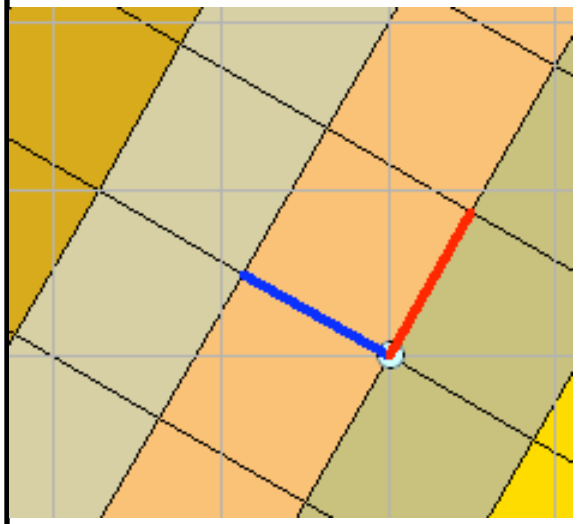
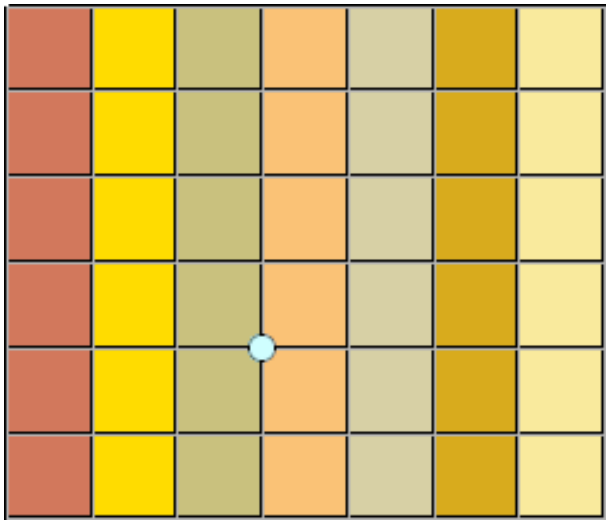
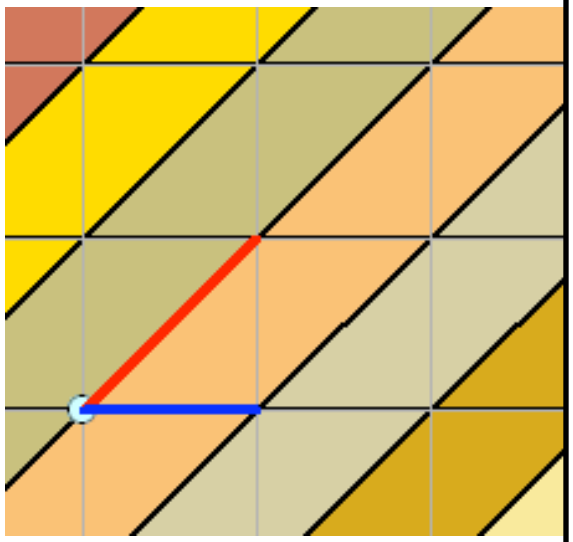
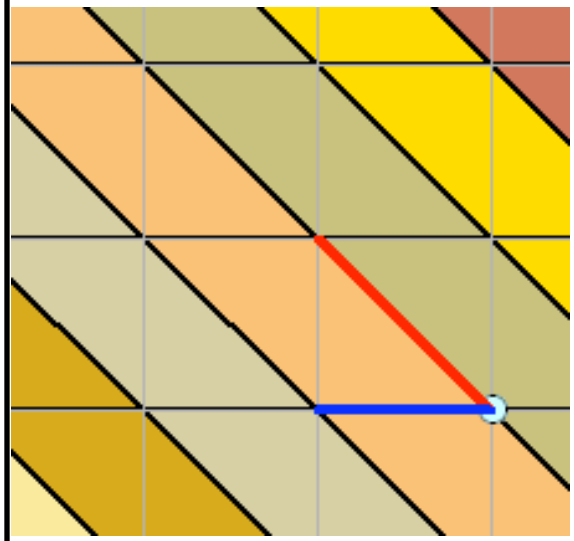
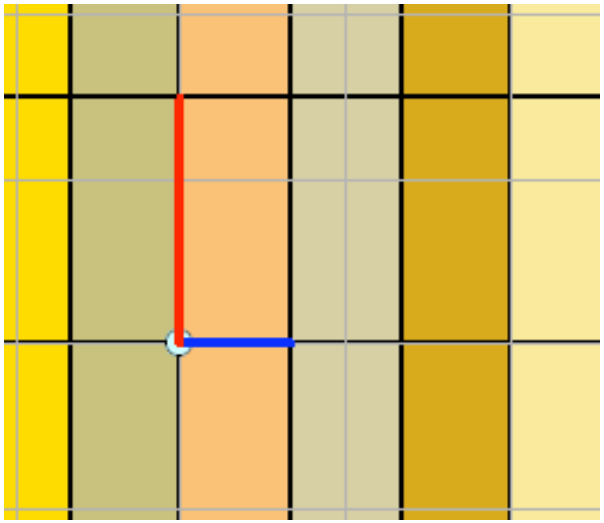
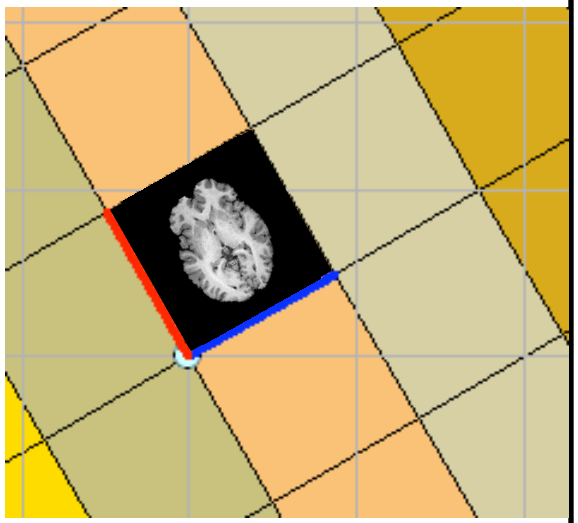
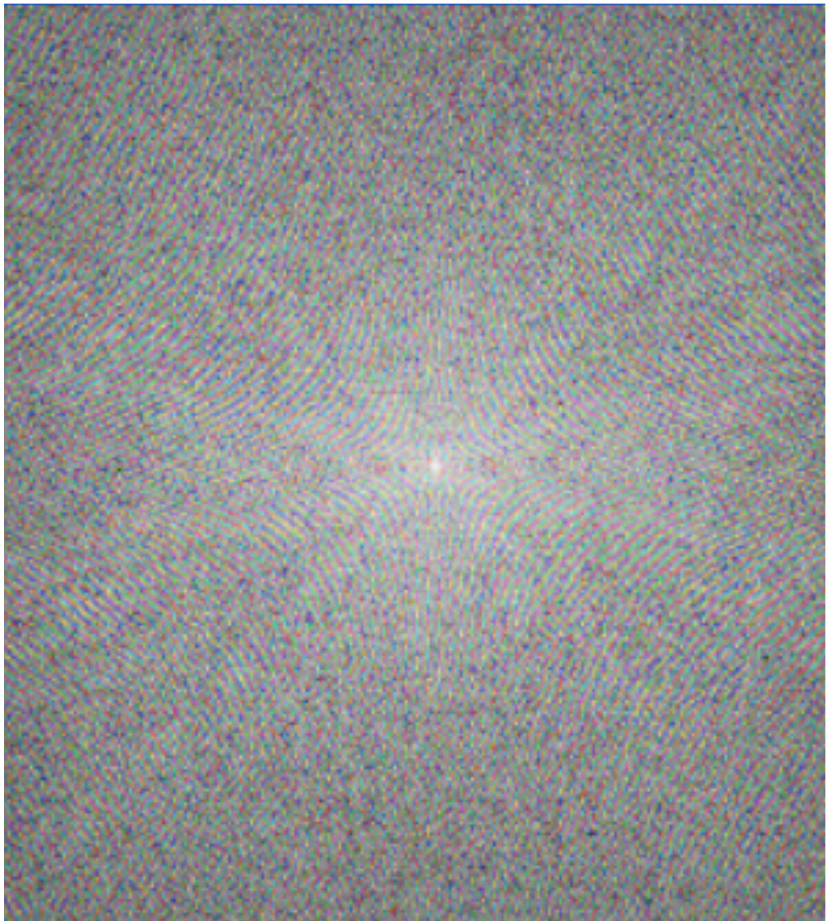
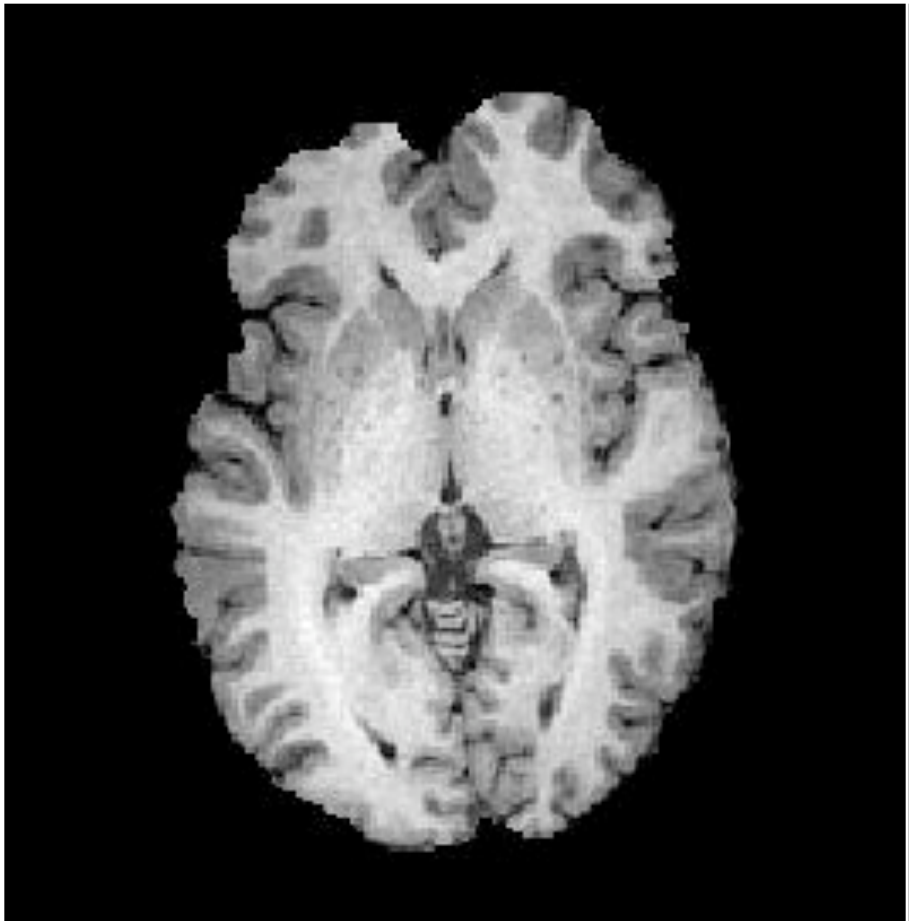
Image Processing and Registration

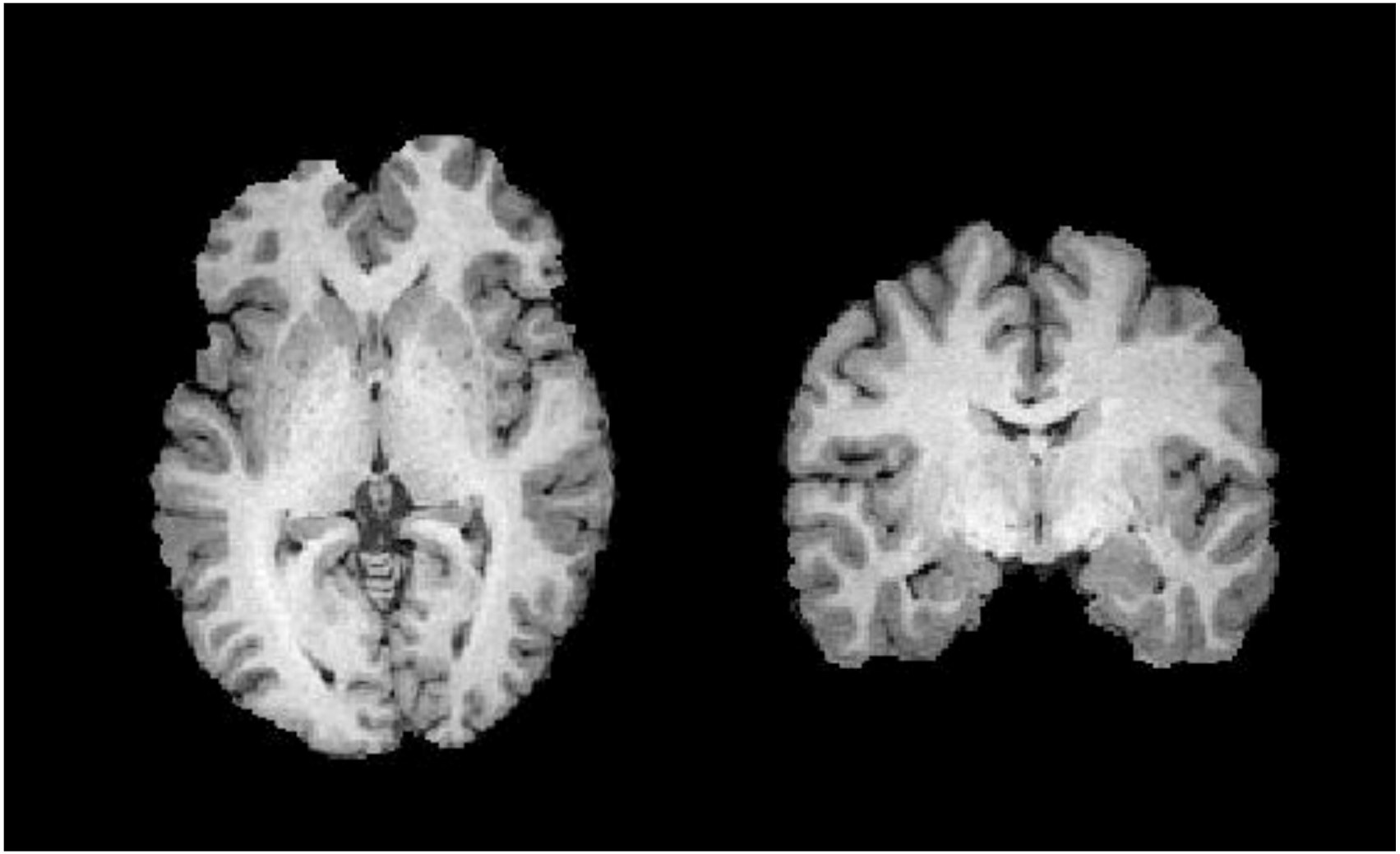







Re: k-space to image



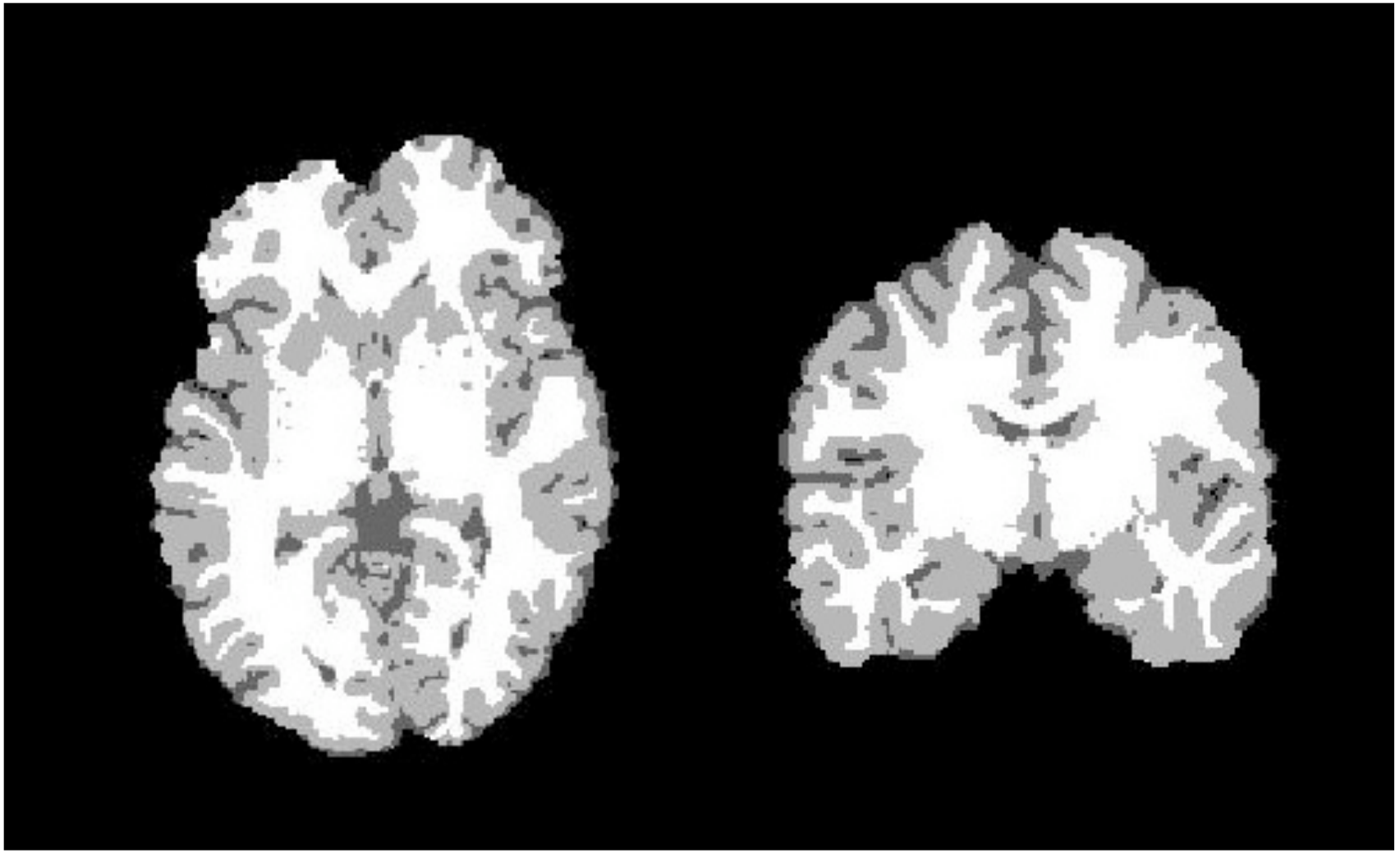


skull-stripping

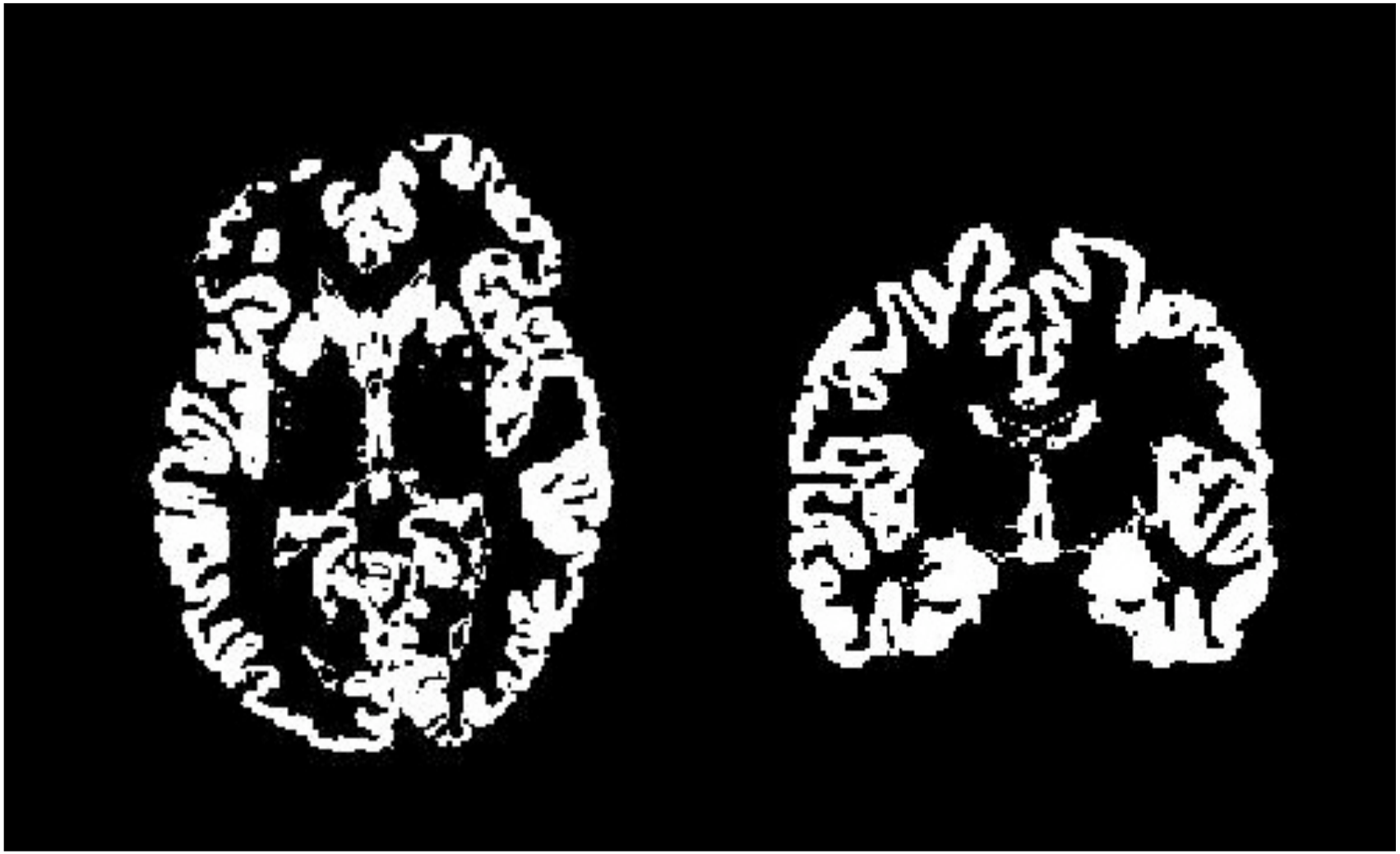


tissue-class segmentation

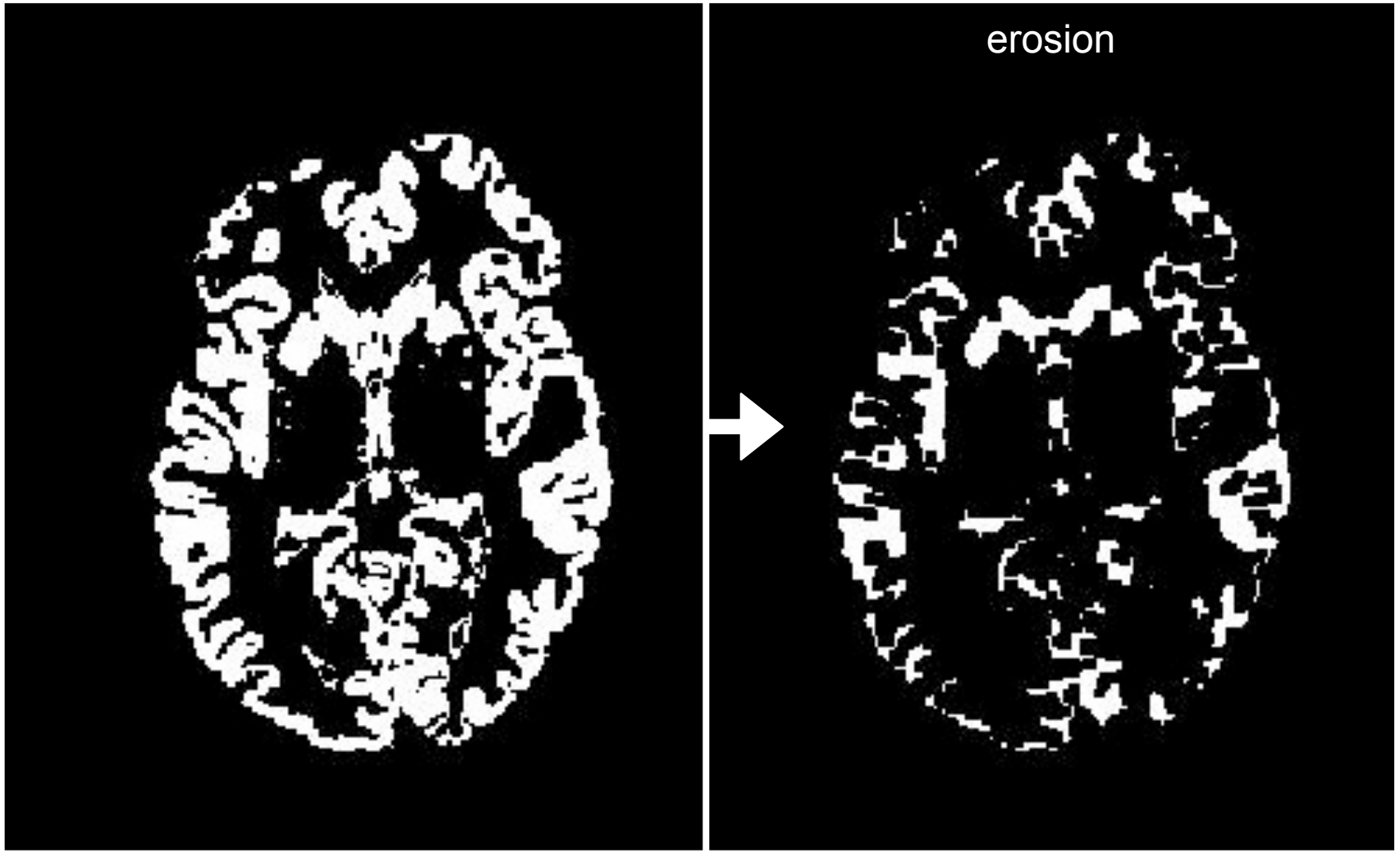
(+ inhomogeneity correction)



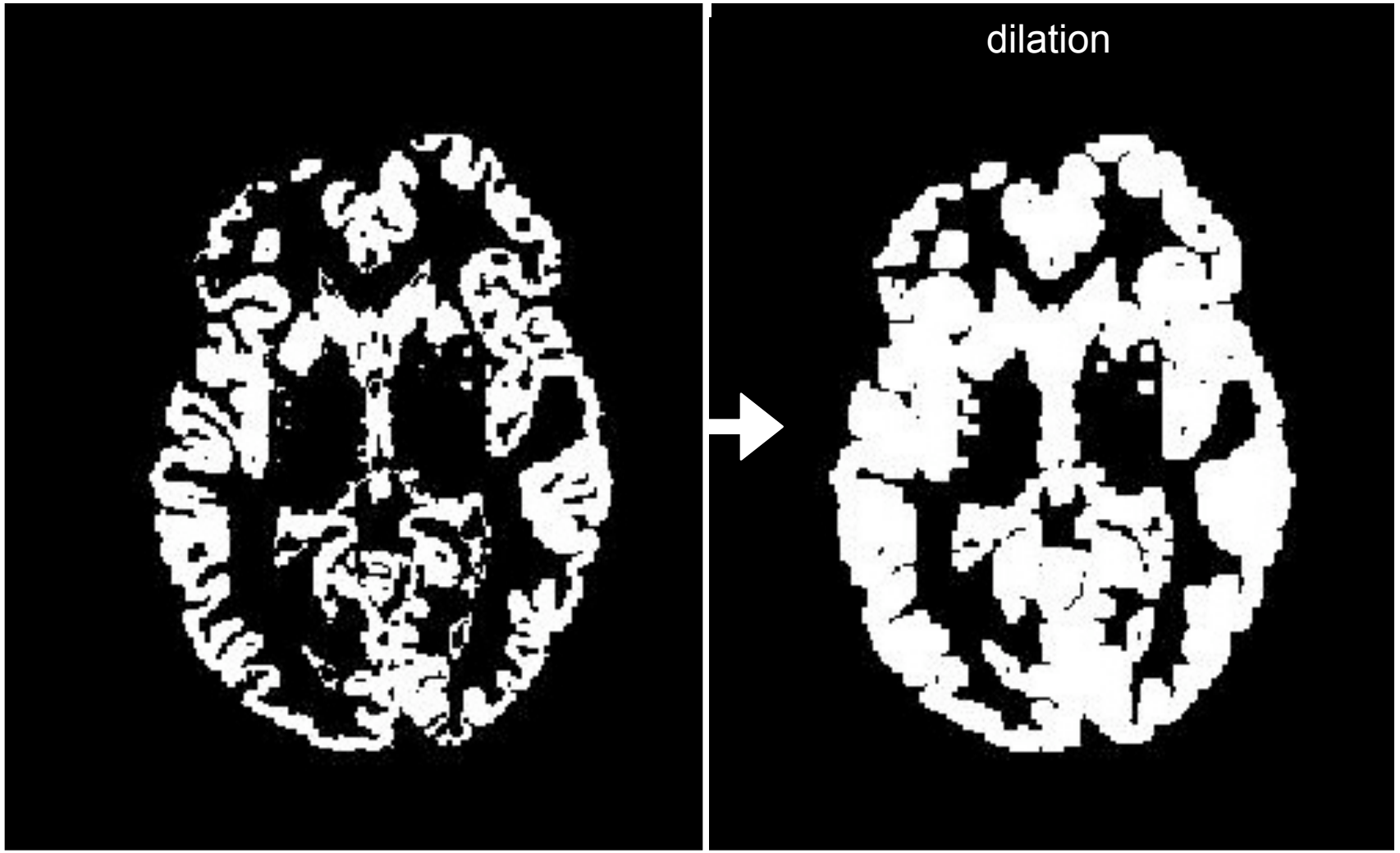
tissue-class segmentation



morphological image processing



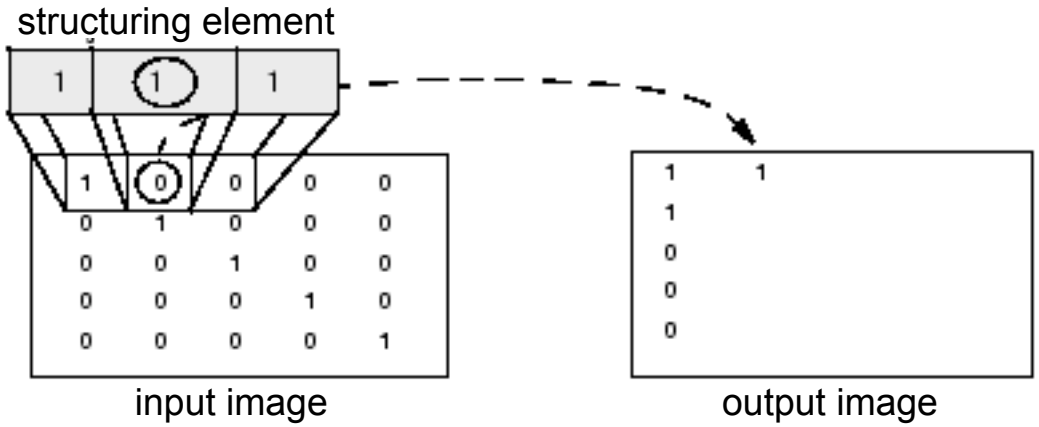
morphological image processing

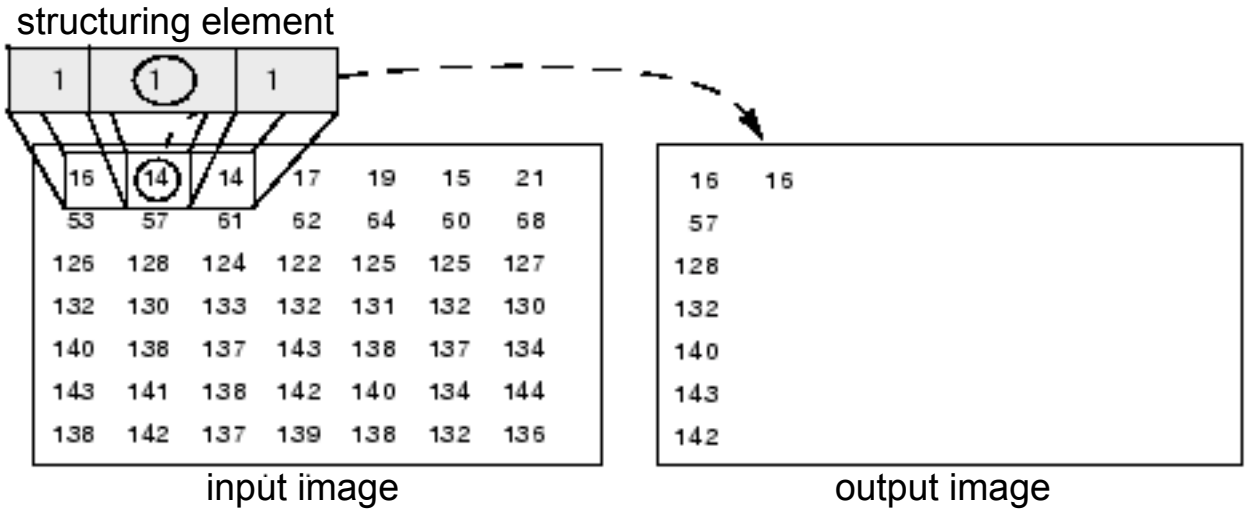


morphological image processing

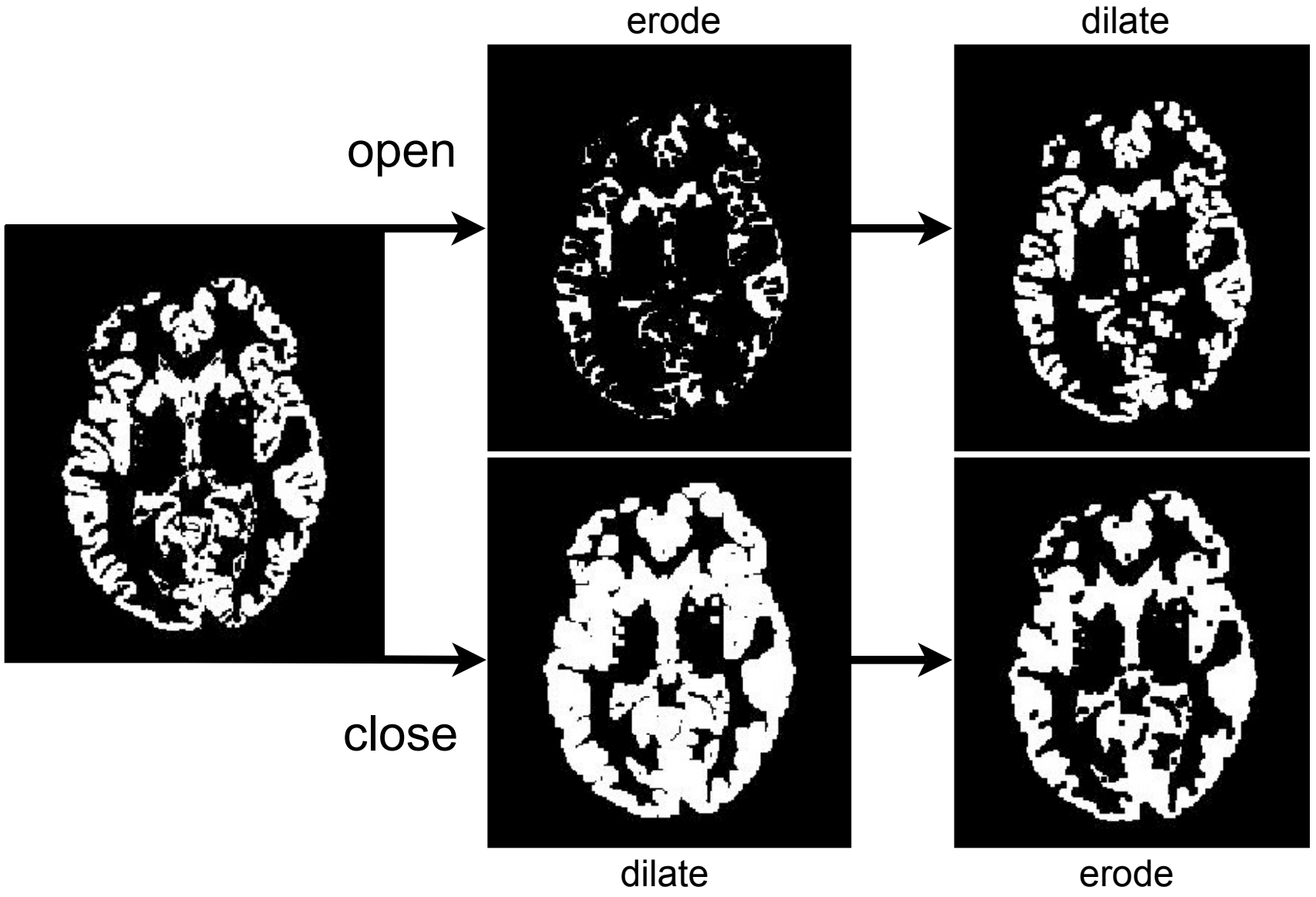
Dilation example

maximum value in neighborhood

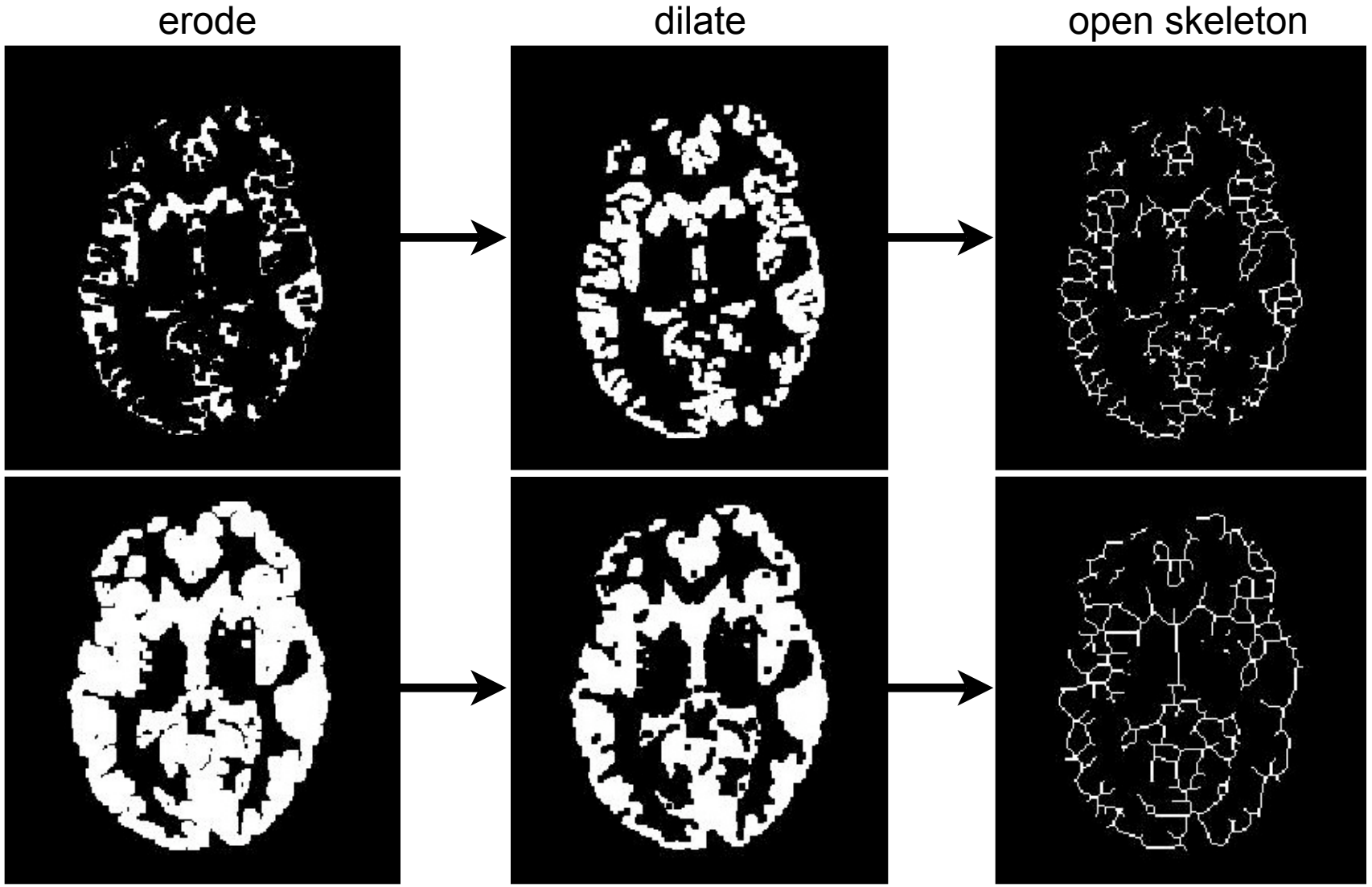




morphological image processing



morphological image processing



morphological reconstruction

Morphological reconstruction:

- Processing is based on two images, a marker and a mask, rather than one image and a structuring element.

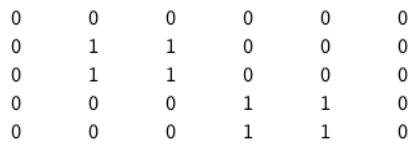
- Processing repeats until stability (the image no longer changes).

- Processing is based on the concept of connectivity, rather than a structuring element

Examples:

1. pixel connectivity
2. flood-fill operations
3. peaks and valleys

pixel connectivity



0	0	0	0	0	0
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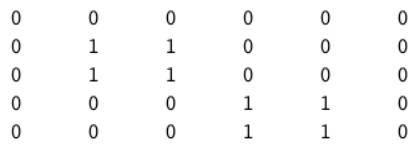
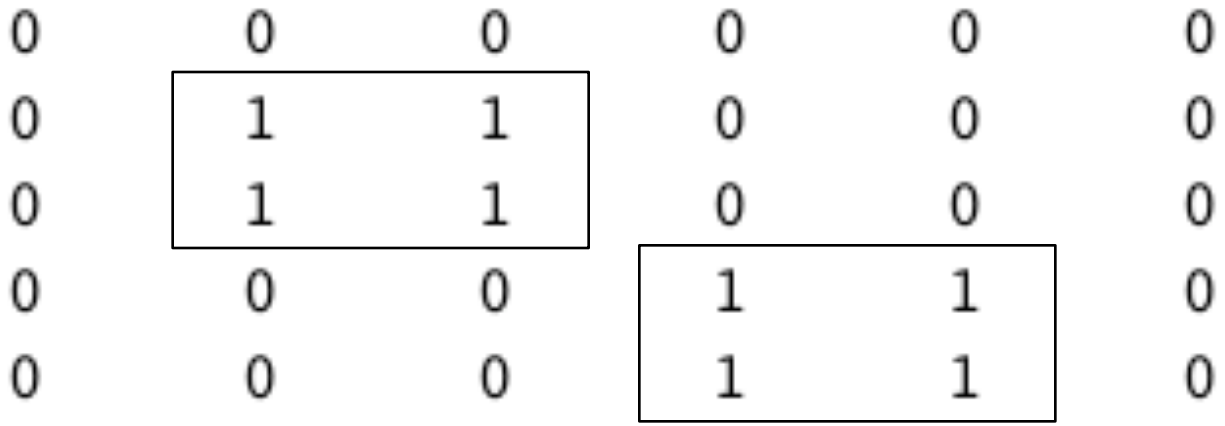
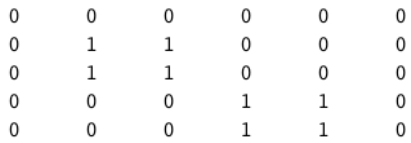
0	1	1	0	0	0
0	0	0	1	1	0
0	0	0	1	1	0

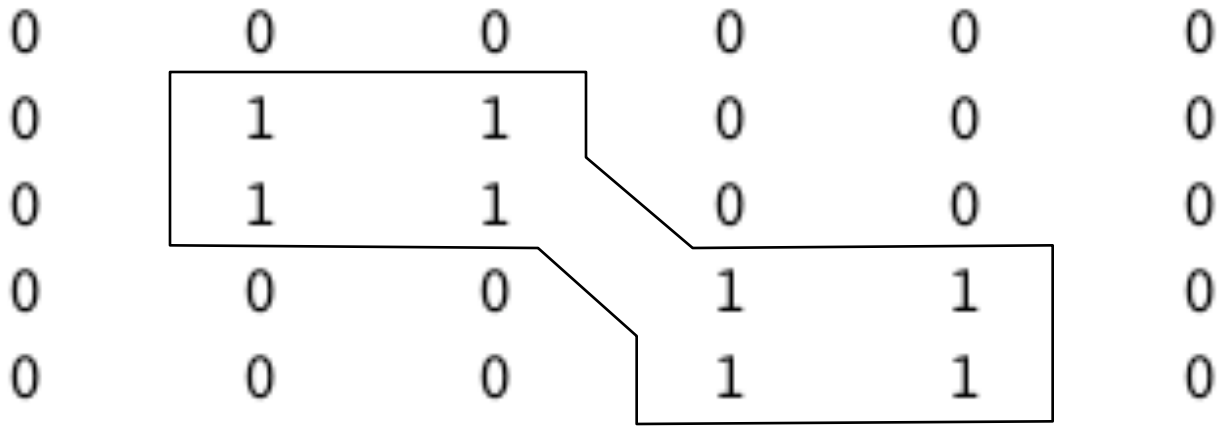
pixel connectivity





pixel connectivity





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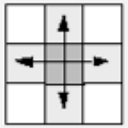
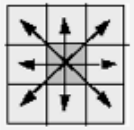
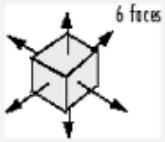
0	1	1	0	0	0
0	1	1	0	0	0
0	0	0	1	1	0
0	0	0	1	1	0

pixel connectivity

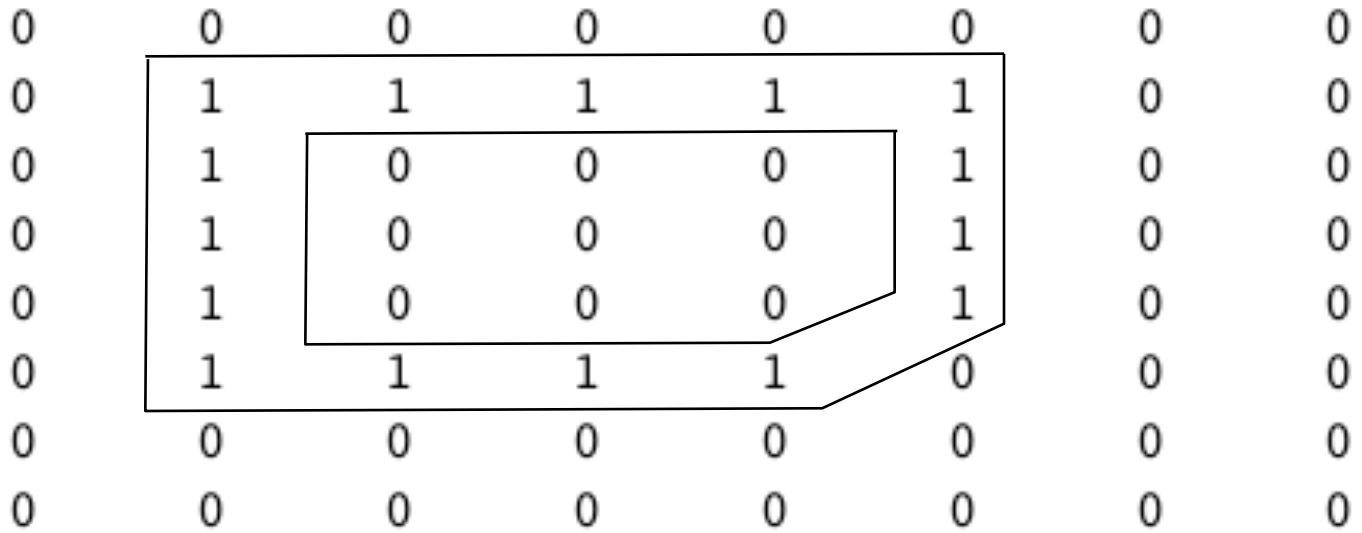
0	0	0	0	0	0
0	1	1	0	0	0
0	1	1	0	0	0
0	0	0	1	1	0
0	0	0	1	1	0

Two-Dimensional Connectivities		
4-connected	Pixels are connected if their edges touch. This means that a pair of adjoining pixels are part of the same object only if they are both on and are connected along the horizontal or vertical direction.	
8-connected	Pixels are connected if their edges or corners touch. This means that if two adjoining pixels are on, they are part of the same object, regardless of whether they are connected along the horizontal, vertical, or diagonal direction.	
Three-Dimensional Connectivities		
6-connected	Pixels are connected if their faces touch.	
18-connected	Pixels are connected if their faces or edges touch.	
26-connected	Pixels are connected if their faces, edges, or corners touch.	

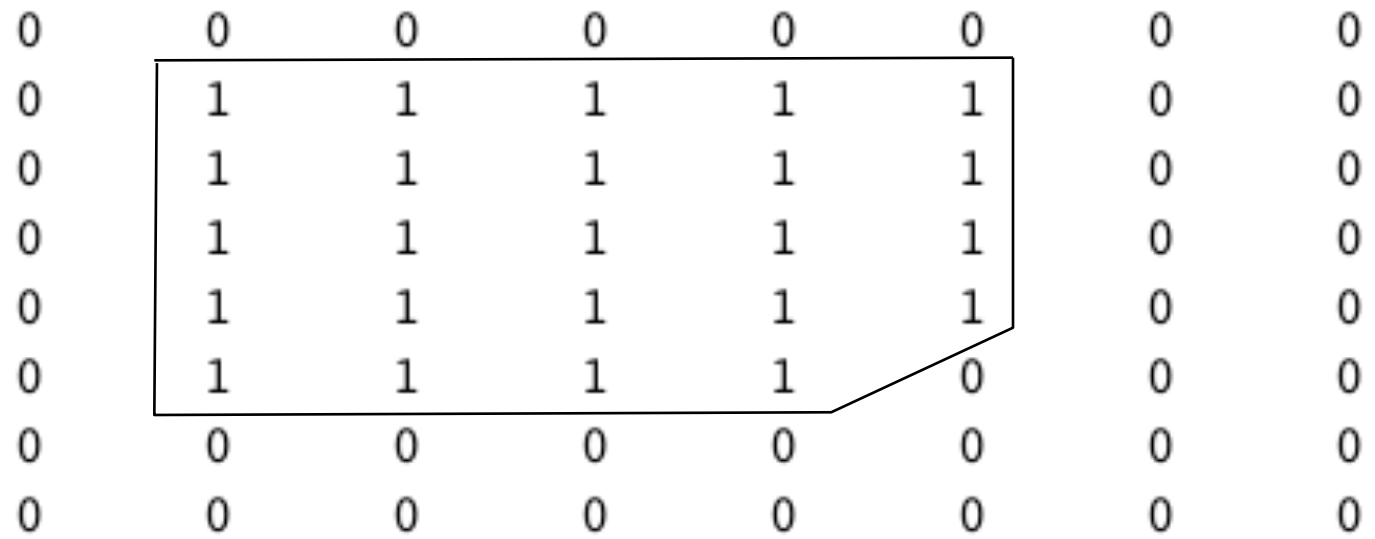
flood filling

0	0	0	0	0	0	0	0
0	1	1	1	1	1	0	0
0	1	0	0	0	1	0	0
0	1	0	0	0	1	0	0
0	1	0	0	0	1	0	0
0	1	1	1	1	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

flood filling



flood filling



peaks & valleys

10	10	10	10	10	10	10	10	10	10
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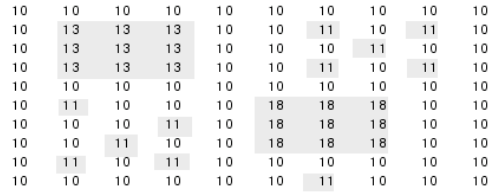
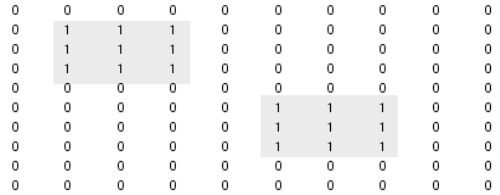
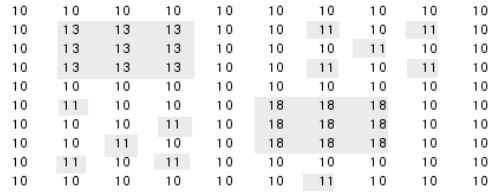
10	13	13	13	10	10	10	11	10	10
10	13	13	13	10	10	11	10	11	10
10	10	10	10	10	10	10	10	10	10
10	11	10	10	10	18	18	18	10	10
10	10	10	11	10	18	18	18	10	10
10	10	11	10	10	18	18	18	10	10
10	11	10	11	10	10	10	10	10	10
10	10	10	10	10	10	11	10	10	10



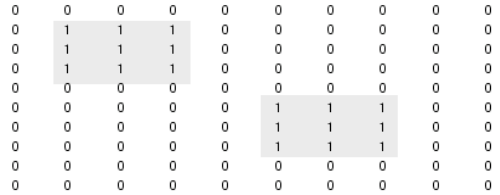
peaks & valleys



0	0	0	0	0	0	0	0	0	0
0	1	1	1	0	0	1	0	1	0
0	1	1	1	0	0	0	1	0	0
0	1	1	1	0	0	1	0	1	0
0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	1	1	1	0	0
0	0	0	1	0	1	1	1	0	0
0	0	1	0	0	1	1	1	0	0
0	1	0	1	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0



peaks & valleys



0	0	0	0	0	0	0	0	0	0
0	1	1	1	0	0	0	0	0	0
0	1	1	1	0	0	0	0	0	0
0	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
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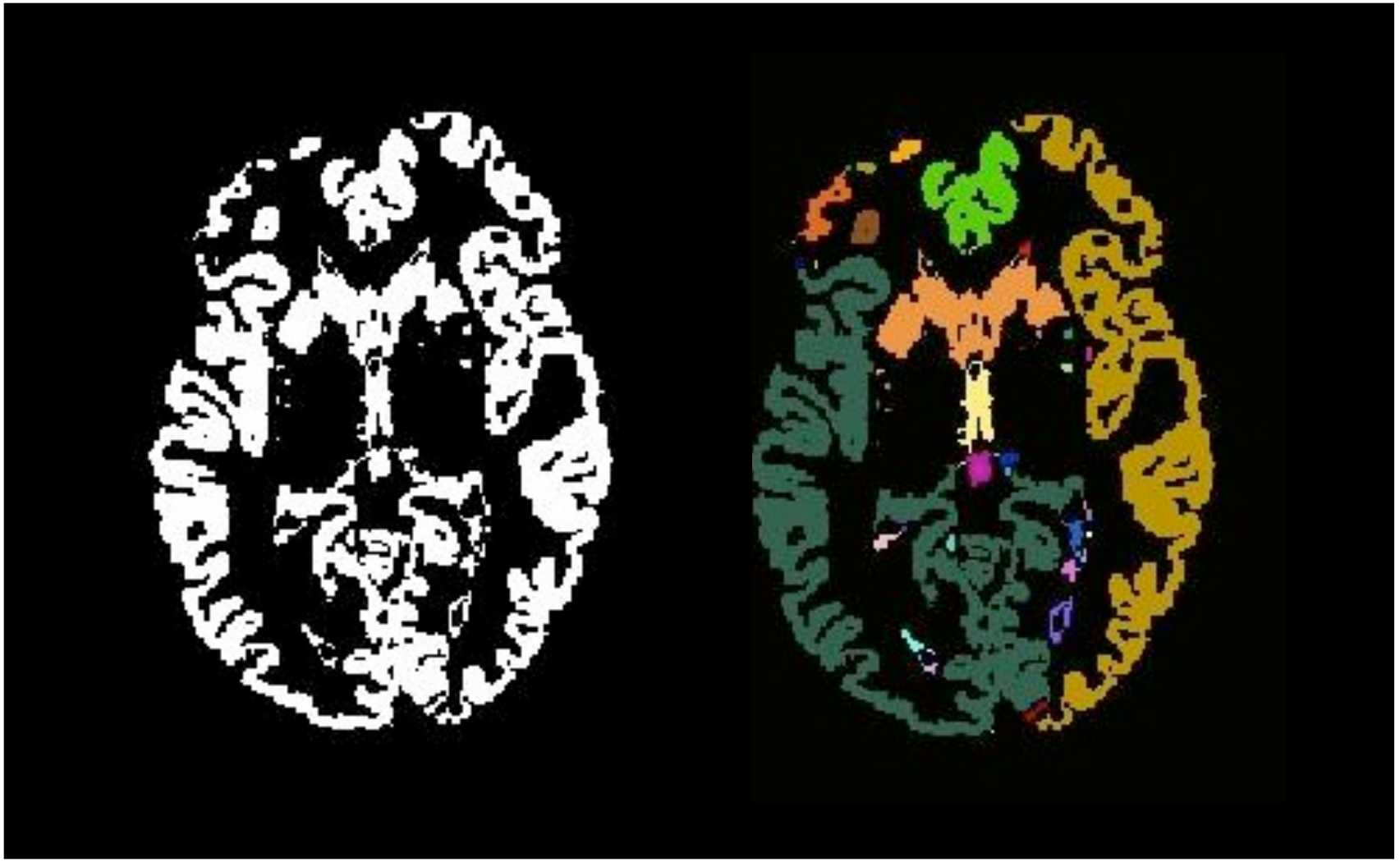
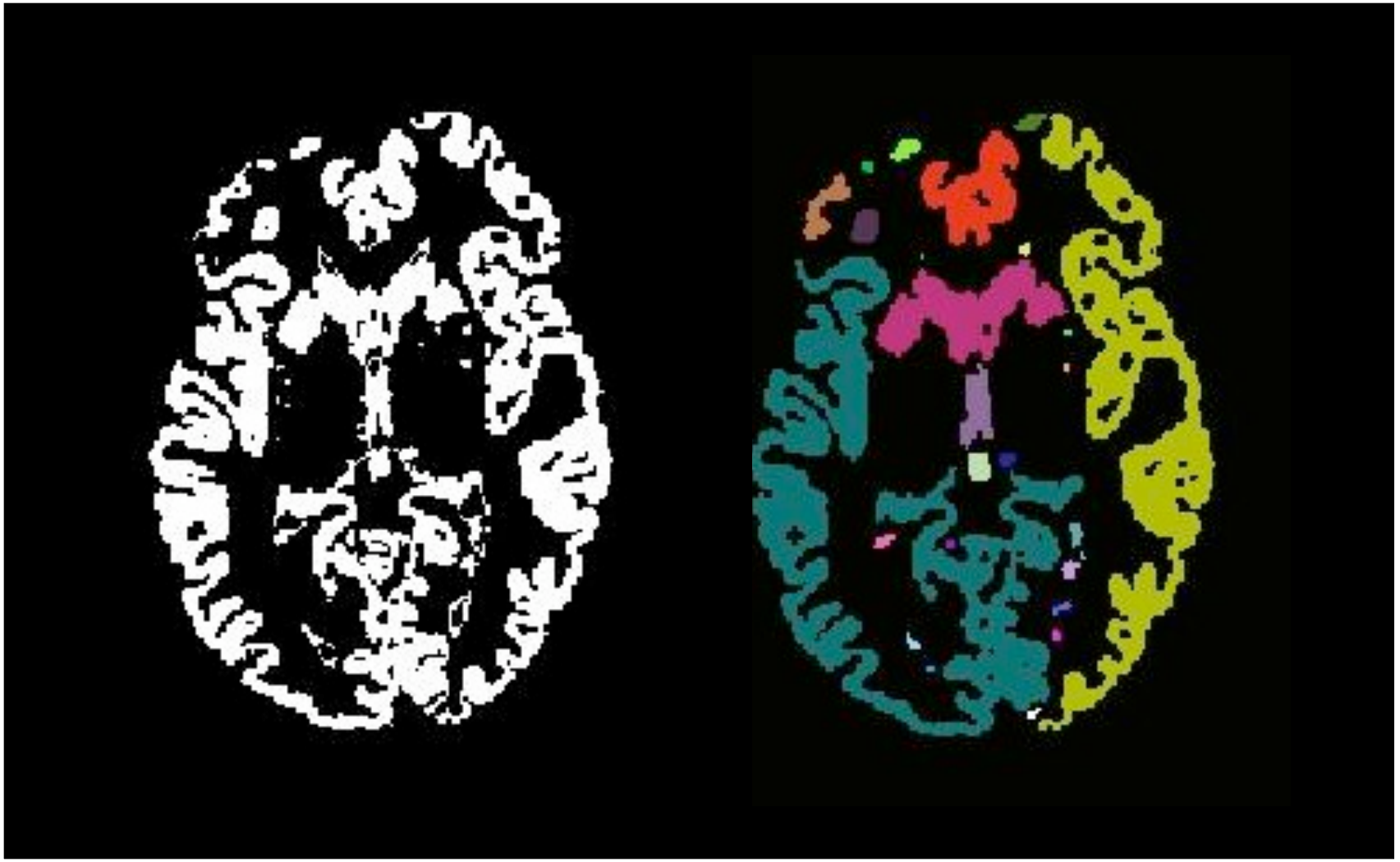
0	0	0	0	0	1	1	1	0	0
0	0	0	0	0	1	1	1	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

labeling connected objects

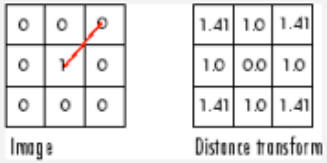
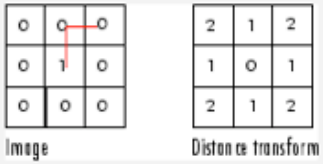
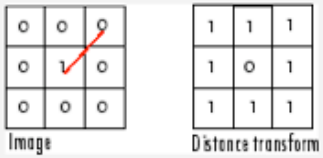
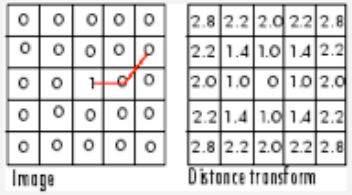


labeling connected objects

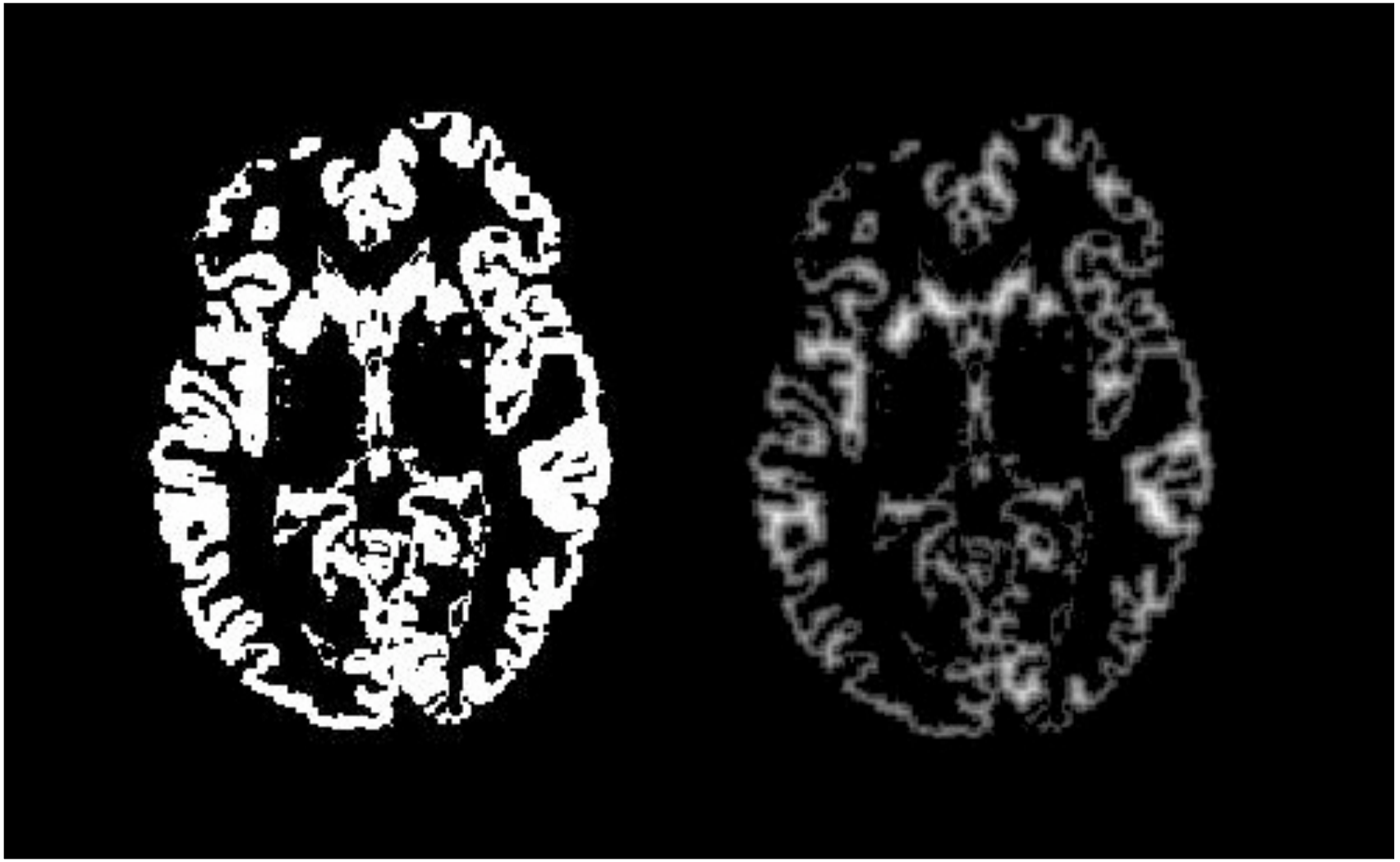


labeling connected objects

distance transforms

Distance Metric	Description	Illustration
Euclidean	The Euclidean distance is the straight-line distance between two pixels.	
City Block	The city block distance metric measures the path between the pixels based on a 4-connected neighborhood. Pixels whose edges touch are 1 unit apart; pixels diagonally touching are 2 units apart.	
Chessboard	The chessboard distance metric measures the path between the pixels based on an 8-connected neighborhood. Pixels whose edges or corners touch are 1 unit apart.	
Quasi-Euclidean	The quasi-Euclidean metric measures the total Euclidean distance along a set of horizontal, vertical, and diagonal line segments.	

distance transforms



distance transforms

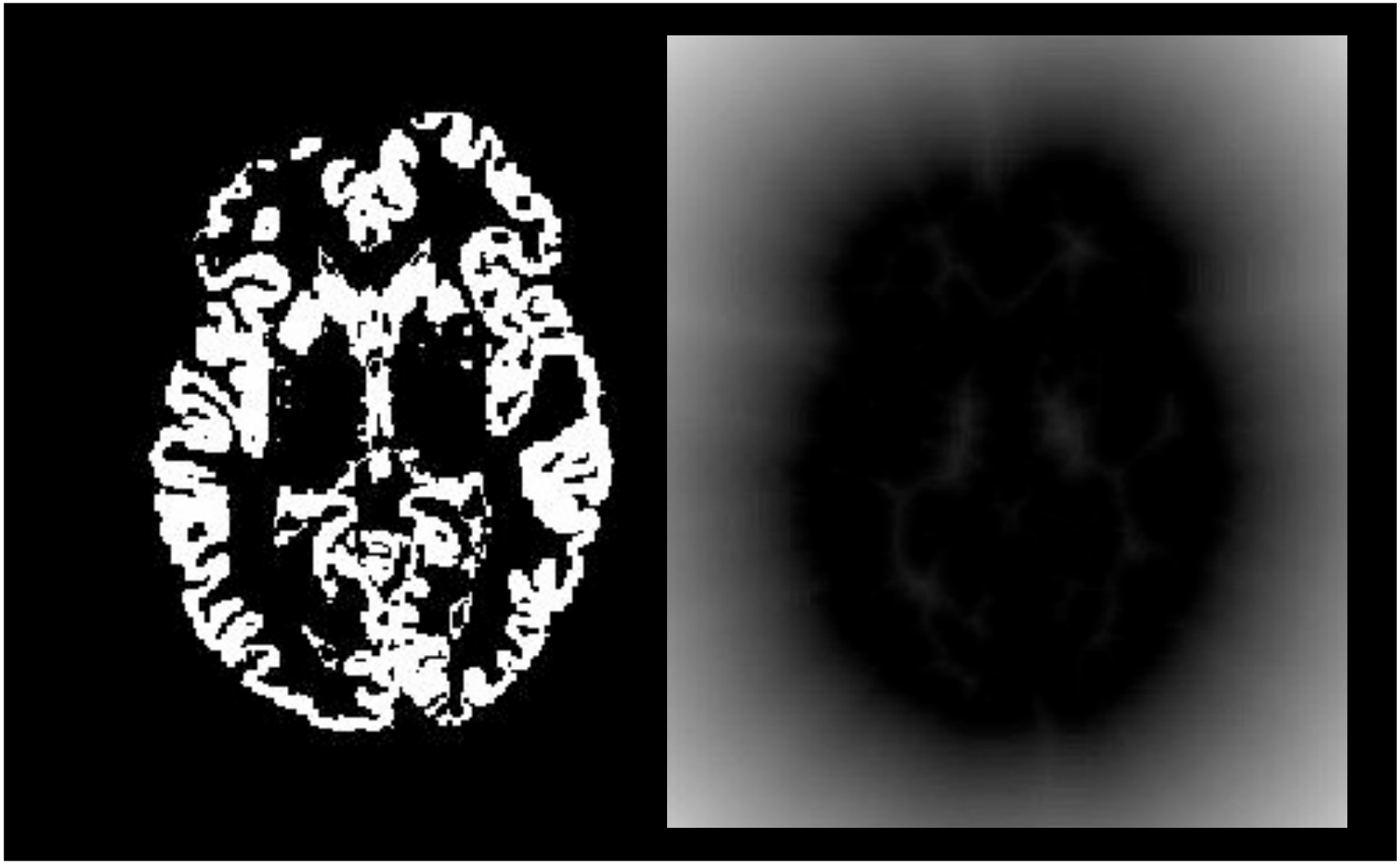
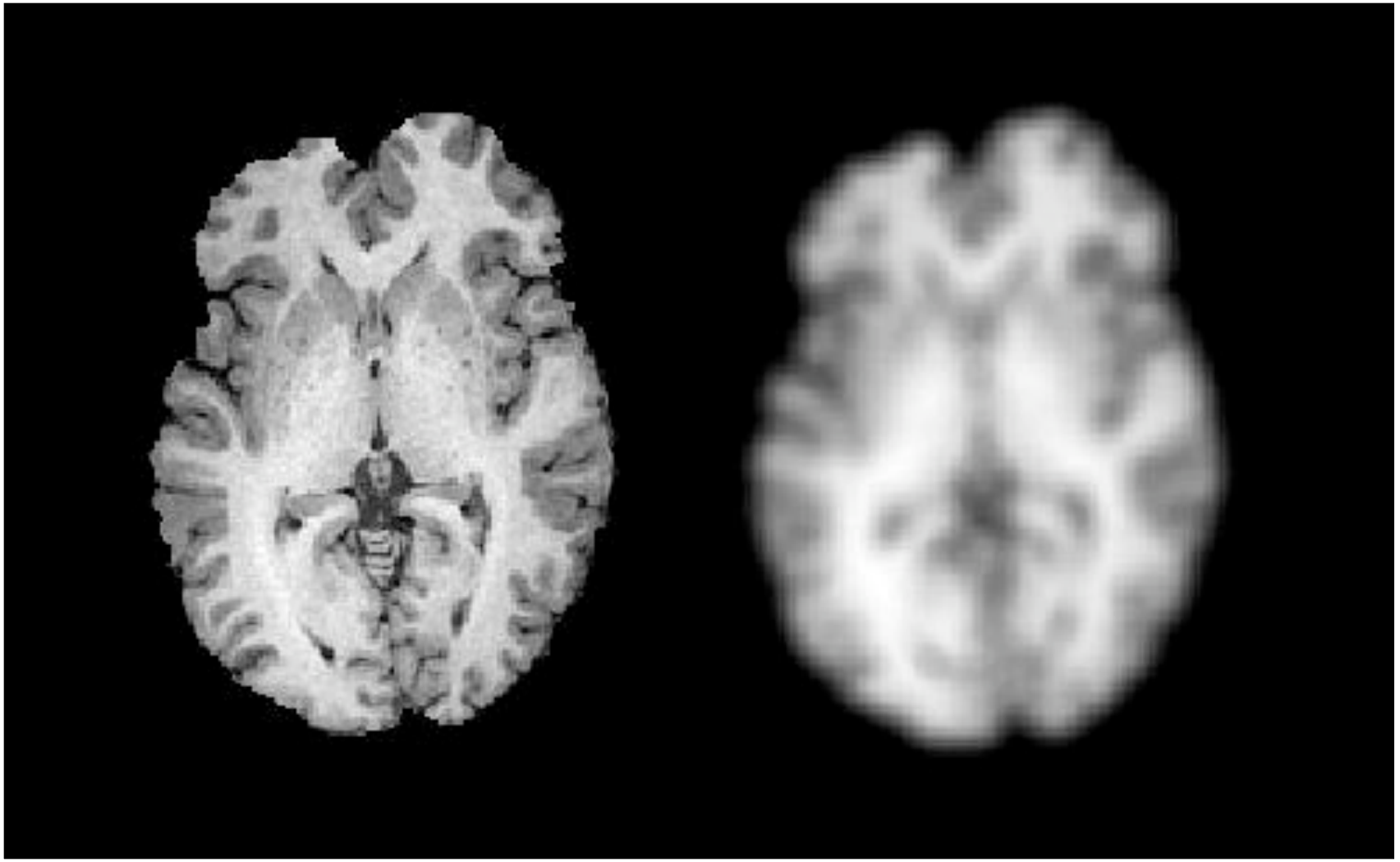
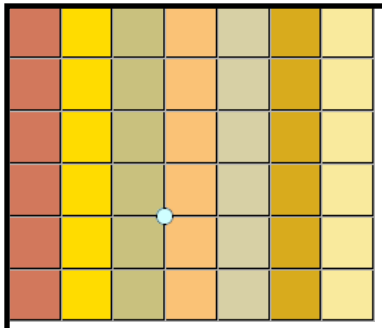
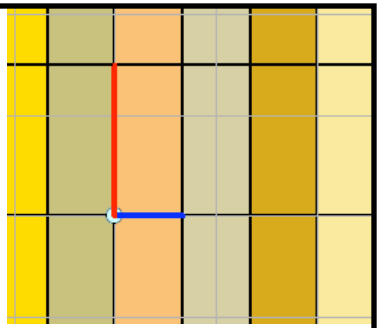


image filters





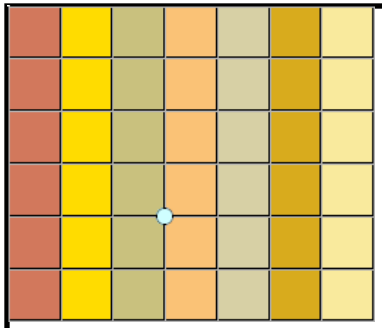
transformation matrices



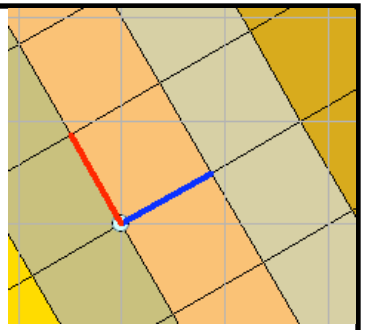
Scale

For scaling (that is, enlarging or shrinking), we have $x' = s_x \cdot x$ and $y' = s_y \cdot y$. The matrix form is:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} s_x & 0 \\ 0 & s_y \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$



transformation matrices



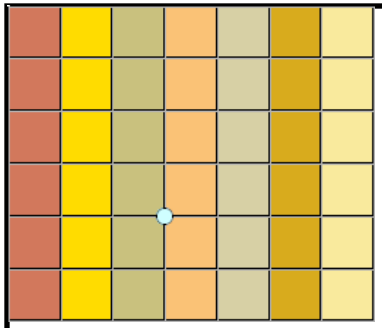
Rotation

For rotation by an angle θ counterclockwise about the origin, the functional form is x' = xcosθ − ysinθ and y' = xsinθ + ycosθ. Written in matrix form, this becomes:

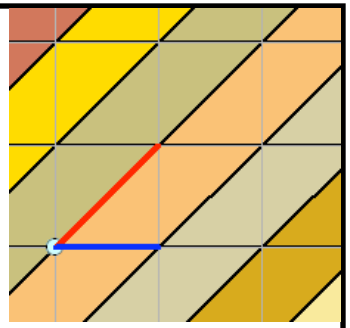
$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

Similarly, for a rotation clockwise about the origin, the functional form is x' = xcosθ + ysinθ and y' = − xsinθ + ycosθ and the matrix form is:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$



transformation matrices



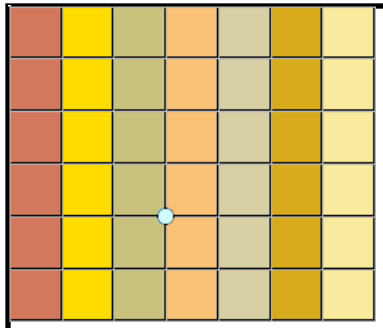
Shear

For shear mapping (visually similar to slanting), there are two possibilities.
For a shear parallel to the x axis has x' = x + ky and y' = y;
the shear matrix, applied to column vectors, is:

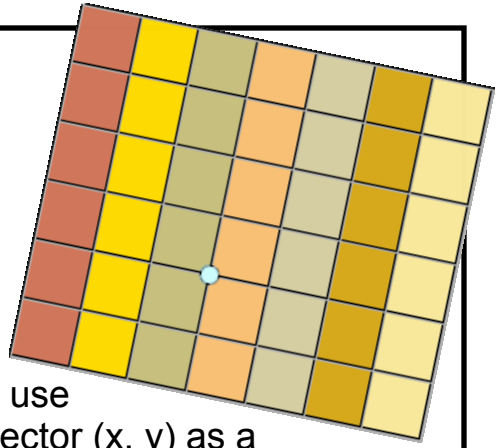
$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & k \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

A shear parallel to the y axis has x' = x and y' = y + kx,
which has matrix form:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ k & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$



transformation matrices



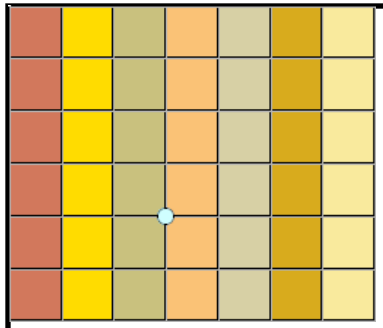
Affine: Translation

To represent affine transformations with matrices, we must use homogeneous coordinates. This means representing a 2-vector (x, y) as a 3-vector (x, y, 1). The functional form x' = x + tx; y' = y + ty of translation is:

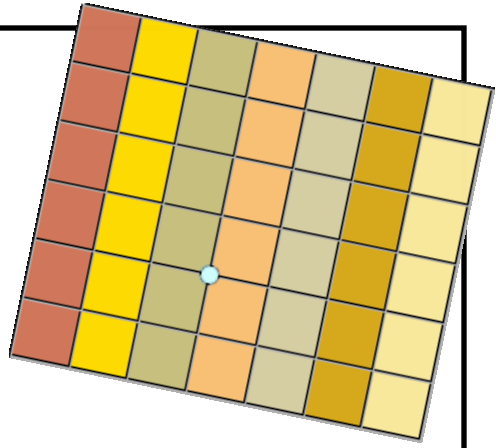
$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}.$$

Affine: Rotation

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}.$$



transformation matrices



degrees of freedom

6 dof: 3 translations, 3 rotations (x,y,z) “rigid-body”

7 dof: 3 translations, 3 rotations, 1 global scale

9 dof: 3 translations, 3 rotations, 3 scales

12 dof: 3 translations, 3 rotations, 3 scales, 3 shears

registration

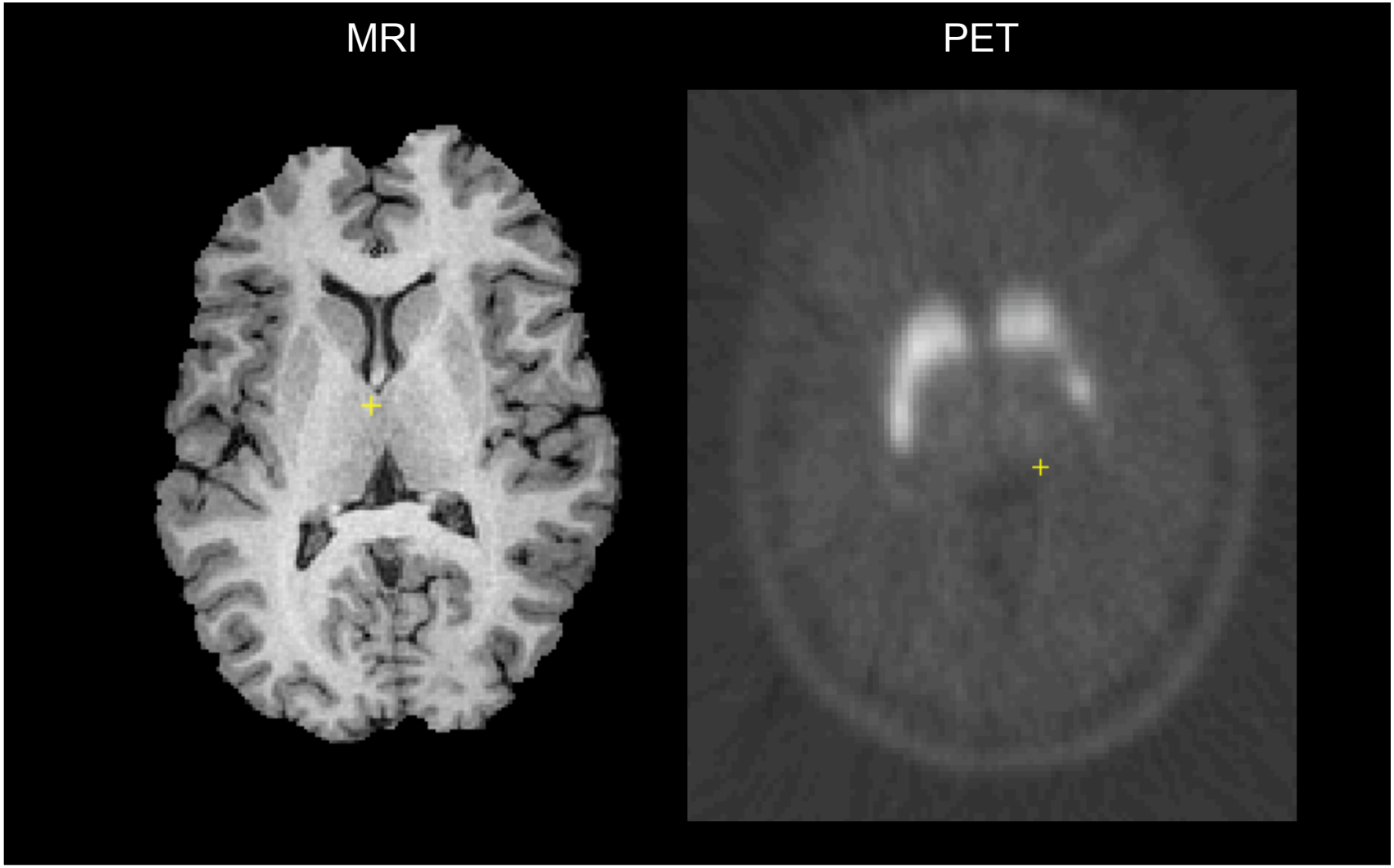
intramodality (T1-to-T1, PET-to-PET,...)

- motion correction
- group analysis
- comparative morphometry
- labeling

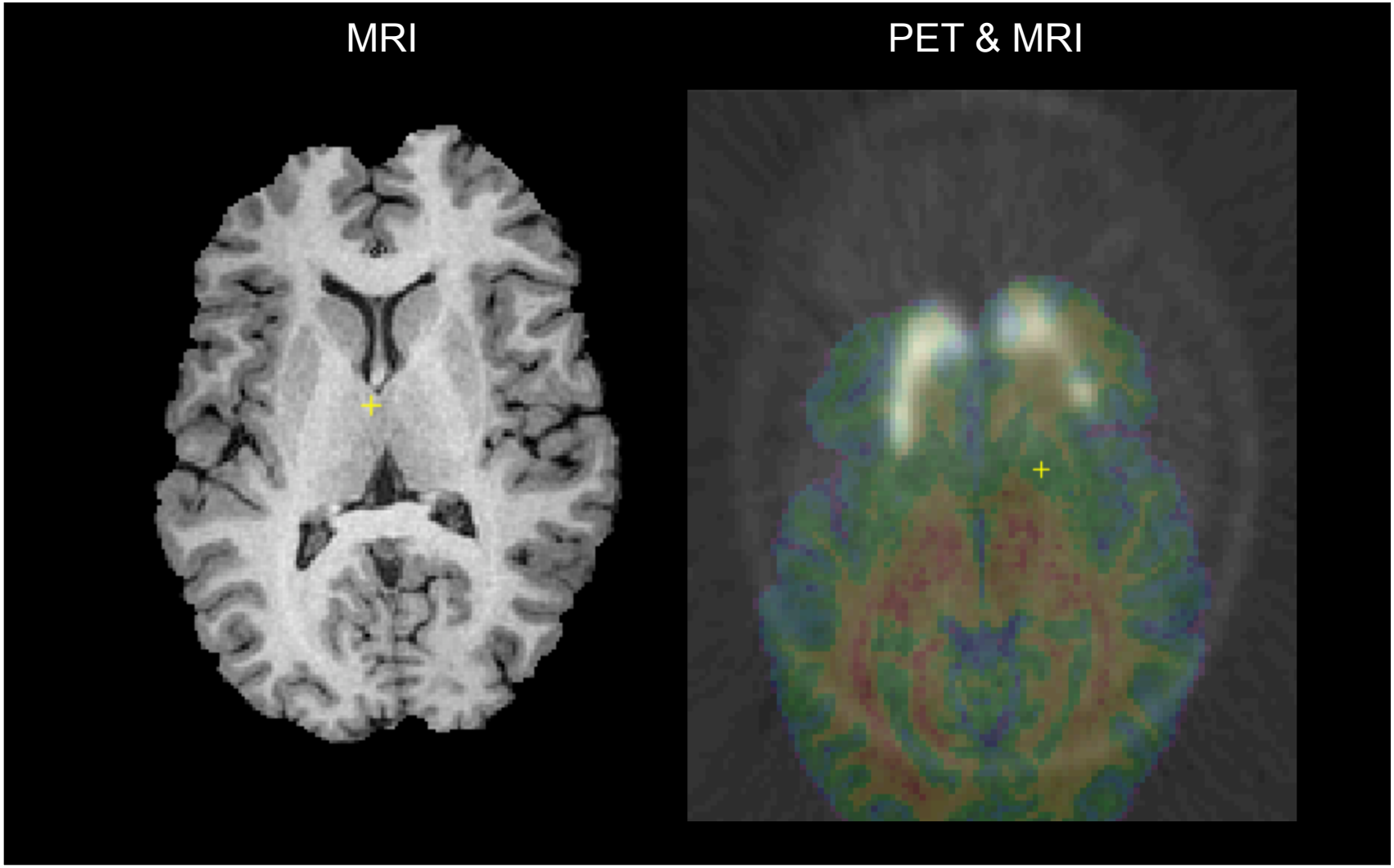
intermodality (T2-to-T1, PET-to-T1,...)

- group analysis
- multispectral analysis
- labeling

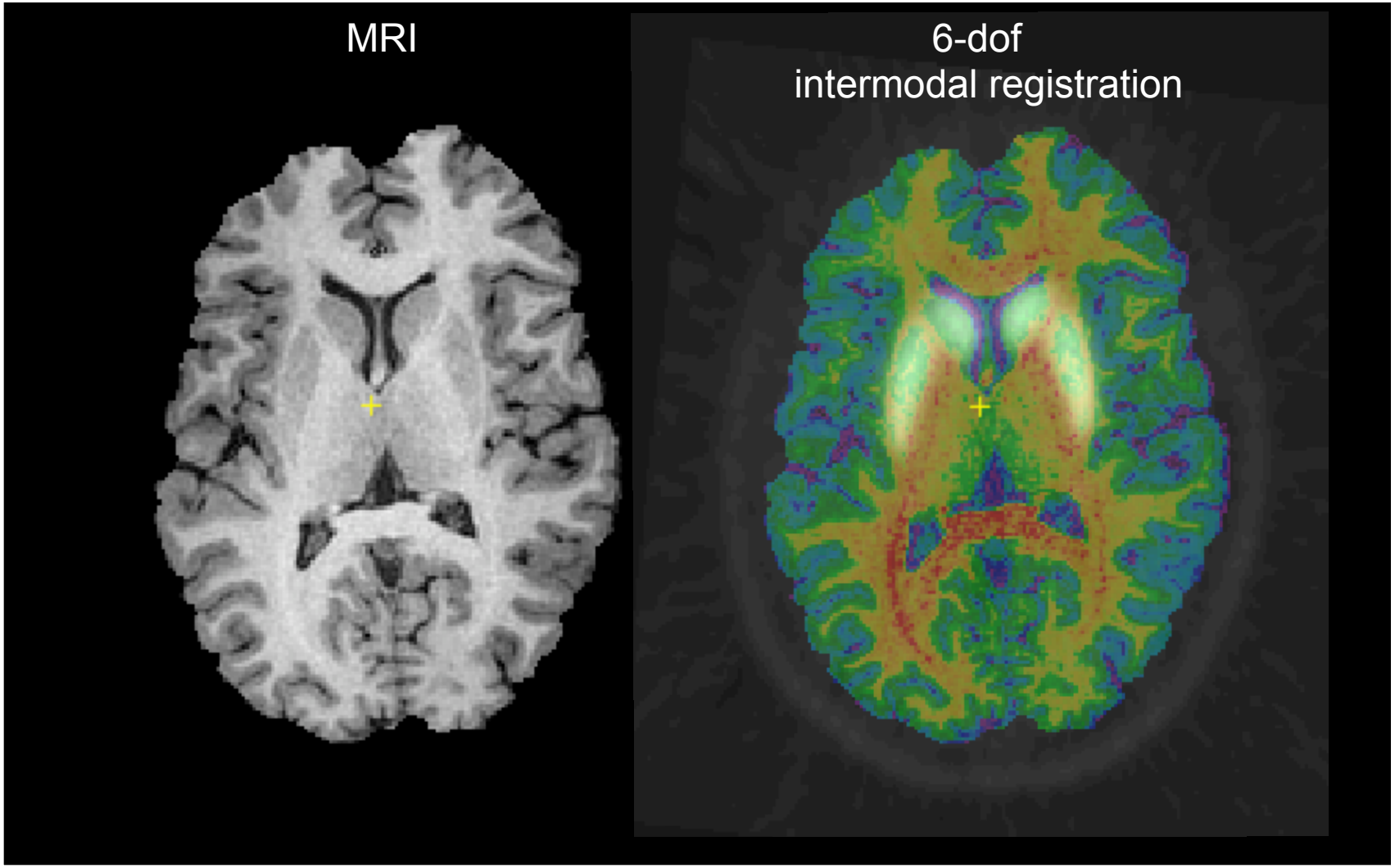
registration



registration



registration



registration

Registration involves:

1. **Similarity** metric: (n)CR, SSD, MSD, (n)CC, MI,...
2. **Transformation** model: affine, piecewise linear, nonlinear,...
3. **Regularization** method: multi-resolution/scale, Gaussian blur,...
4. **Optimization** strategy: simplex, gradient descent,...
5. **Interpolation** type: nearest-neighbor, trilinear, cubic, sinc,...

References

http://www.mathworks.com (Matlab Image Processing Toolbox documentation)

http://mathworld.wolfram.com/AffineTransformation.html

http://www.wikipedia.org

http://www.quantdec.com/GIS/affine.htm