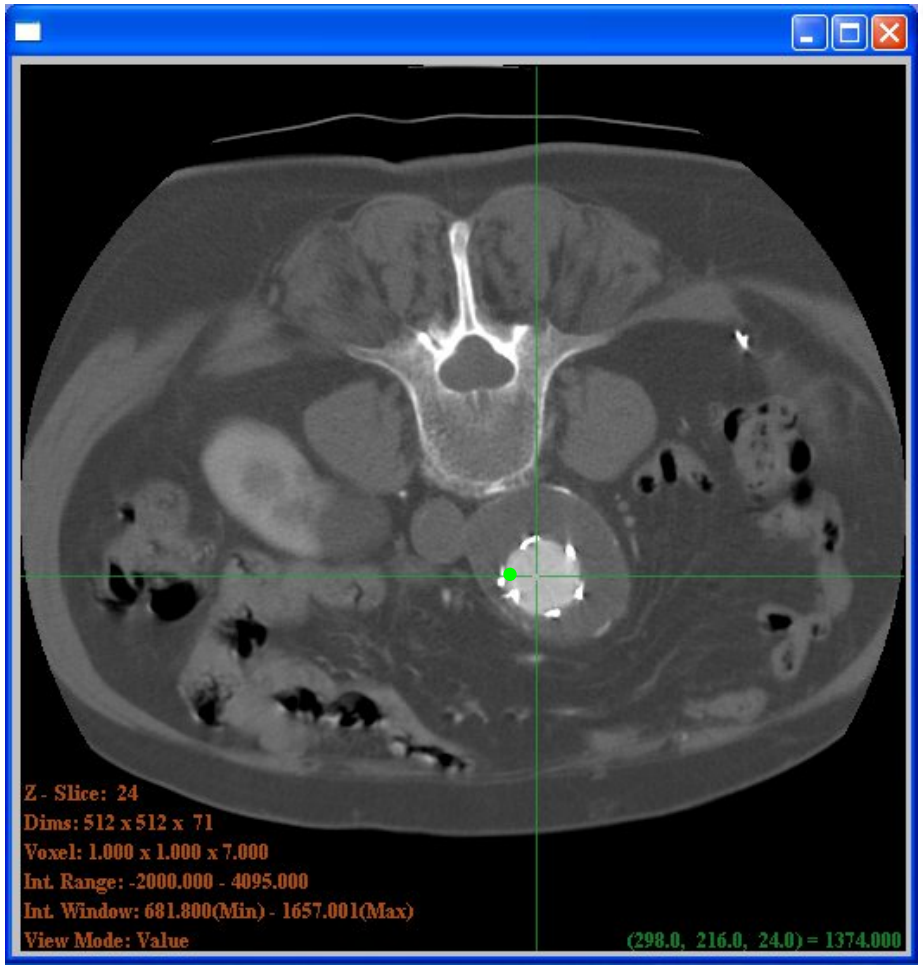
Connected Threshold





Seed Point

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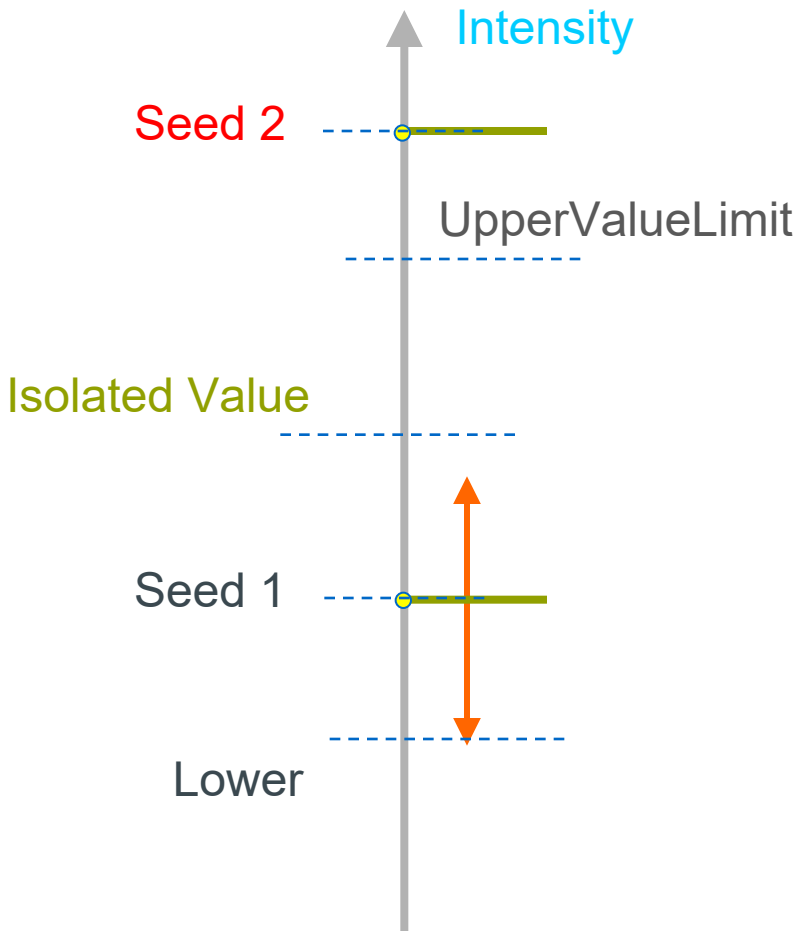
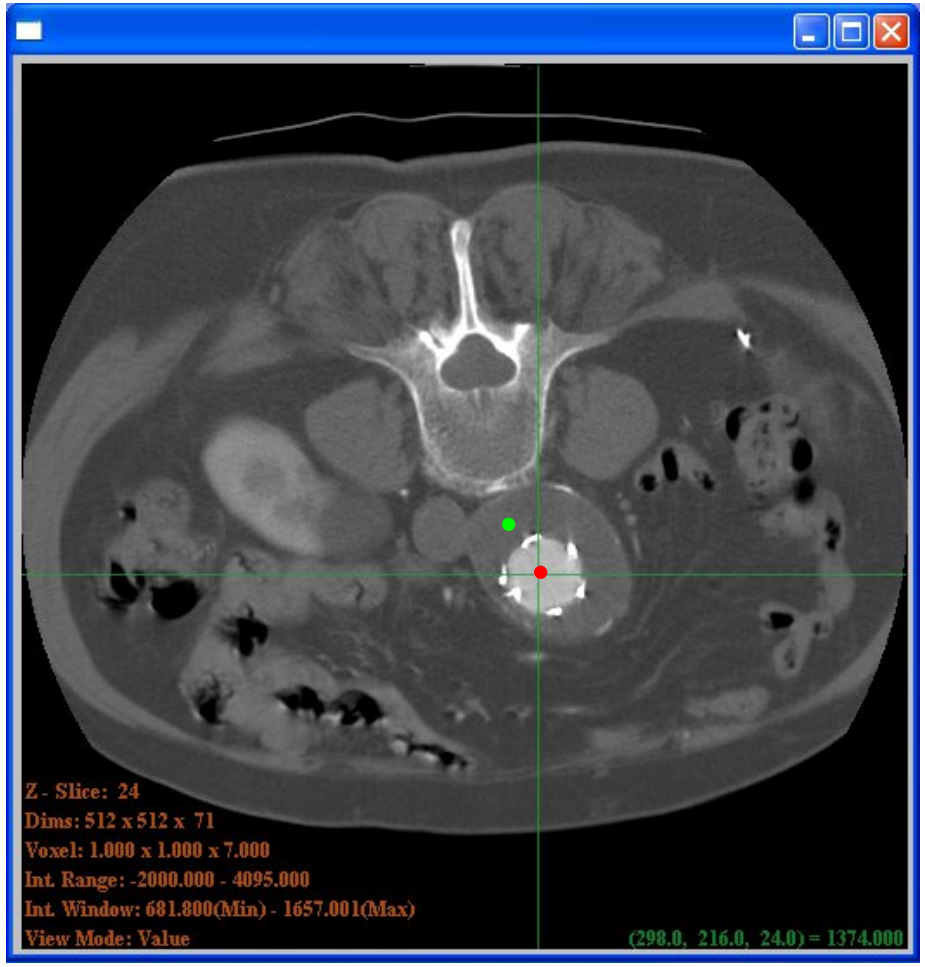
Isolated Connected





2 Seed Points

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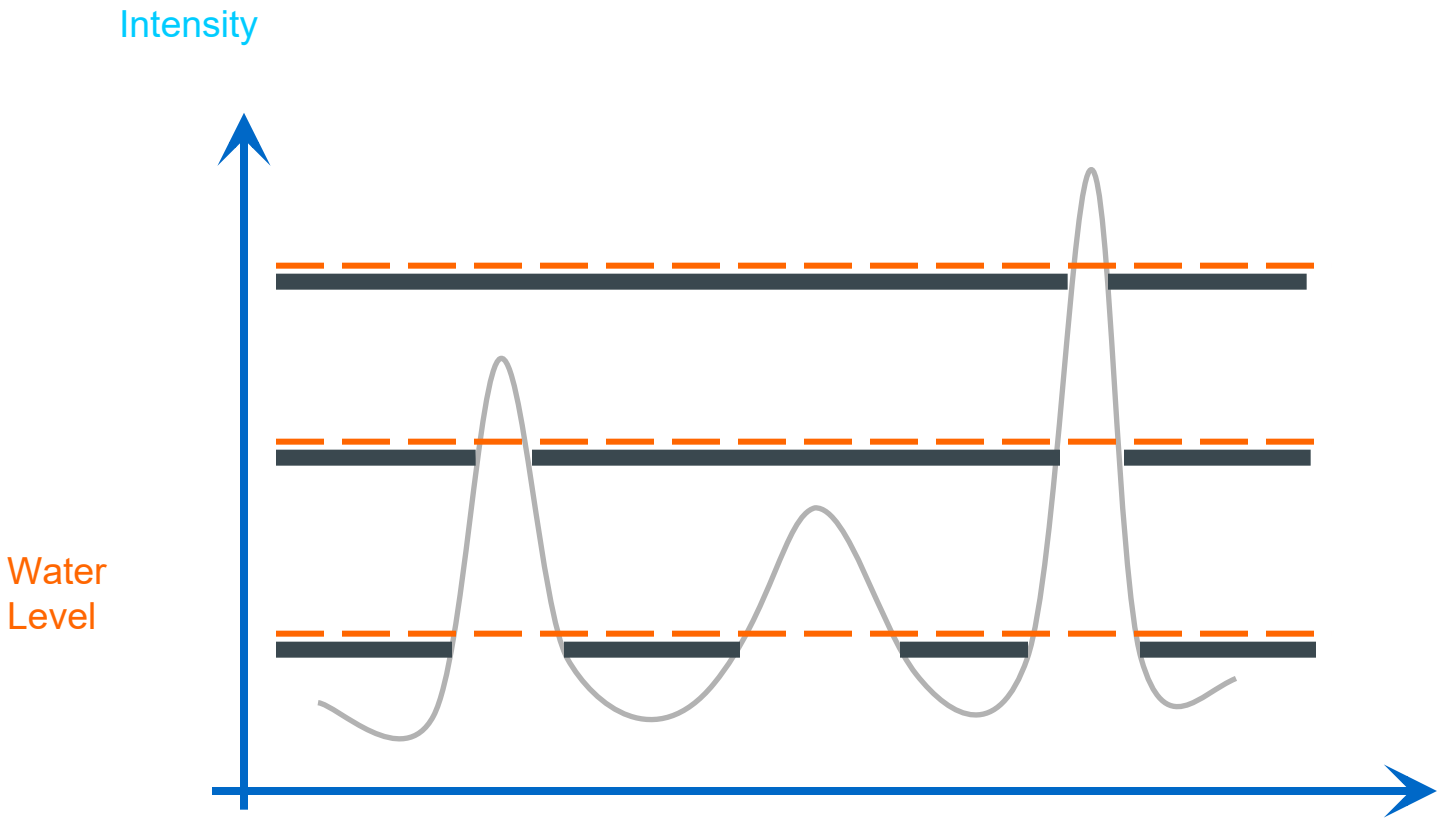
Watershed Concept



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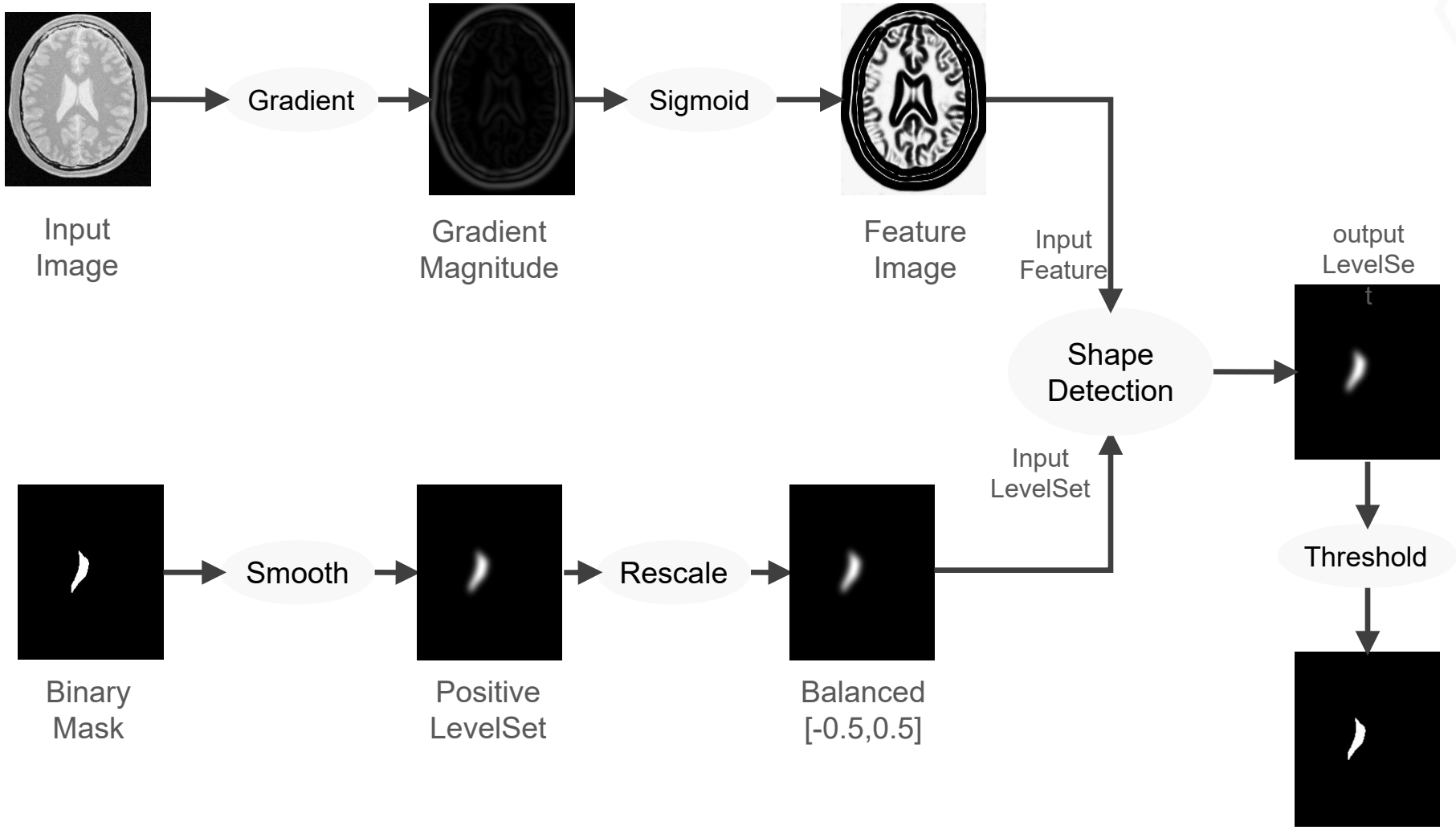
Shape Detection



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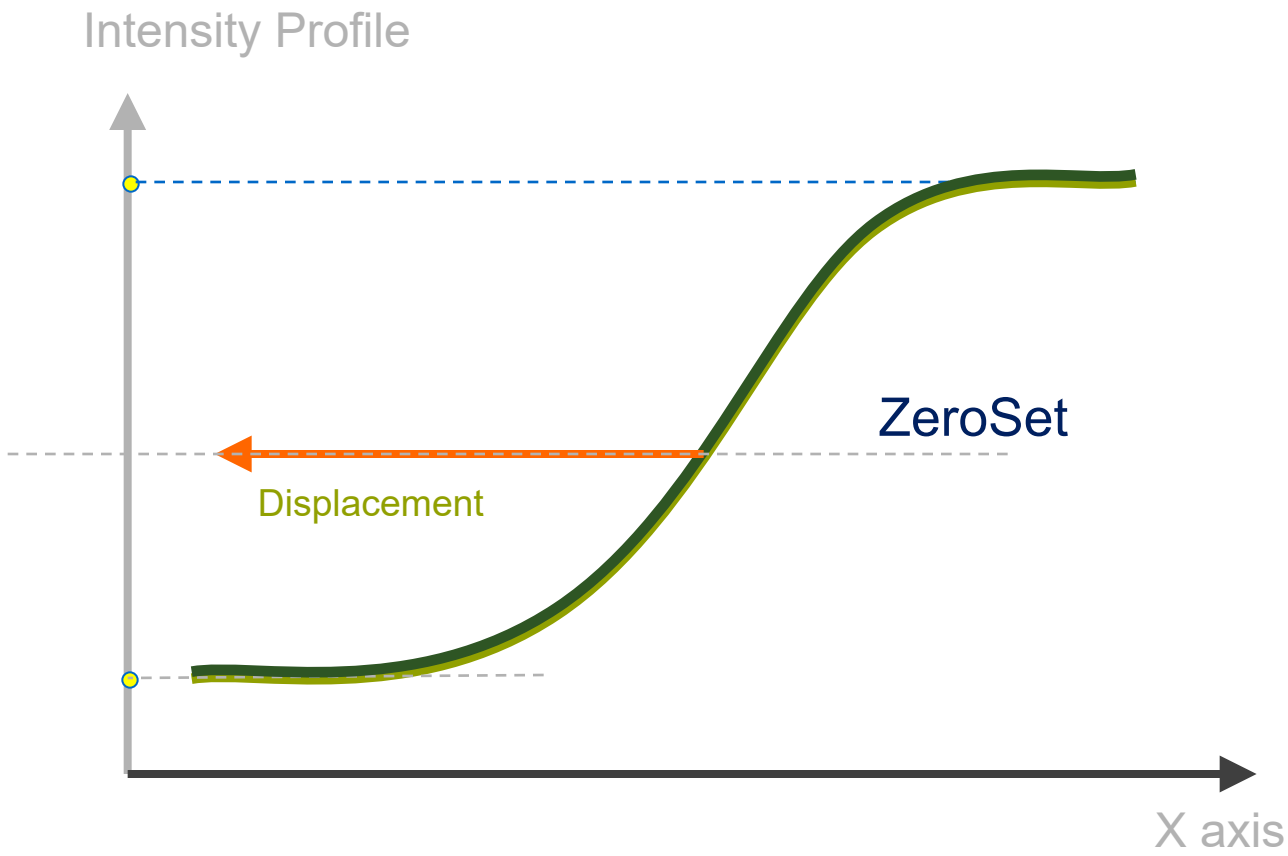
Geodesic Active Contour



Advection term added

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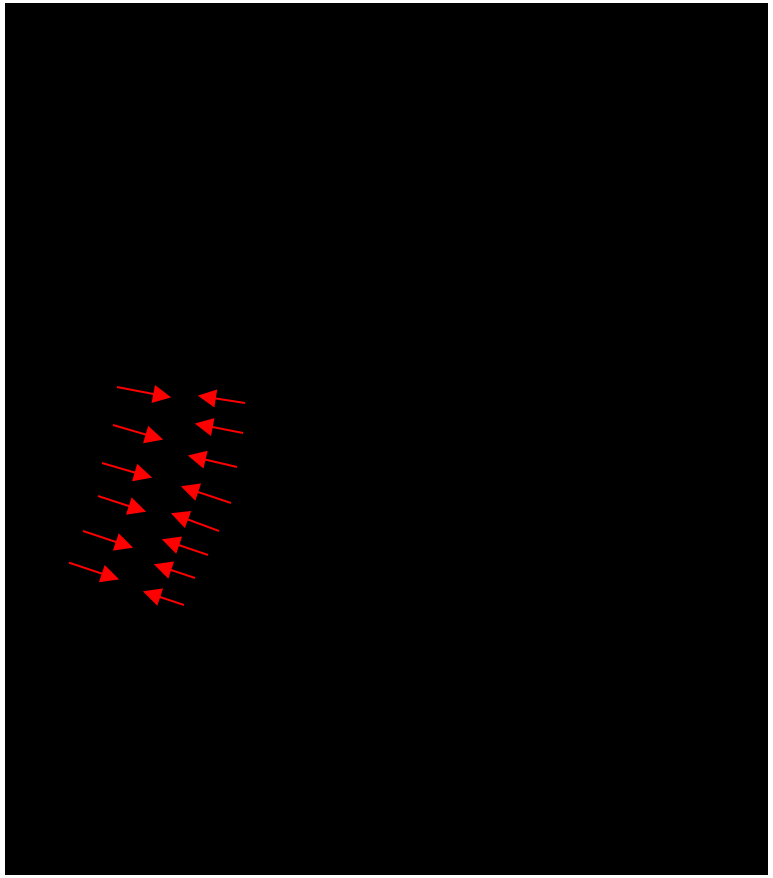
Geodesic Active Contour

- Vector Field Computed Internally



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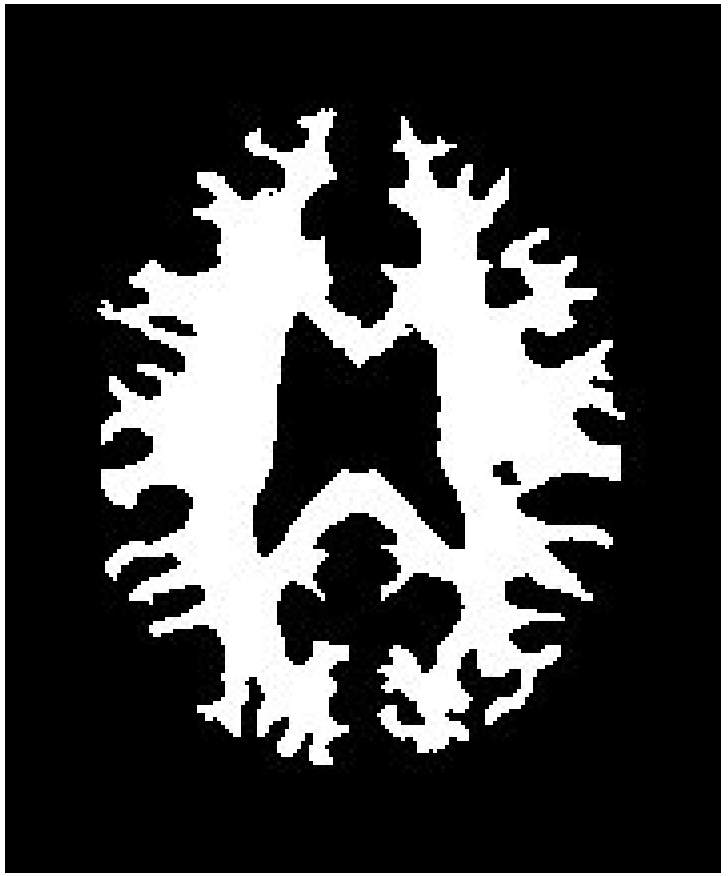
Threshold Level Set

- Advection term added controlled by a threshold
- LevelSet equivalent of a connected components method inside a threshold
- but… with options for preventing leaks



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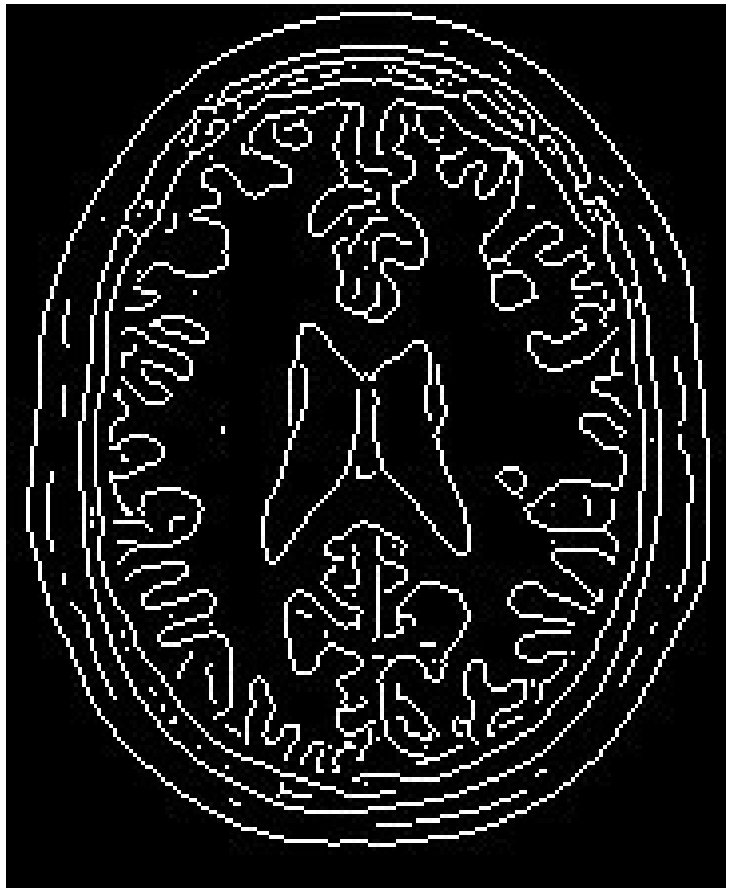
Canny Level Set

- Advection term added controlled by edges
- Canny edges attract the zero set



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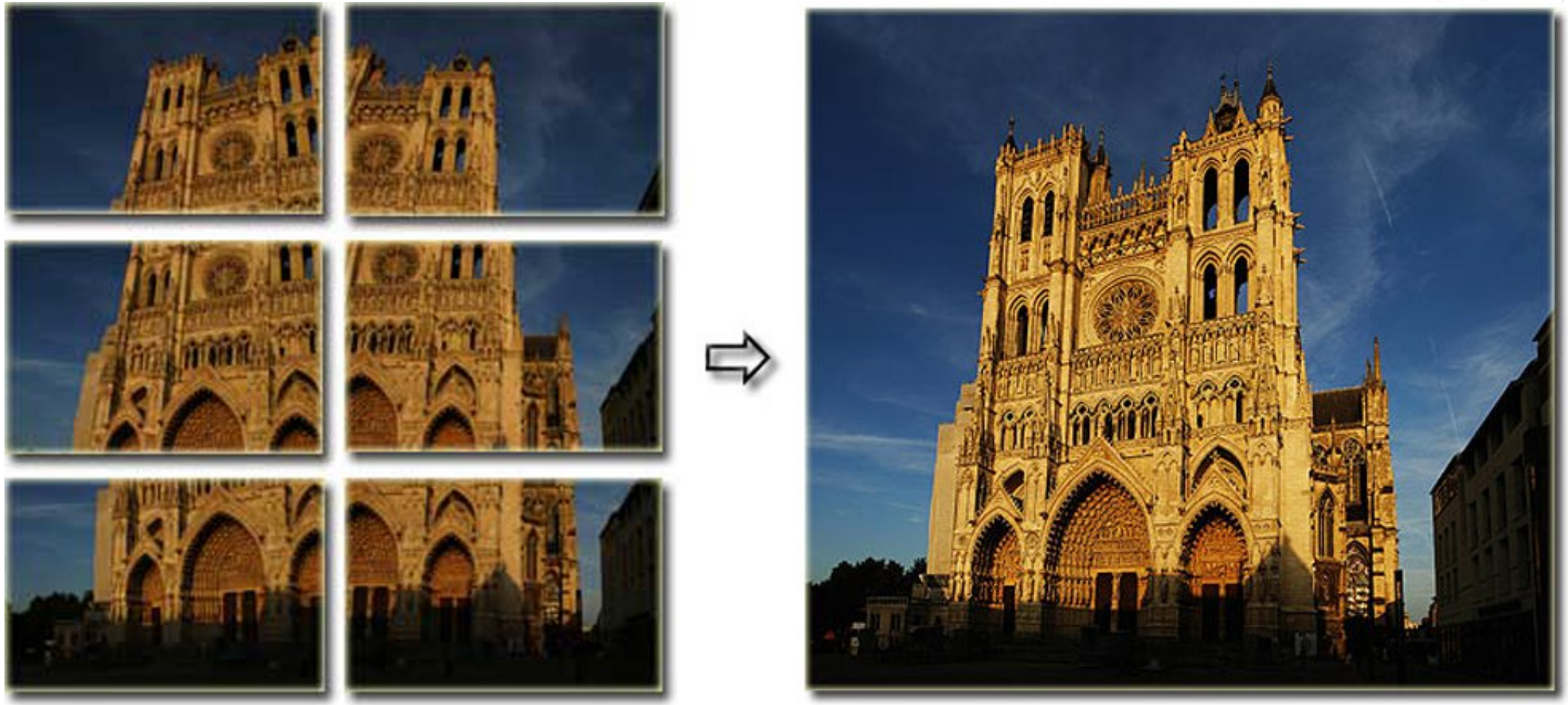
Recalage



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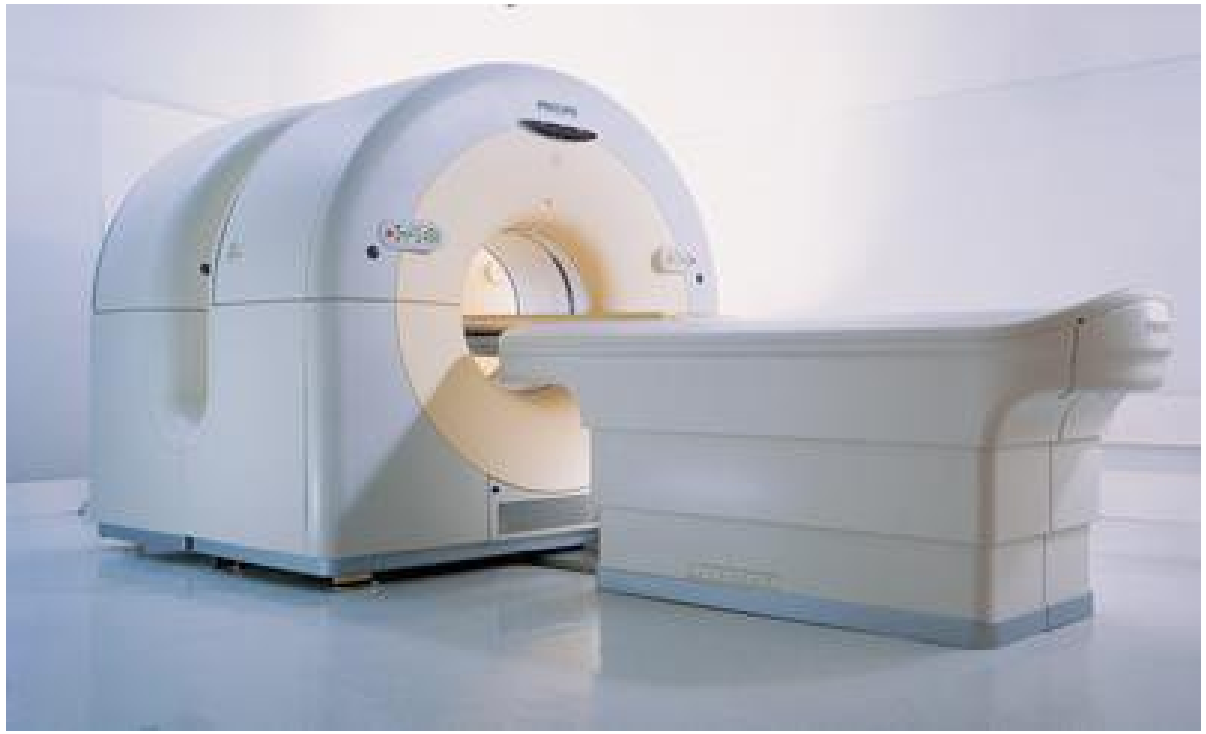

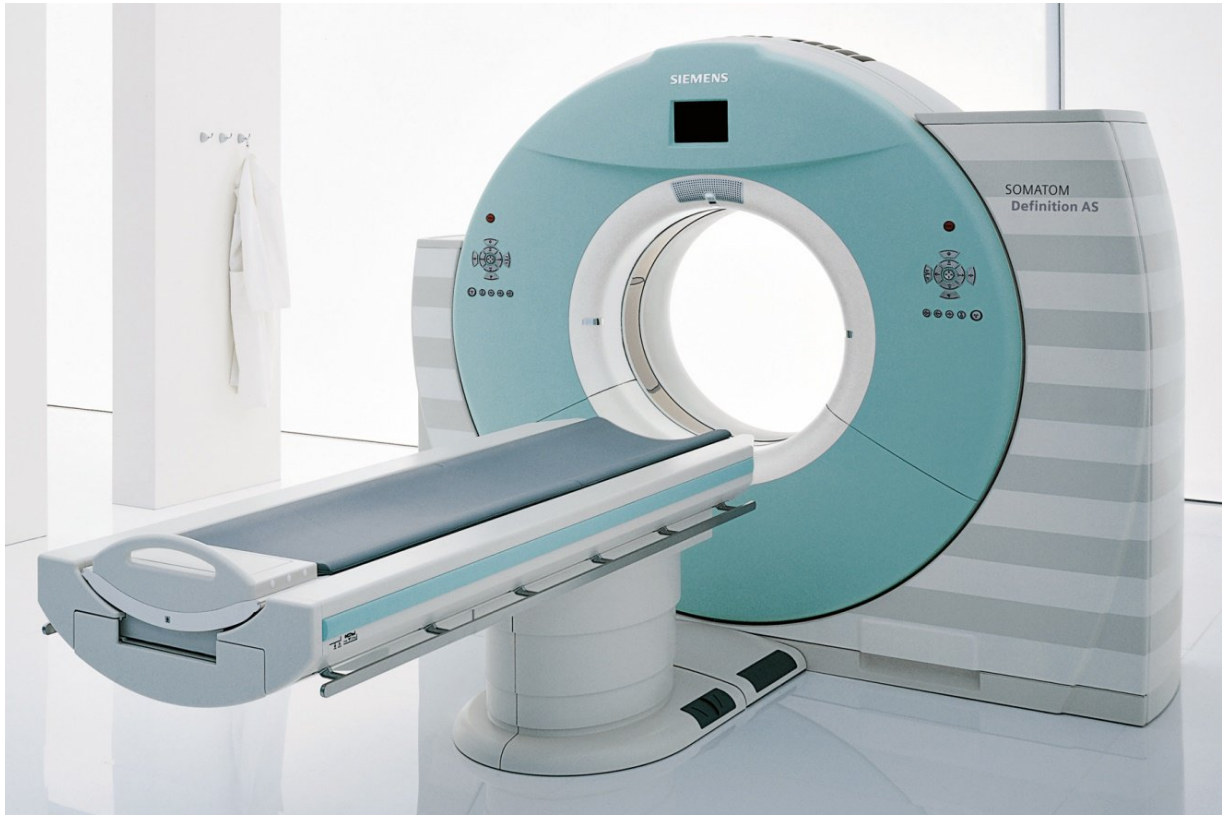

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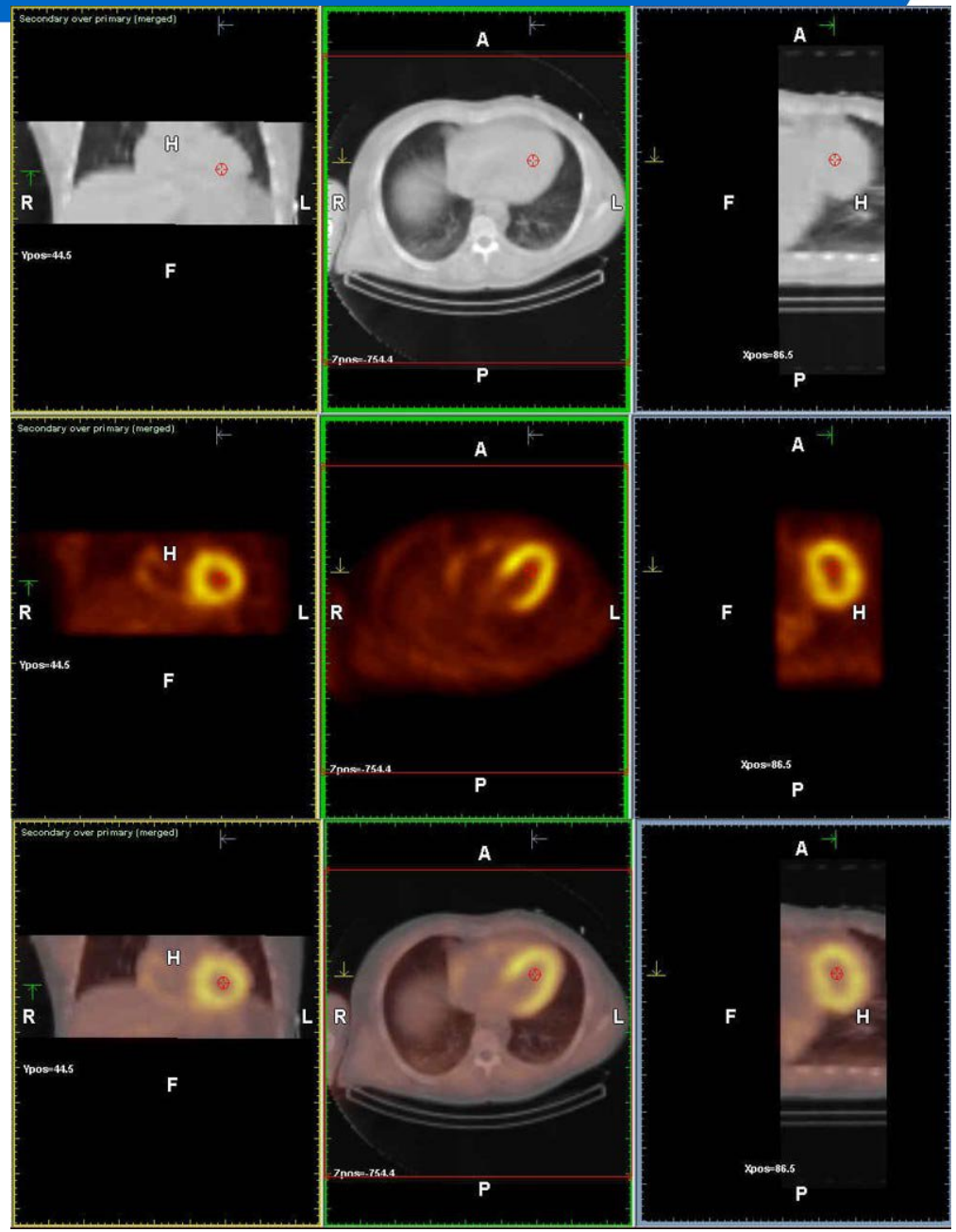
Secondary over primary (merged)
A
H
R
L
F
P
Ypos=44.5
Zpos=-754.4
Xpos=86.5

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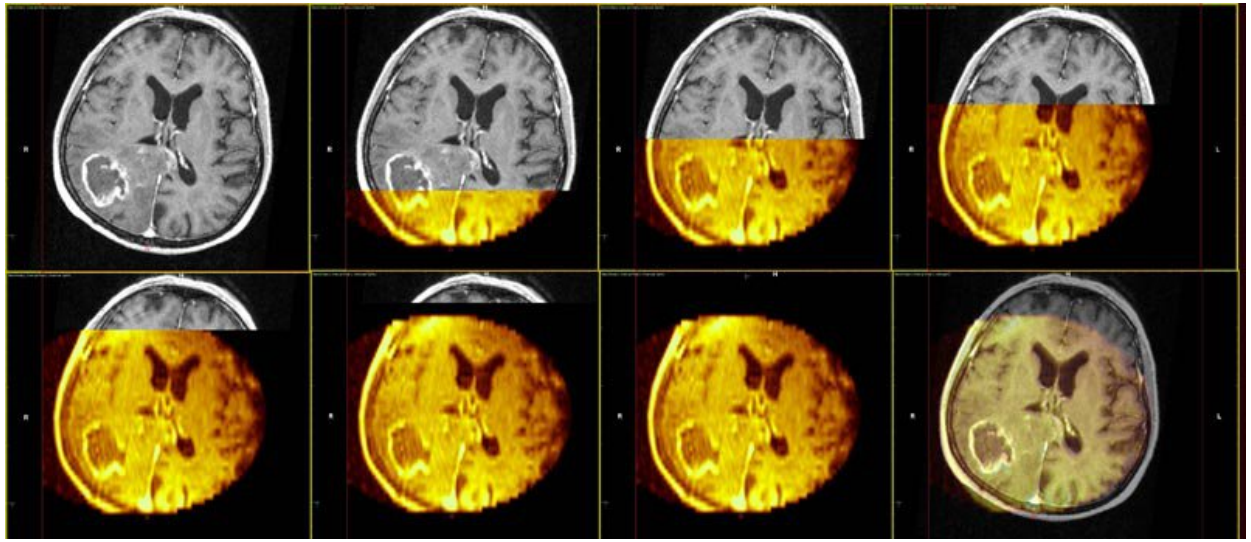
Articles Récents (MICCAI 2020)

- MvMM-RegNet: A new image registration framework based on multivariate mixture model and neural network estimation
- Database Annotation with few Examples: An Atlas-based Framework using Diffeomorphic Registration of 3D trees
- Large Deformation Diffeomorphic Image Registration with Laplacian Pyramid Networks
- Flexible Bayesian Modelling for Nonlinear Image Registration
- Cross-Modality Multi-Atlas Segmentation Using Deep Neural Networks

Recalage

Technique qui consiste en la mise en correspondance d'images (ou modèles) afin de pouvoir les comparer ou combiner leurs informations respectives.



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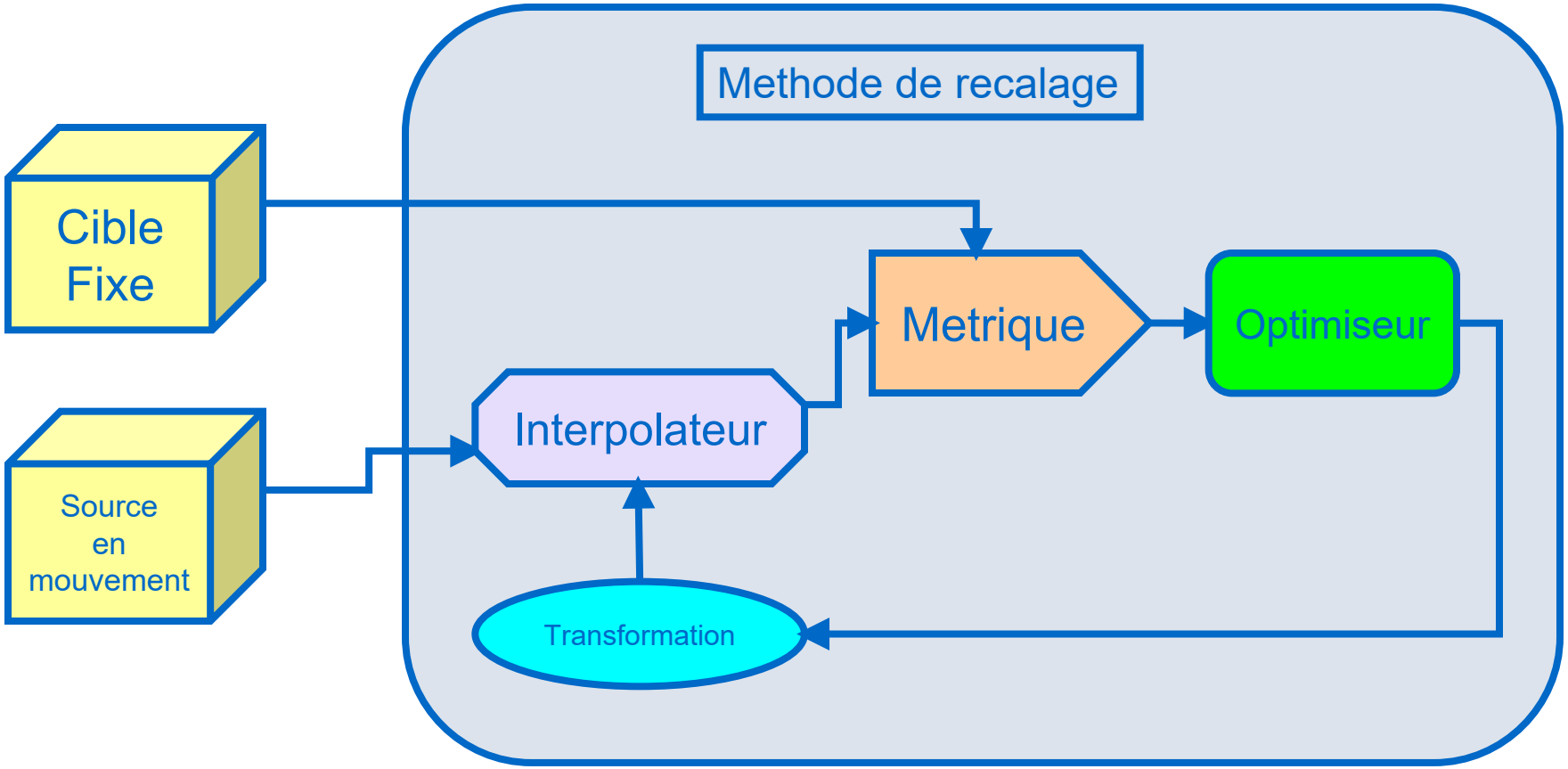
Composants du recalage

- Transformation
- Métrique
- Optimiseur
- Interpolateur

Composants du recalage



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Composants du recalage

- Transformation
- Métrique
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- Interpolateur

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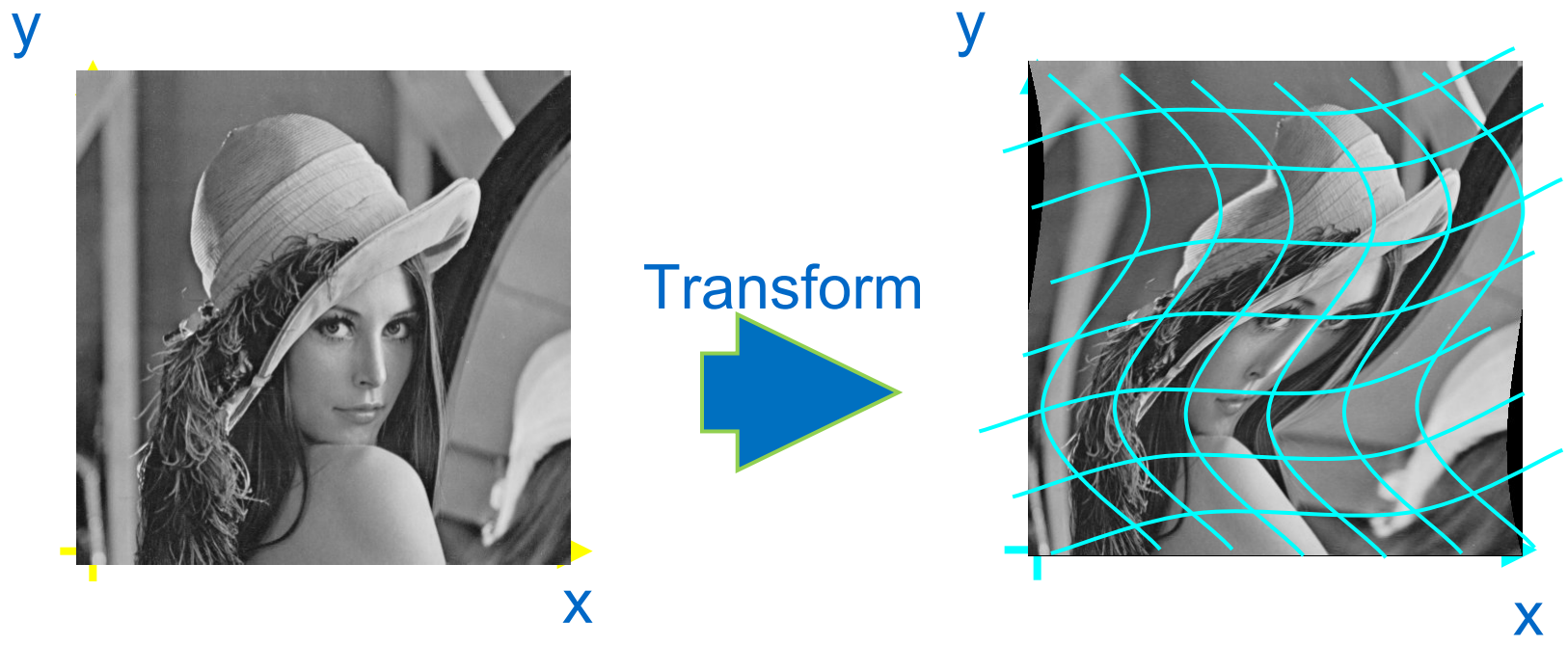
Composants du recalage



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Transformations

- Translations (déplacements)
  - conserve distances et angles orientés
- Rotations (isométrie)
  - conserve distances et angles
- Homothéties (similitude)
  - conserve les rapports entre les distances
- Affinités
  - conserve le parallélisme
- Non-Linéaires

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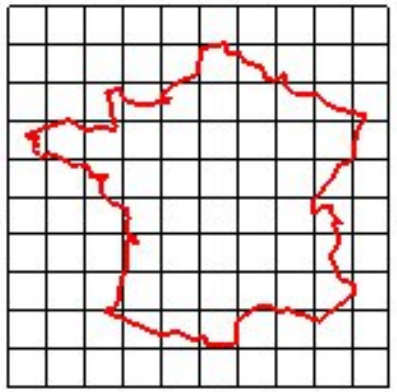
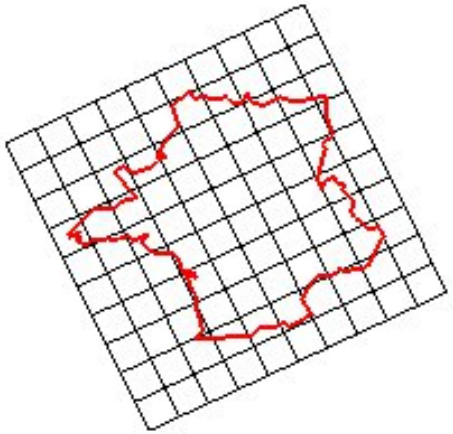
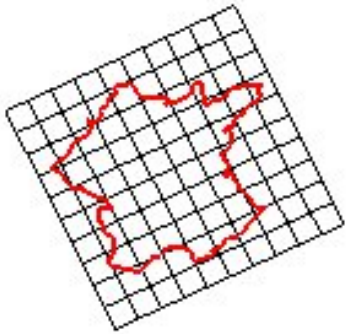
Transformations



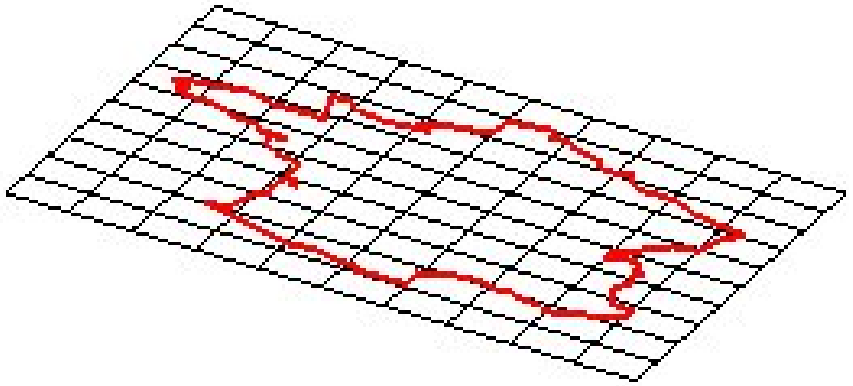
original



isometrie



similitude



affine

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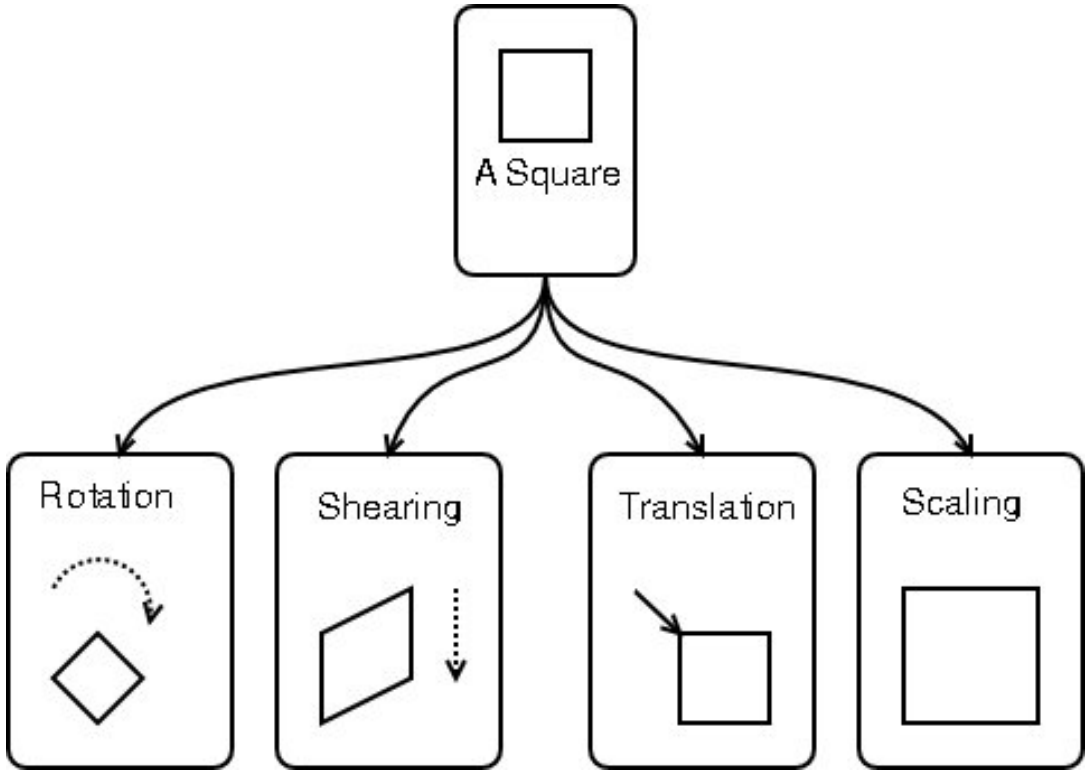
Affinité



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Quelle transformation?

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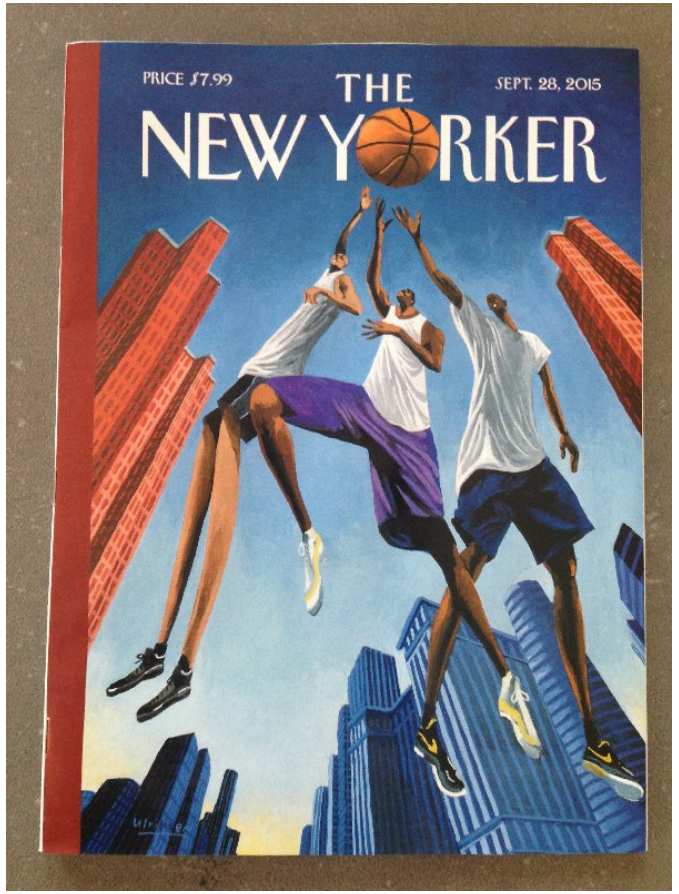
Quelle transformation?



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Quelle transformation?

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Quelle transformation?

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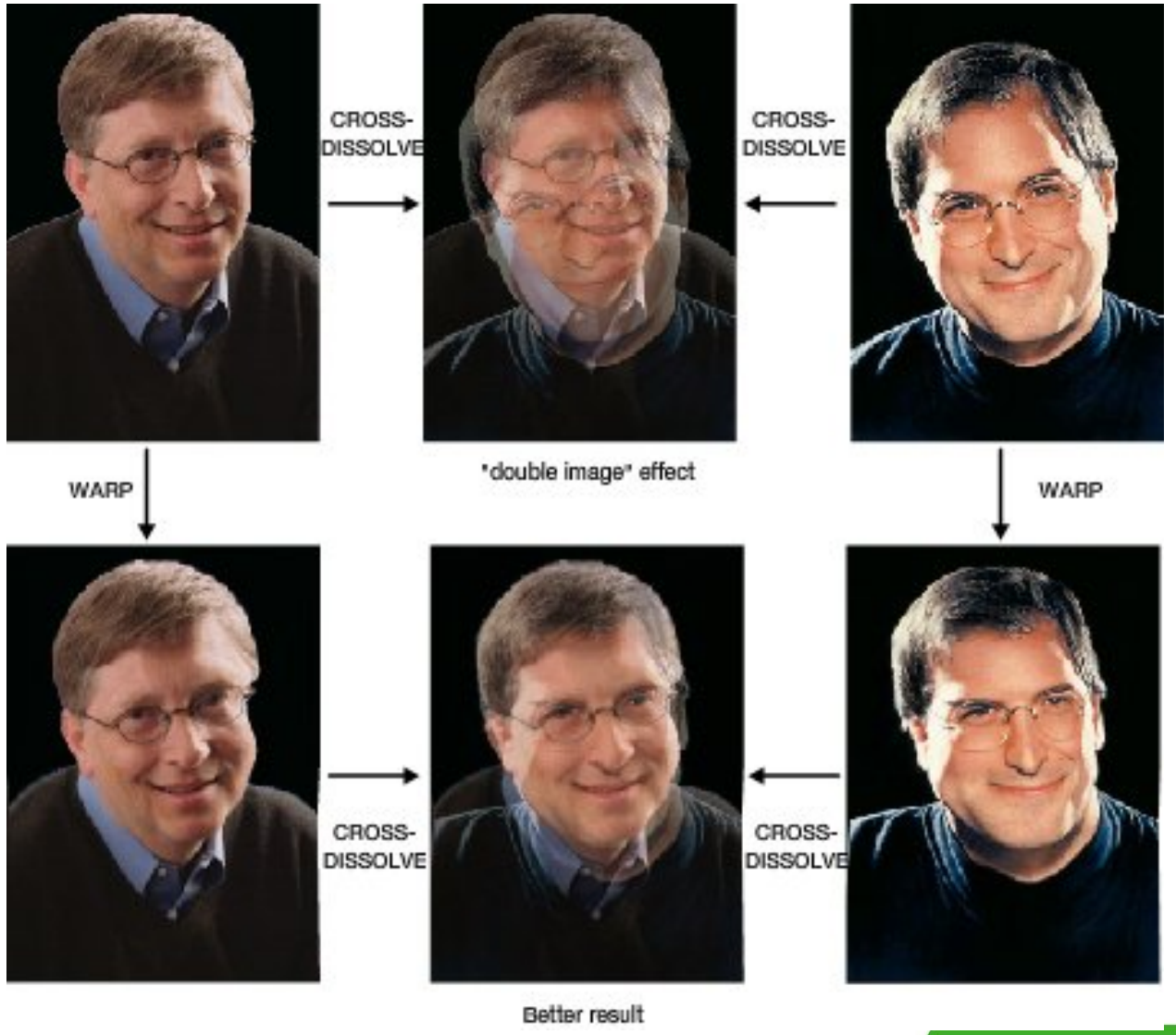
Transformations Non-Lineaires



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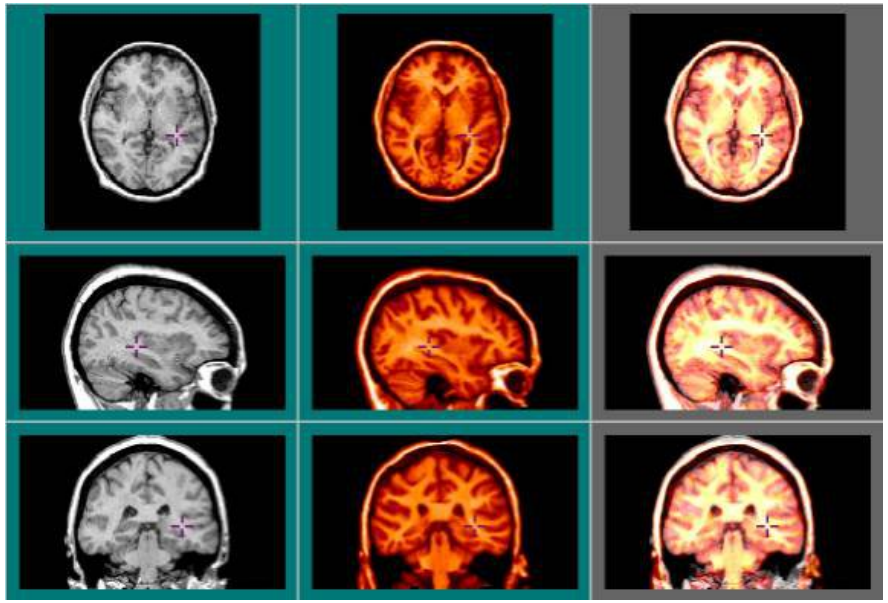
Transformations Non-Linéaires

- Transformations élastiques ou non-rigides
- Exemples:
  - B-Splines (Combinaison linéaire de Spline)
  - Thin-plate splines



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Composants du recalage

- Transformation
- **Métrique**
- Optimiseur
- Interpolateur

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Métriques

- Quantifier la correspondance entre la cible fixe et la source (transformée).

- qRecalage iconique (métrique sur la valeur des pixels)
  - Somme des différences au carré
  - Coefficient de corrélation
  - Information mutuelle

- Recalage géométrique (correspondance de primitives ou points clé)
  - distances: Iterative Closest Point

Métrique: Somme des différences au carré

- $\sum_{x,y}(f(x,y) - t(x-u, y-v))^2$

- Probleme: les deux images doivent avoir la meme intensites (relation lineaire)

Métrique: Iterative Closest Point

- Algorithme simple et rapide
  - Pour chaque point clé on trouve le point le plus proche
  - métrique = moyenne des distances
  - On transforme le nuage de points
  - On réitère jusqu'à convergence: la moyenne des distance diminue

- Problèmes?

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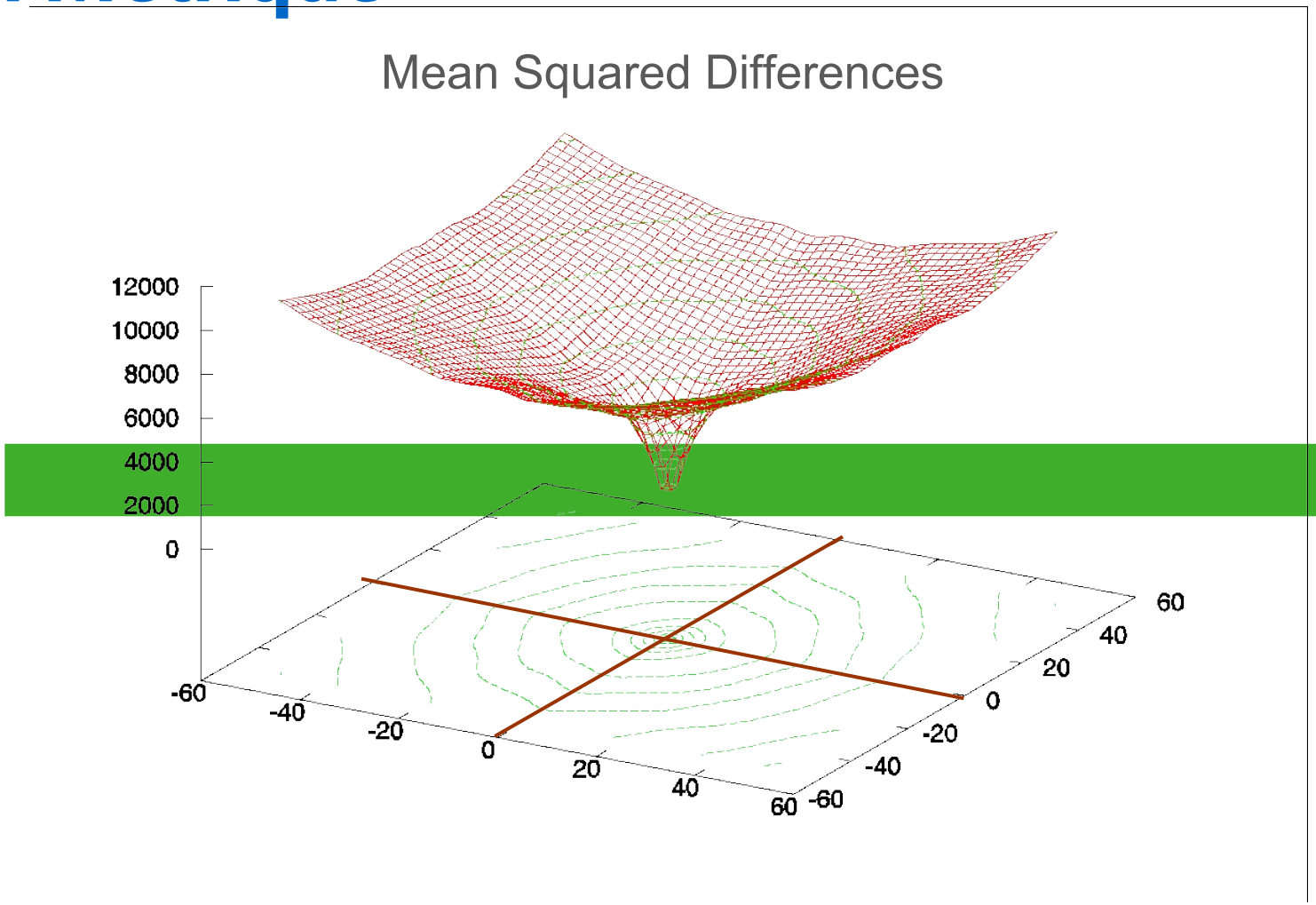
Afficher la Métrique



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Métrique: Cross-Corrélation

- Convolution sans inverse le signal

$$\frac{1}{n-1}\sum_{x,y}\frac{\left(f(x,y)-\bar{f}\right)(t(x,y)-\bar{t})}{\sigma_f \sigma_t}$$

- $\bar{f}$= moyenne de f
- σf= ecart type de f
- Relation affine entre les intensités des deux images

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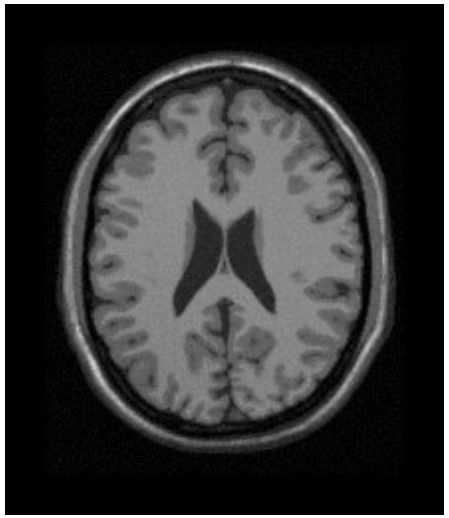
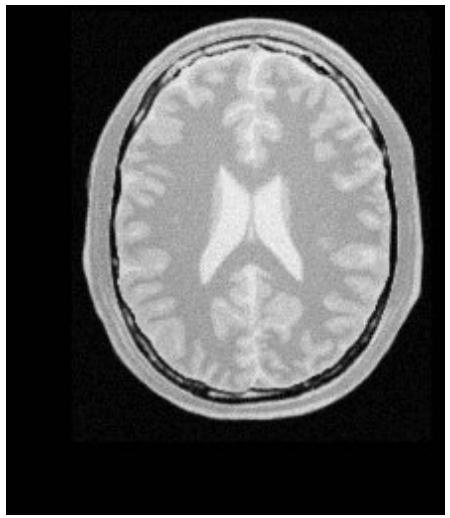
Métrique: Information Mutuelle

- Issue de la théorie de l'information
- Relation statistique entre les intensités des deux images
- Densité conjointe de probabilité des niveaux de gris
- Calcul d'un histogramme conjoint
- Mesure d'entropie





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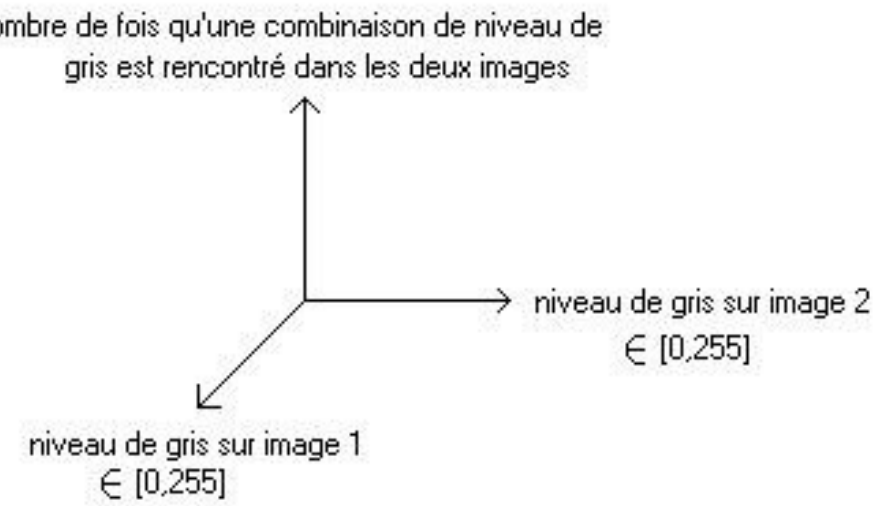
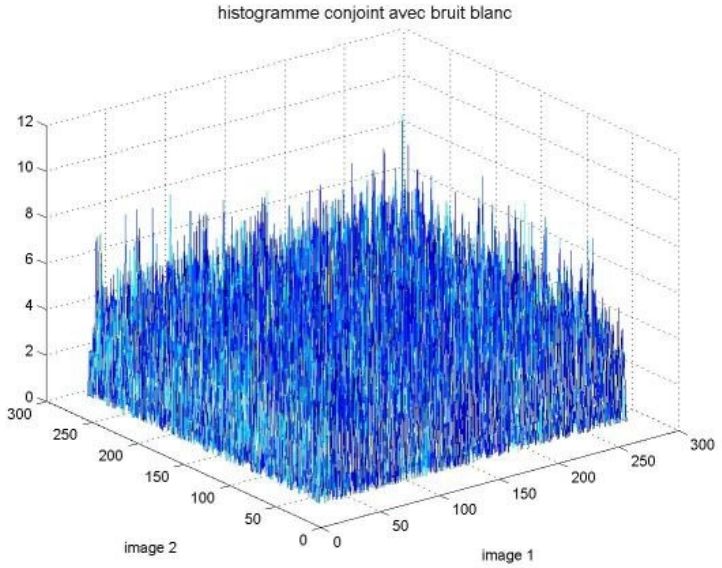
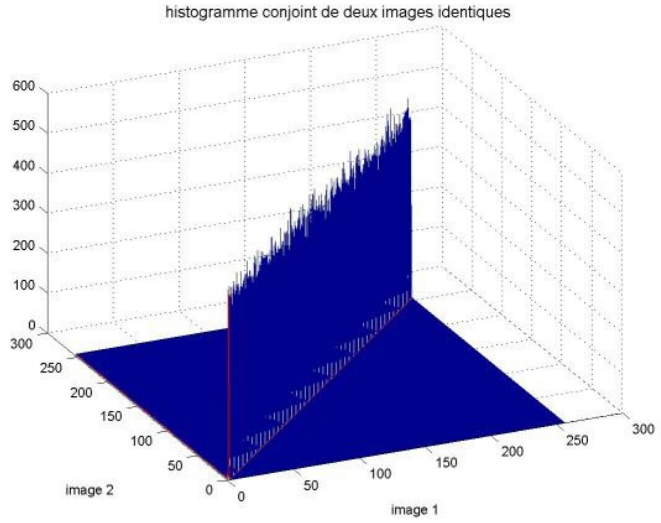
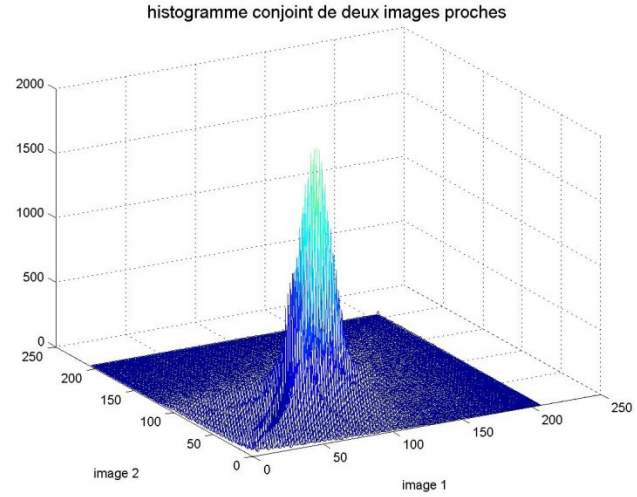
Histogramme Conjoint









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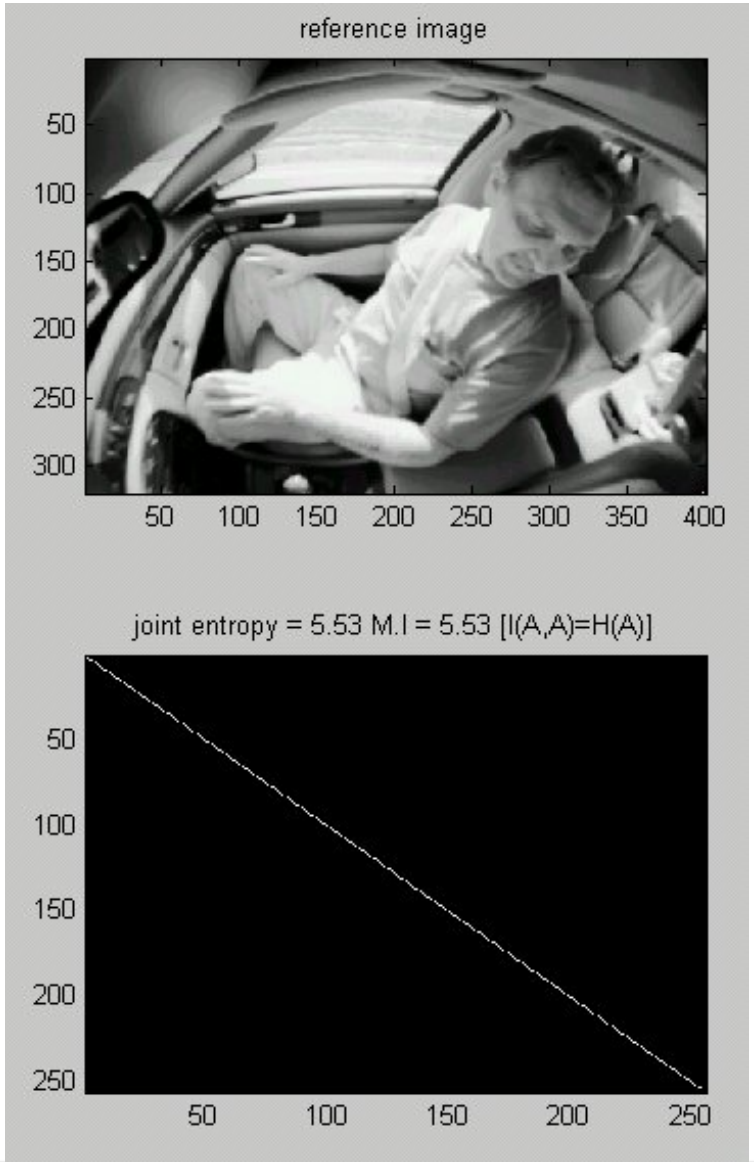
Métrique: Information Mutuelle



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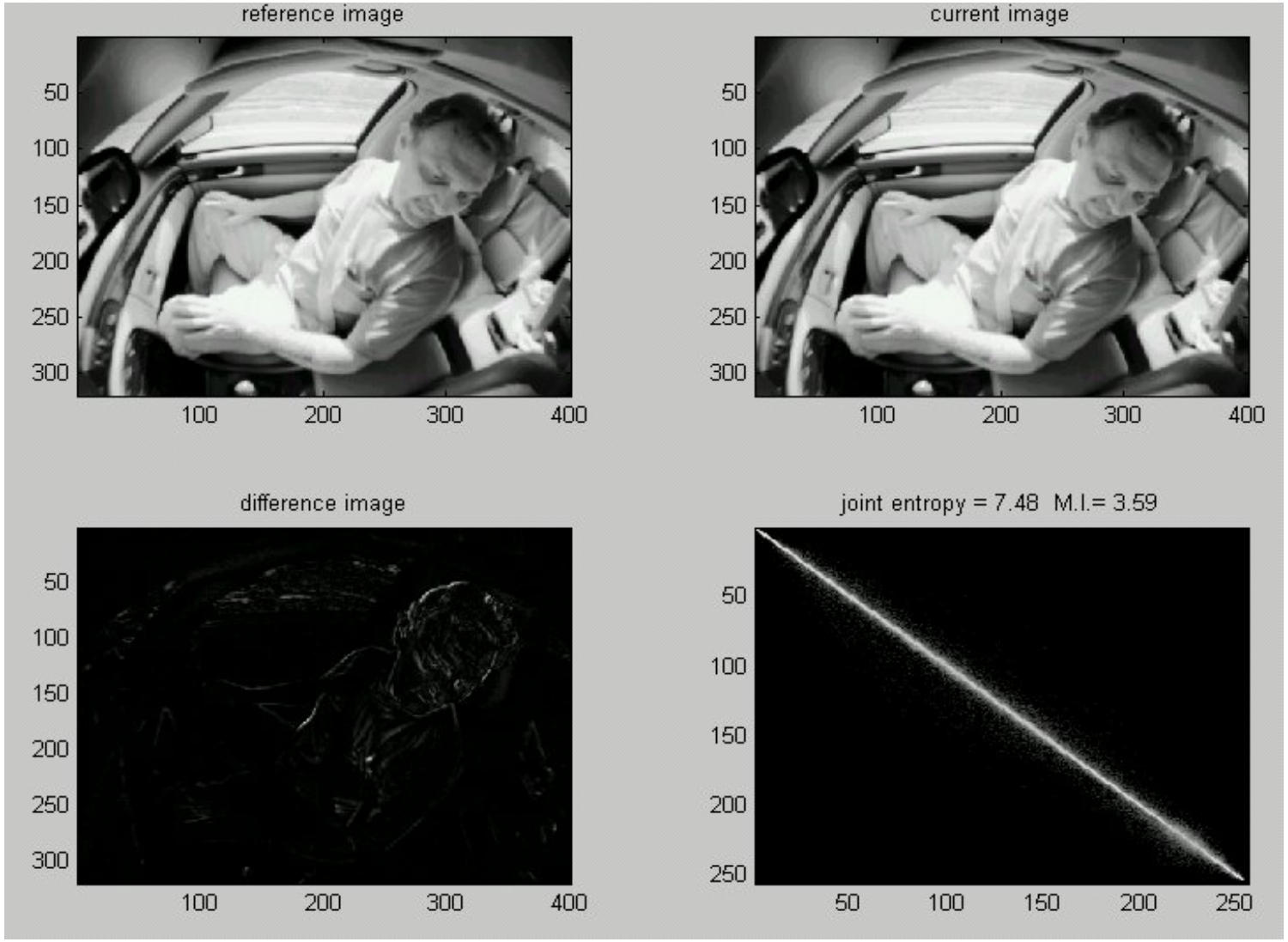
Métrique: Information Mutuelle



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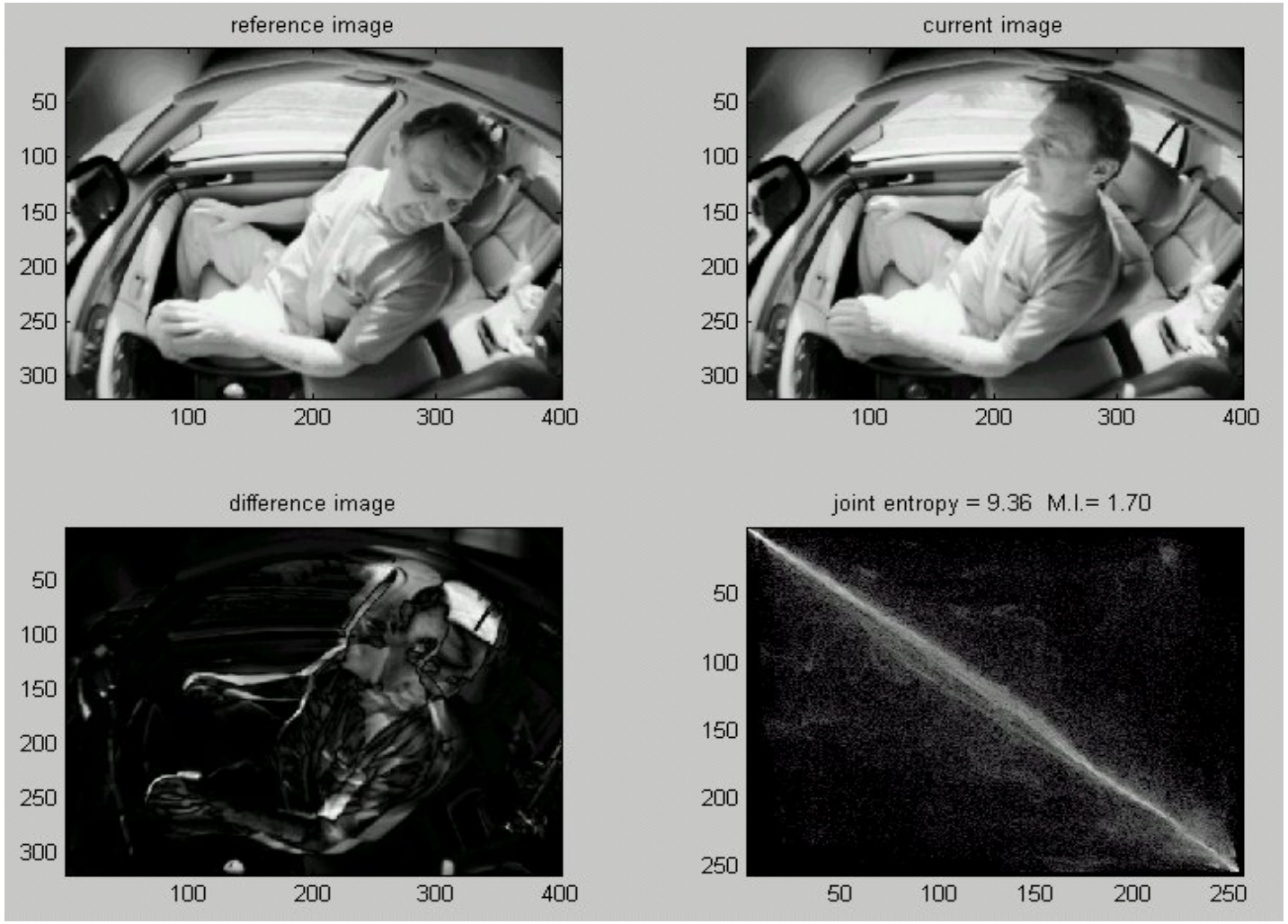
Métrique: Information Mutuelle



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Métrique: Information Mutuelle

- Soit g(x,y) la valeur de l'histogramme conjoint au point [x,y].

$$p_{1,2}(x,y) = \frac{g(x,y)}{\sum_{a,b} g(a,b)}$$
$$p_1(x) = \sum_b p_{1,2}(x,b)$$
$$p_2(y) = \sum_a p_{1,2}(a,y)$$

$$MI = \sum_{a,b} p_{1,2}(a,b) log_2 \frac{p_{1,2}(a,b)}{p_1(a).p_2(b)}$$

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Métrique: Information Mutuelle

- $\sum_{a,b} g(a,b)$: nombre de point utilisés pour créer l'histogramme conjoint.

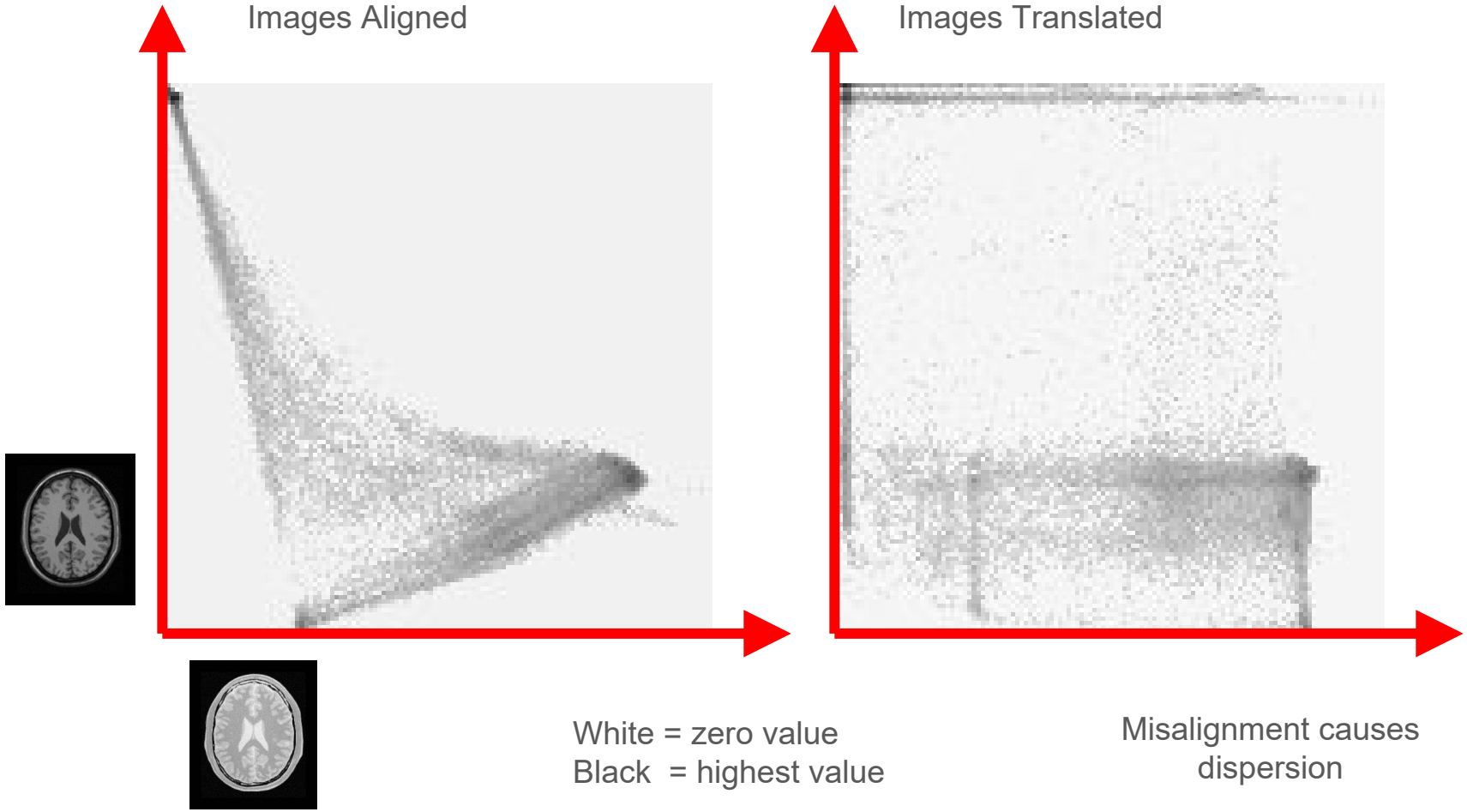
- $p_{1,2}(x,y)$ = histogramme conjoint normalisé. C'est aussi une distribution de probabilité. Probabilité qu'un point pris au hasard dans l'image soit la combinaison de niveau de gris x sur I1 et y sur I2.

- $p_1(x)$=distribution de probabilité. Pour un x donne = probabilité de que l'on trouve un point de niveau de gris x sur l'image 1.

Mutual Information (Same Modality)

Insight/Examples/Registration/ImageRegistrationHistogramPlotter.cxx

Mutual Information (Different Modality)



Insight/Examples/Registration/ImageRegistrationHistogramPlotter.cxx

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Composants du recalage

- Transformation
- Métrique
- **Optimiseur**
- Interpolateur

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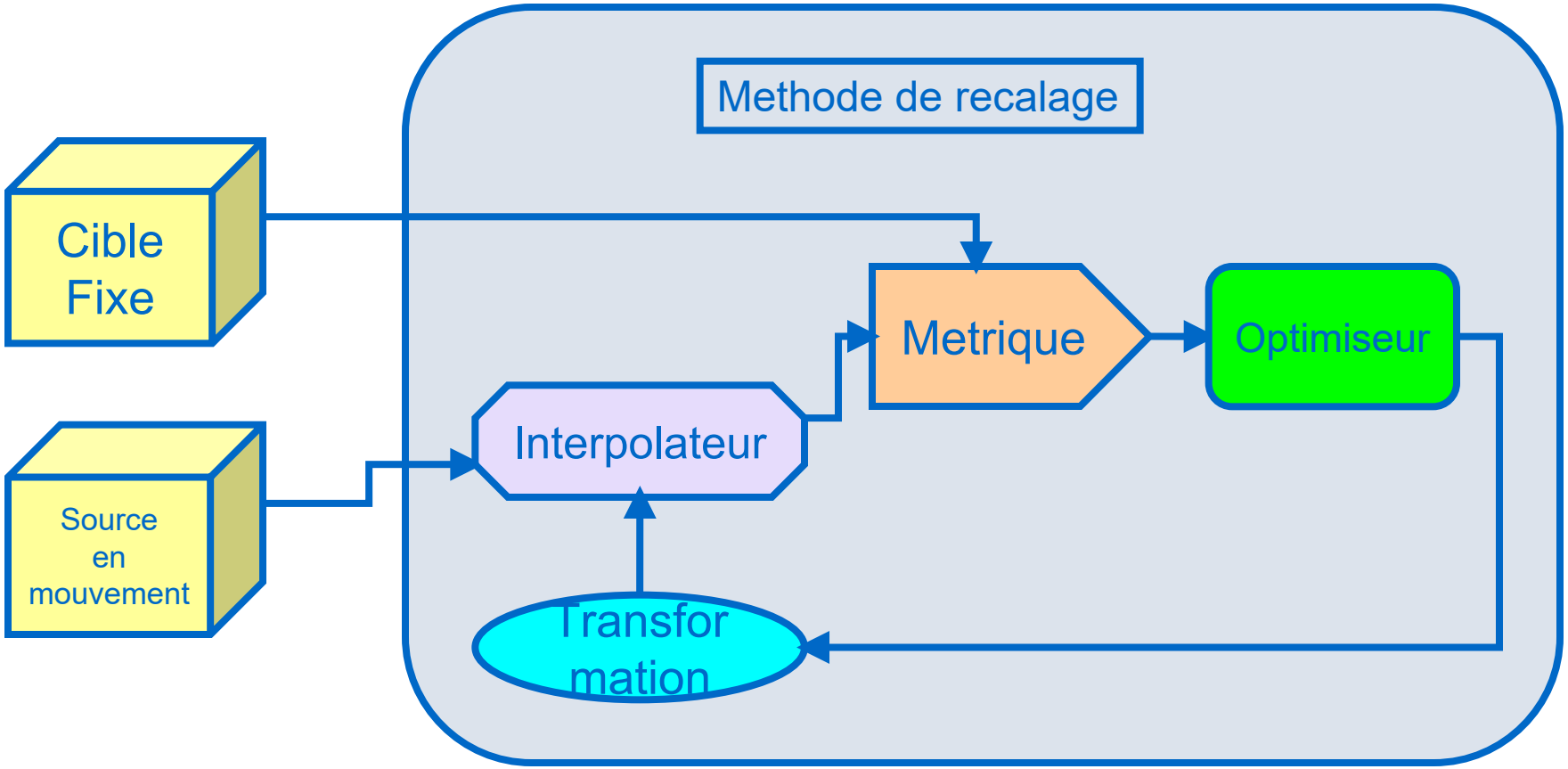
Composants du recalage



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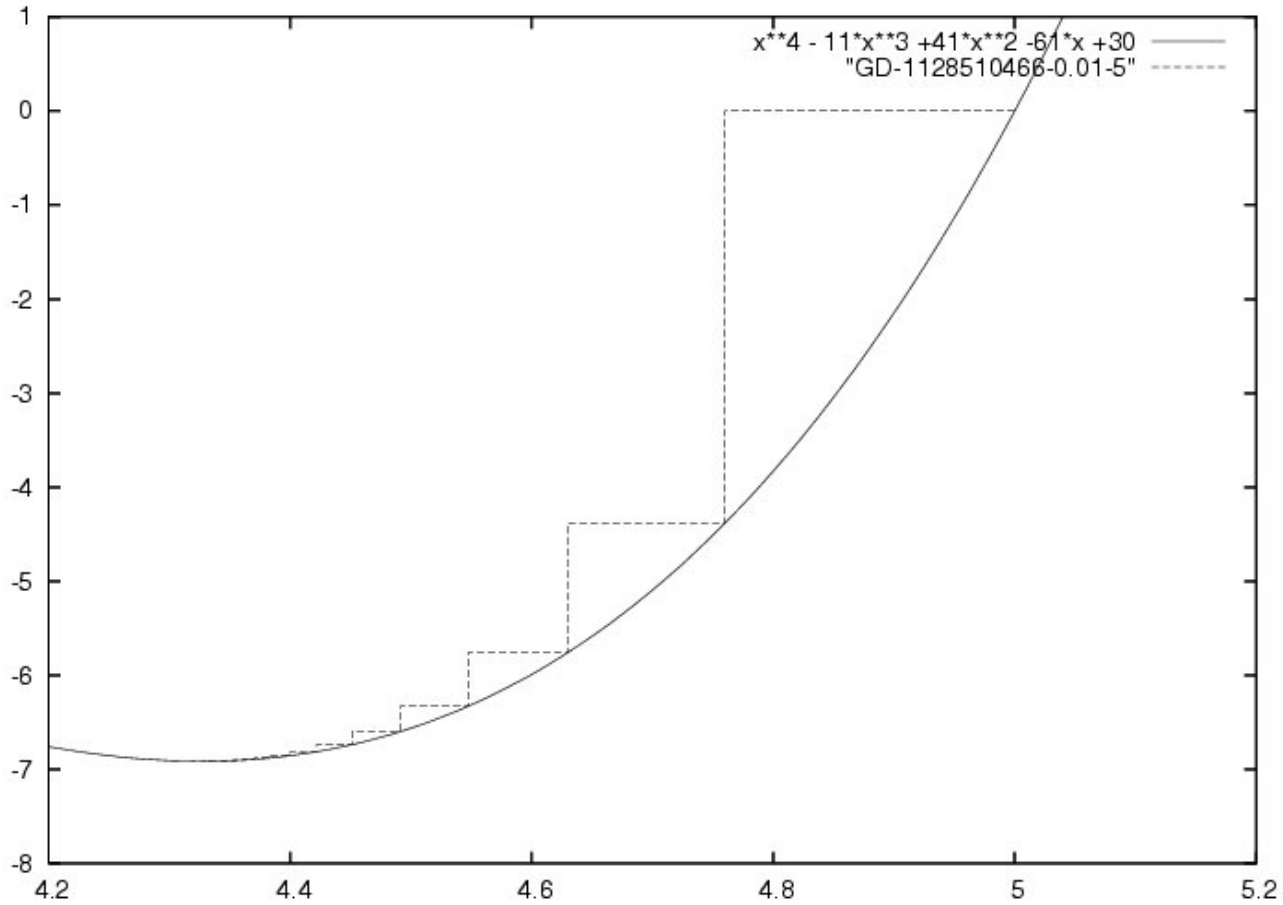
Optimiseur: Descente de gradient

f : Fonction C1

$x_{i+1} = x_i - L \cdot f'(x_i)$



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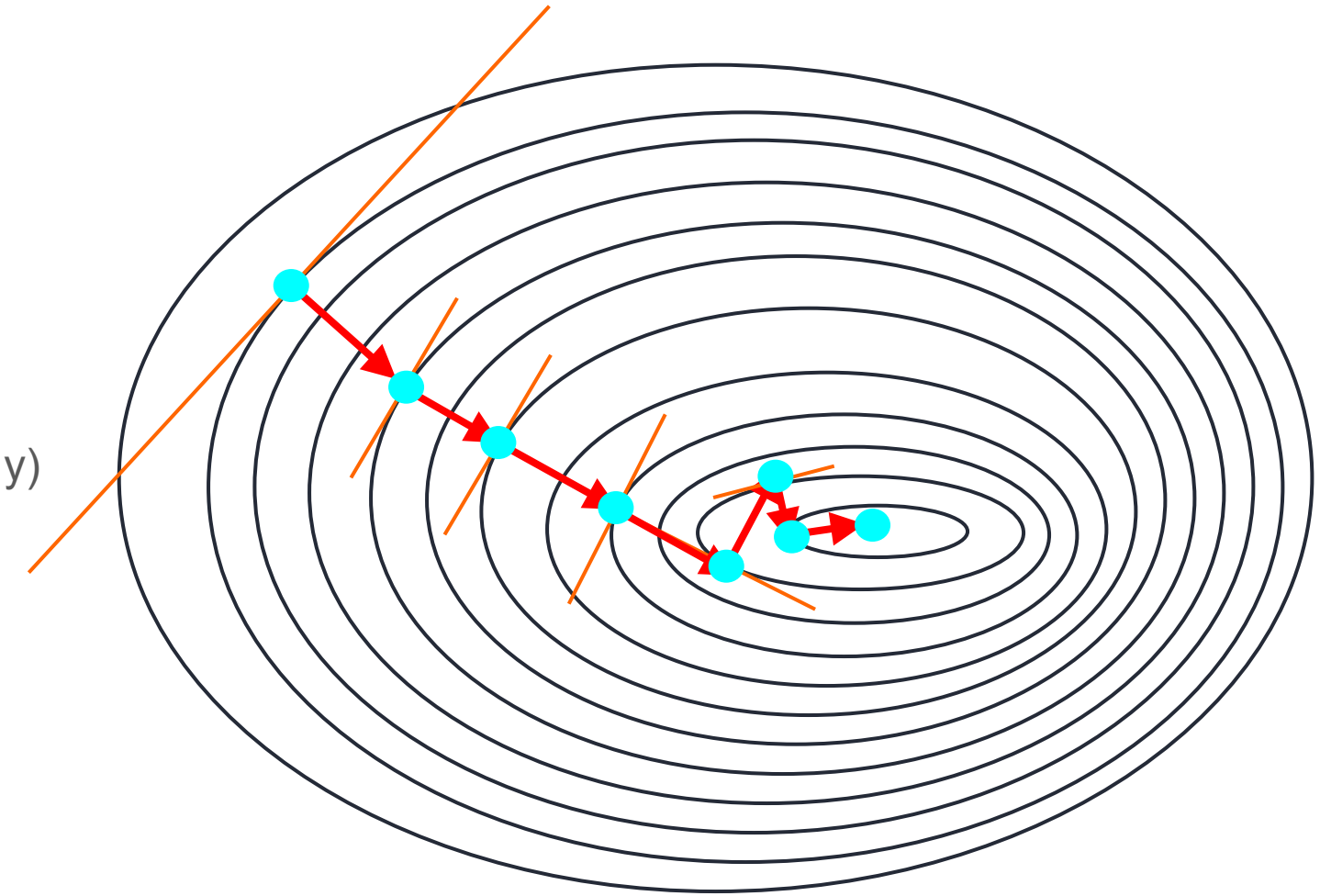
Gradient Descent Optimizer

$f(x,y)$

$\mathbf{G}(x, y) = \nabla f(x,y)$

$\mathbf{S} = \mathbf{L} \cdot \mathbf{G}(x, y)$



S = Step

L = Learning Rate

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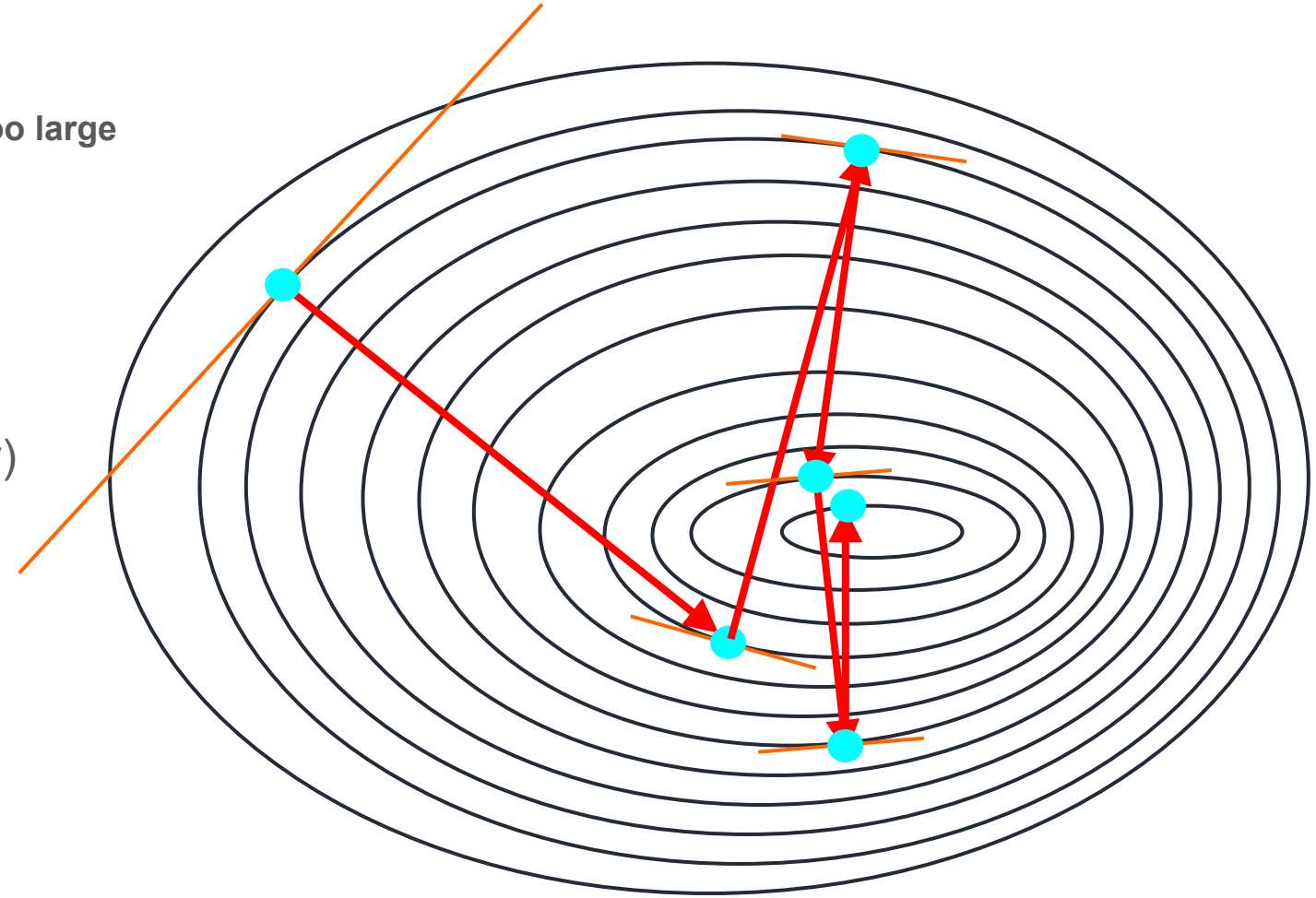
Gradient Descent Optimizer

L too large

$f(x,y)$

$\mathbf{G}(x, y) = \nabla f(x,y)$

$\mathbf{S} = \mathbf{L} \cdot \mathbf{G}(x, y)$



S = Step

L = Learning Rate

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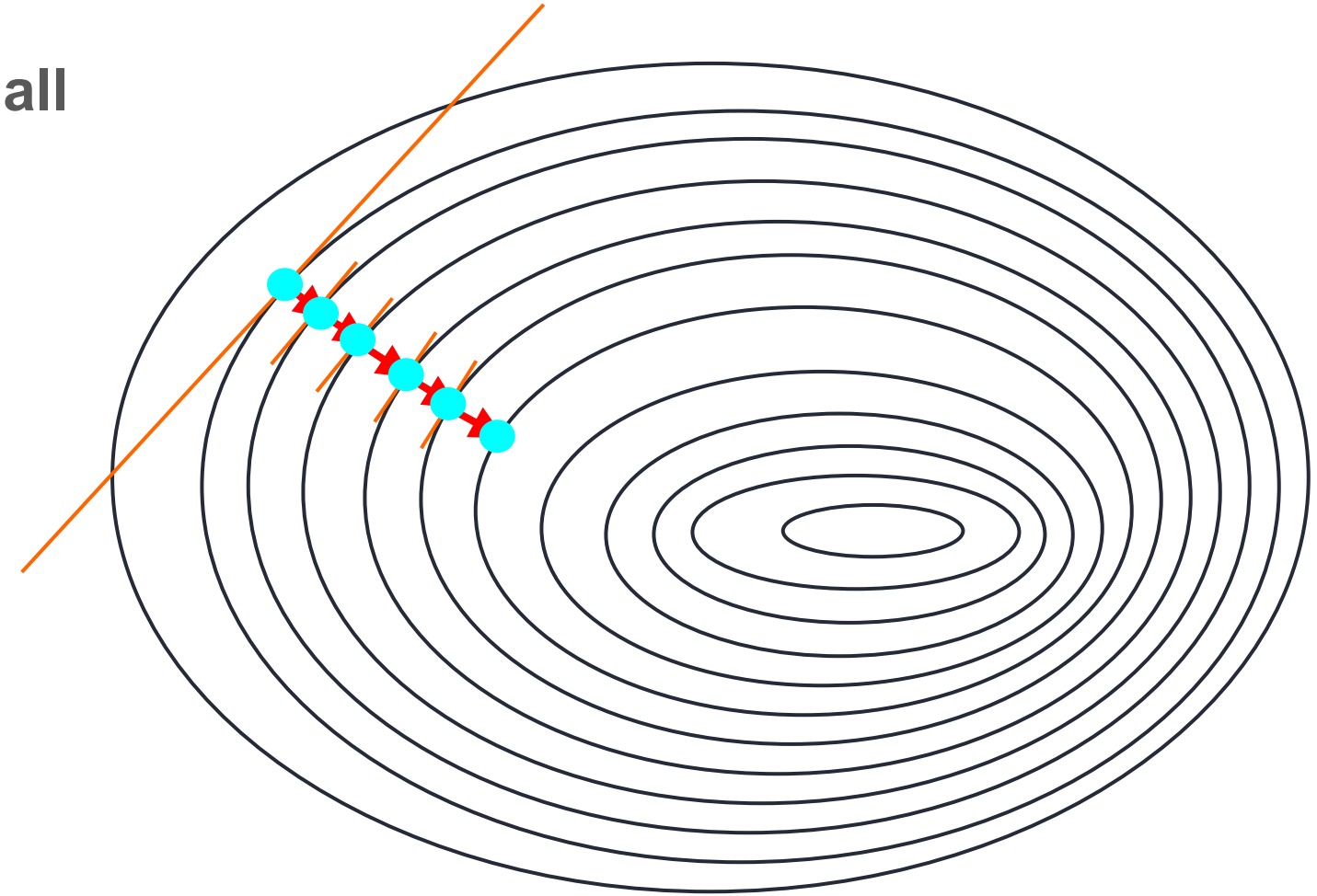
Gradient Descent Optimizer

L too small



f(x , y)

G(x , y) = ∇ f(x , y)

S = L · **G**(x , y)

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Autres optimiseurs

- Gradient Conjugué
- Algorithmes génétiques:
  - 1+1 evolutionary
  - Amoeba
- Powell
- LBFGS
- Levenberg Marquardt

Composants du recalage

- Transformation
- Métrique
- Optimiseur
- **Interpolateur**

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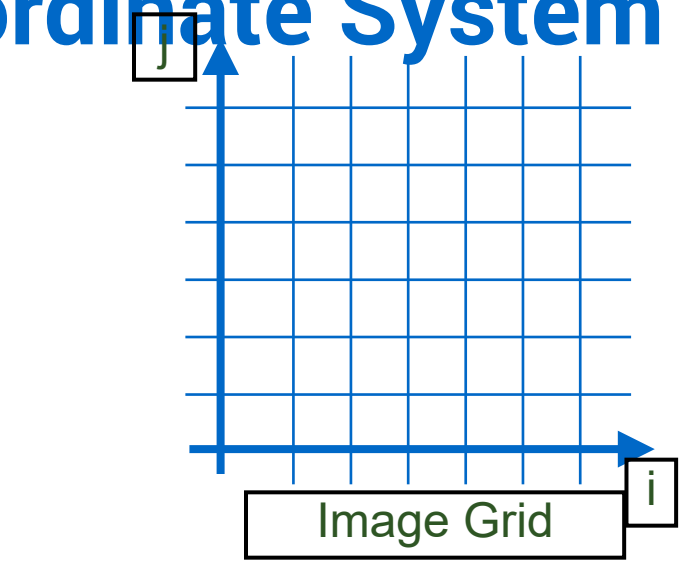
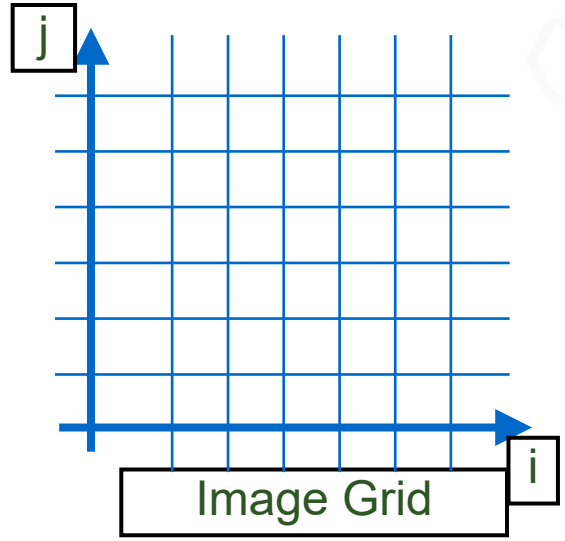
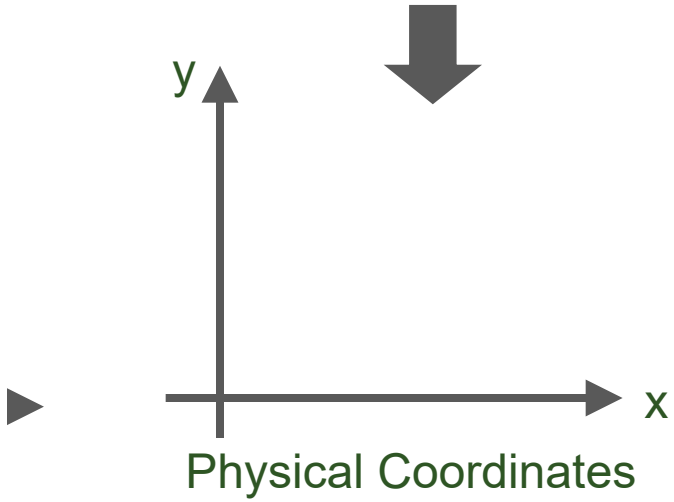
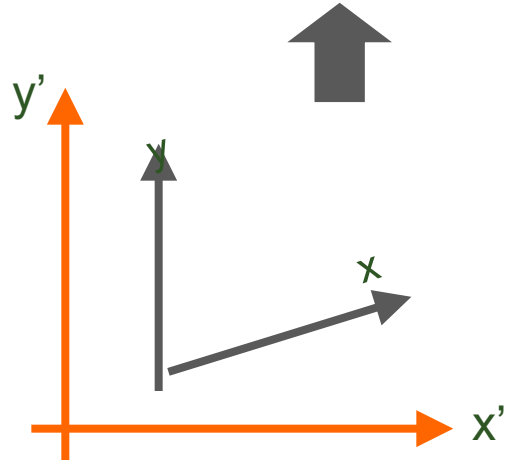
Coordinate System Conversions







Space Transform



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Quiz #1

Images from the same patient

MRI-T2

256 x 256 pixels

Moving Image ?

Fixed Image ?

PET

128 x 128 pixels

Images provided as part of the project: “Retrospective Image Registration Evaluation”,
NIH, Project No. 8R01EB002124-03, Principal Investigator, J. Michael Fitzpatrick, Vanderbilt University, Nashville, TN.

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Quiz #2

Images from the same patient

MRI-T2

256 x 256 pixels

Scaling Transform

What scale factor ?

a) 2.0

b) 1.0

c) 0.5

PET

128 x 128 pixels

Images provided as part of the project: “Retrospective Image Registration Evaluation”, NIH, Project No. 8R01EB002124-03, Principal Investigator, J. Michael Fitzpatrick, Vanderbilt University, Nashville, TN.

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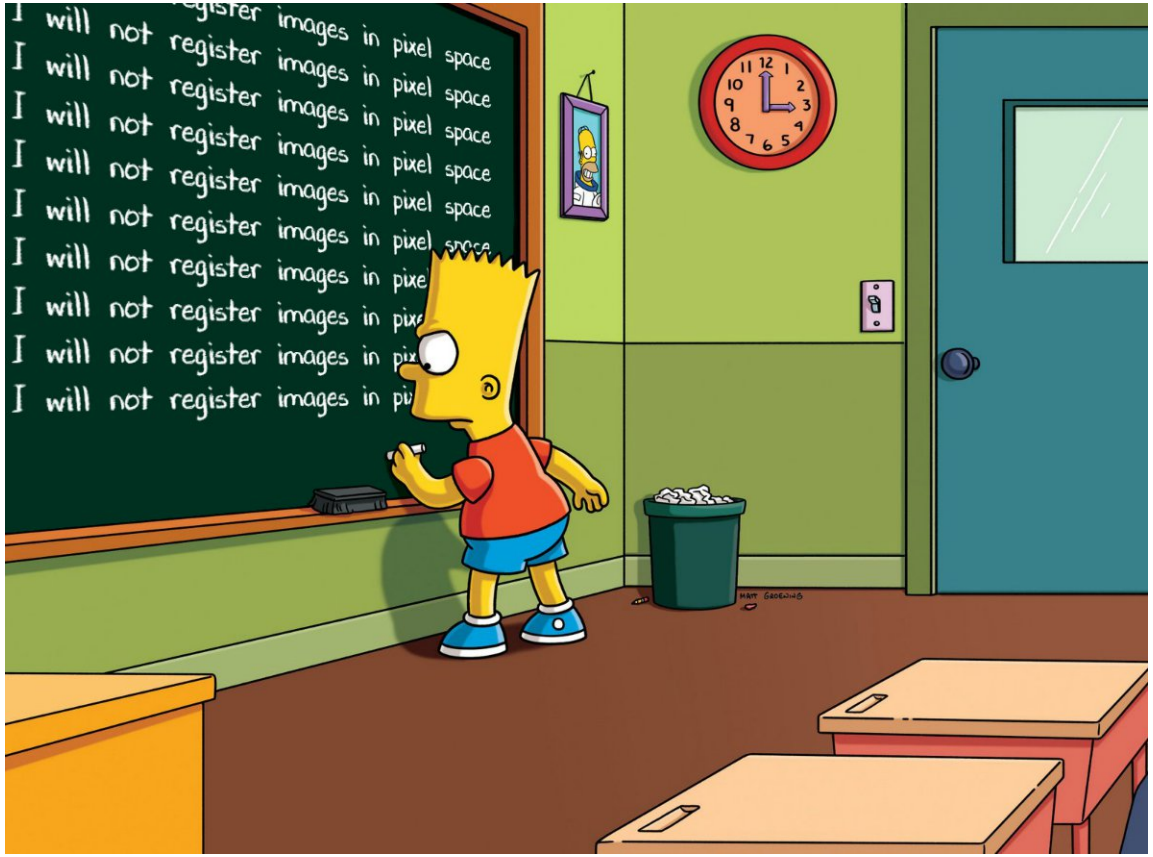
Things I will not do…



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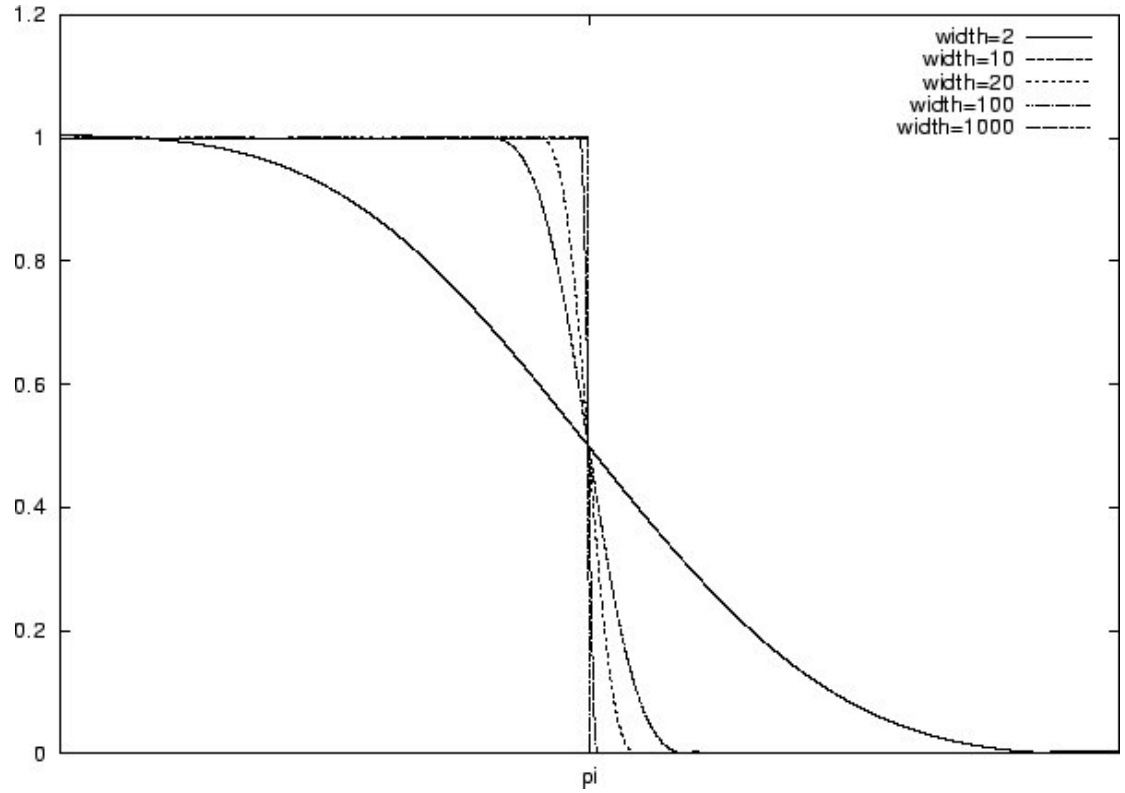
Interpolation

- Plus proche voisin (nearest neighbor)
- Linéaire
- Window Sinc
- BSpline
- ...



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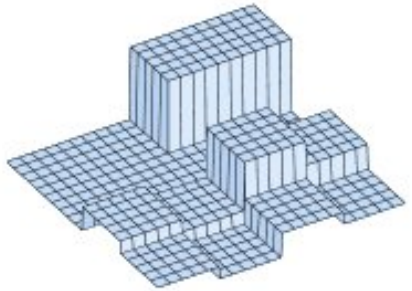
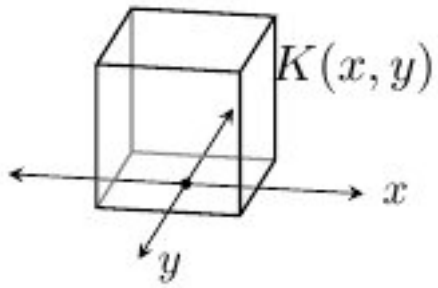
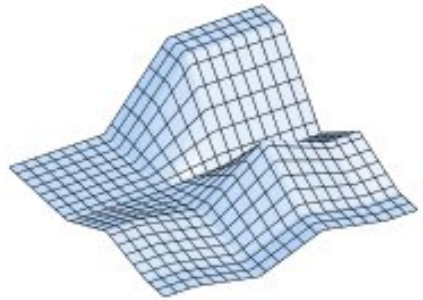
Interpolation

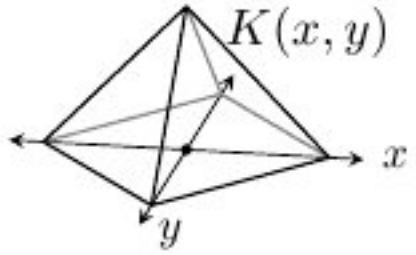
Nearest Neighbor



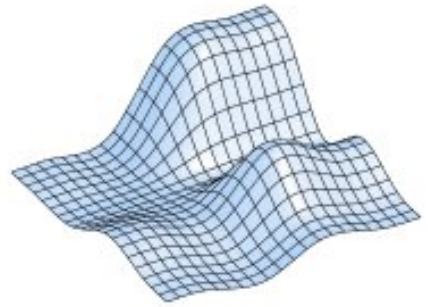


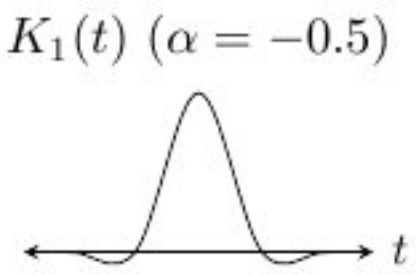
Bilinear





Bicubic





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Interpolation

Nearest

Bilinear

Bicubic

Cubic BSpline

Sinc

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TP

- En Python
- Lecture/Ecriture d’image
- Filtrage
- Segmentation
- Recalage