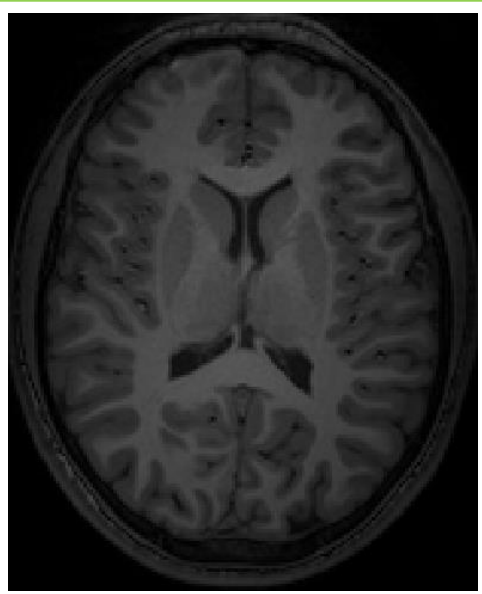

Image Enhancement



Image Enhancement

	Conventional methods	Deep Learning methods
Enhancement	Normalization Histogram equalization Filtering Dictionary learning	SRCNN GAN

Linear Normalization



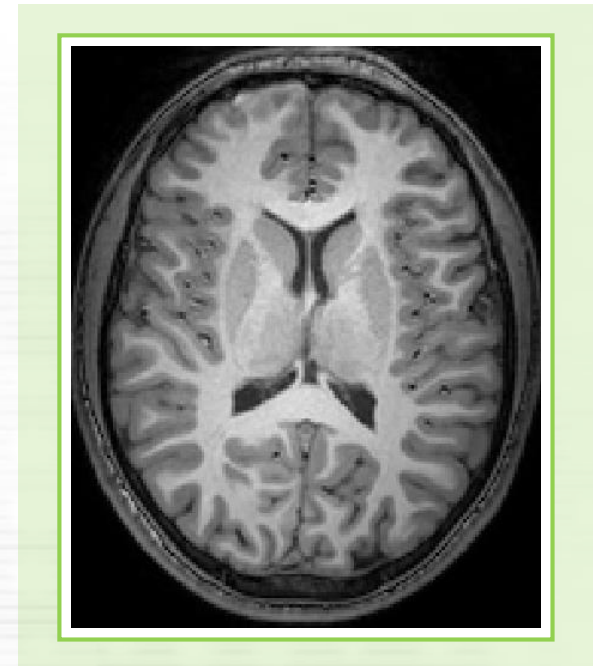
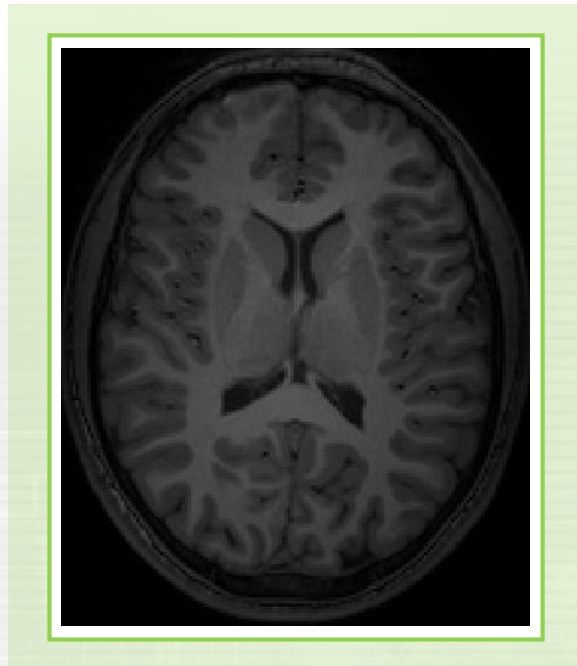
Linear Normalization

$$g(f) = \begin{cases} I_{min}, & \text{if } f < w_{min}, \\ \frac{f - w_{min}}{w_{max} - w_{min}} \times (I_{max} - I_{min}) + I_{min}, & \text{if } w_{min} \leq f \leq w_{max}, \\ I_{max}, & \text{if } f > w_{max}. \end{cases}$$

Histogram



Histogram



Histogram Equalization

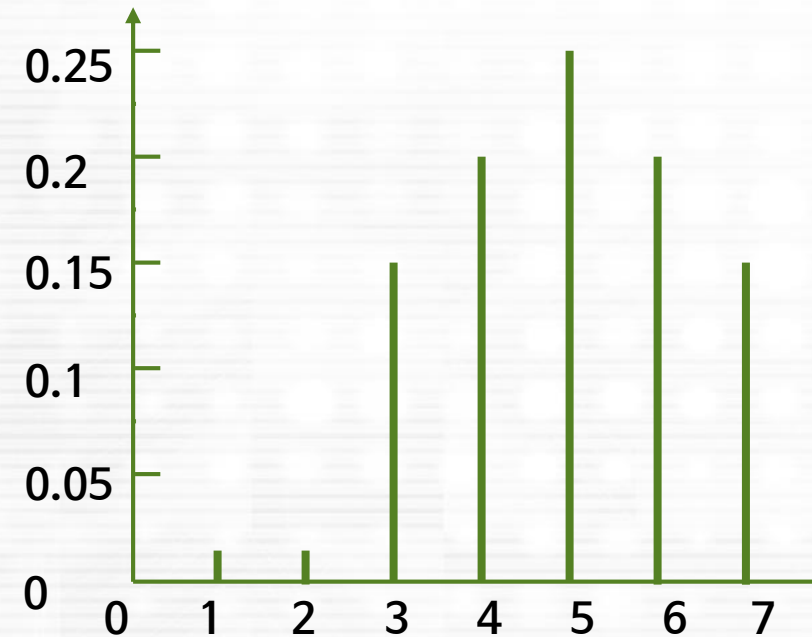
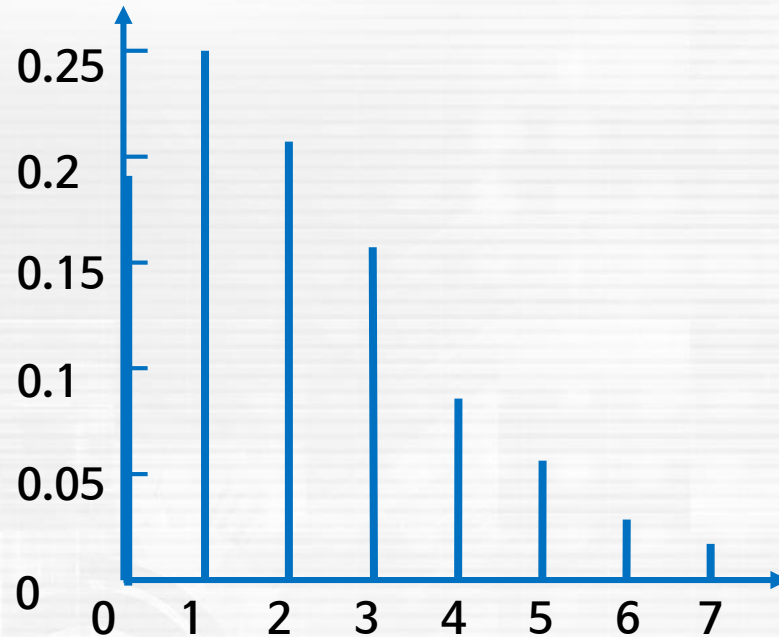
4	4	5	6	7
4	5	6	7	7
6	6	7	7	8
6	7	7	8	9
7	7	8	9	10

Intensity	Cumul.	Norm.
4		
5		
6		
7		
8		
9		
10		

31	31	51	102	194
31	51	102	194	194
102	102	194	194	224
102	194	194	224	245
194	194	224	245	255

Histogram Matching

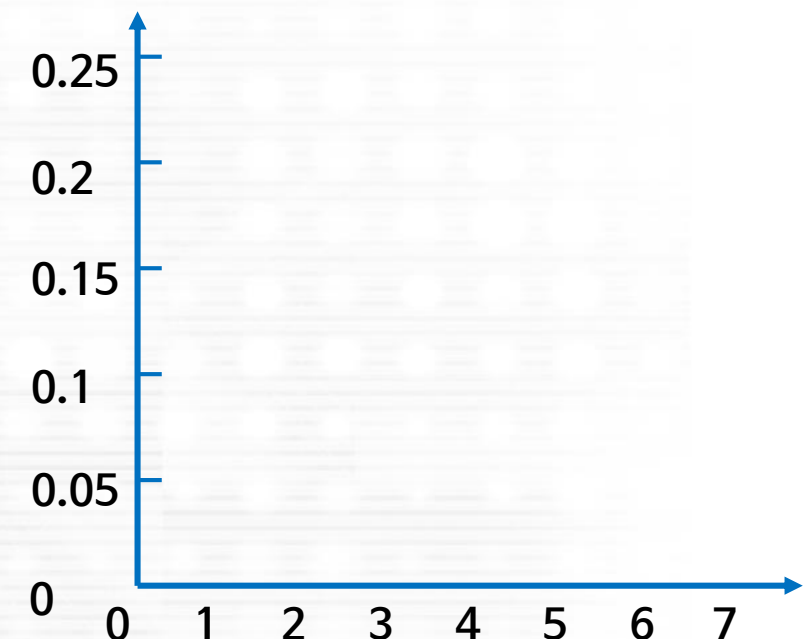
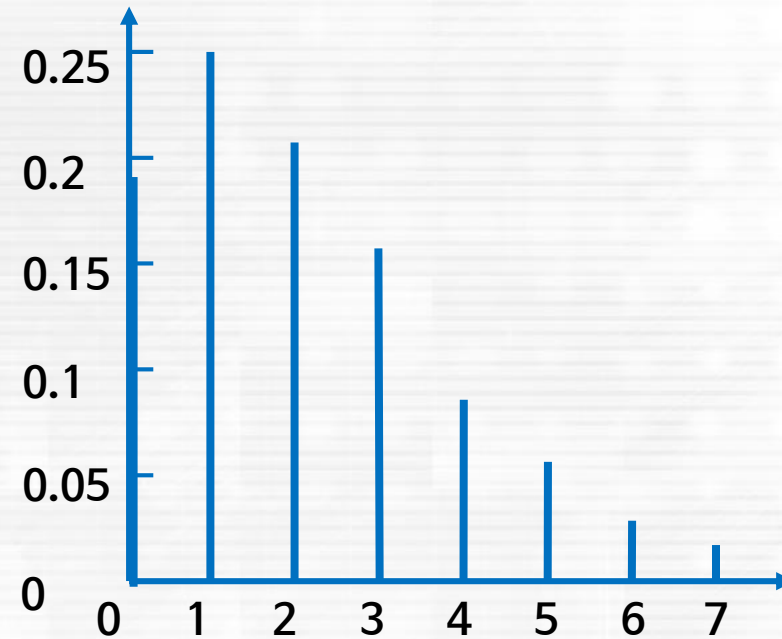
0	0.19	0.19
1	0.25	0.44
2	0.21	0.65
3	0.16	0.81
4	0.08	0.89
5	0.06	0.95
6	0.03	0.98
7	0.02	1



0	0	0
1	0	0
2	0	0
3	0.15	0.15
4	0.2	0.35
5	0.3	0.65
6	0.2	0.85
7	0.15	1

Histogram Matching

0	0.19	0.0	3
1	0.44	0.0	4
2	0.65	0.0	5
3	0.81	0.15	6
4	0.89	0.35	6
5	0.95	0.65	7
6	0.98	0.85	7
7	1.0	1.0	7



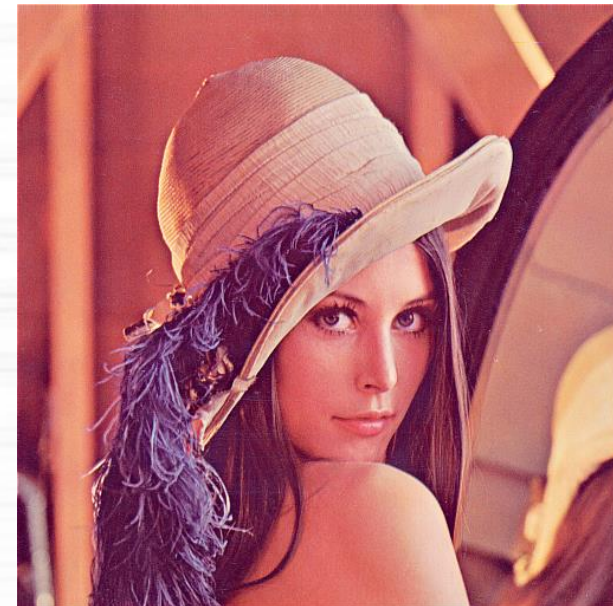
Spatial Filtering

Original

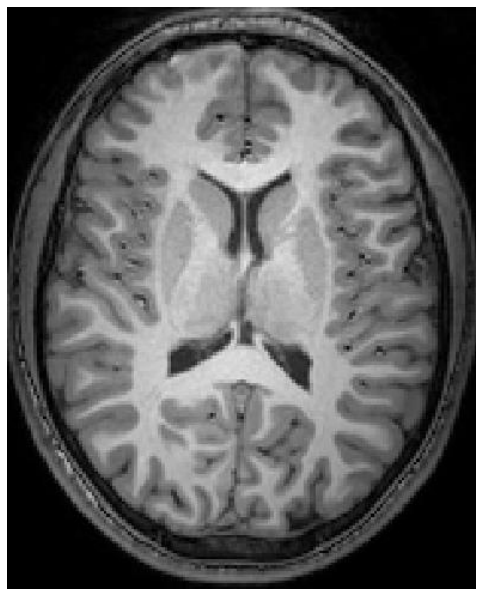
$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$

0	1	0
1	-4	1
0	1	0

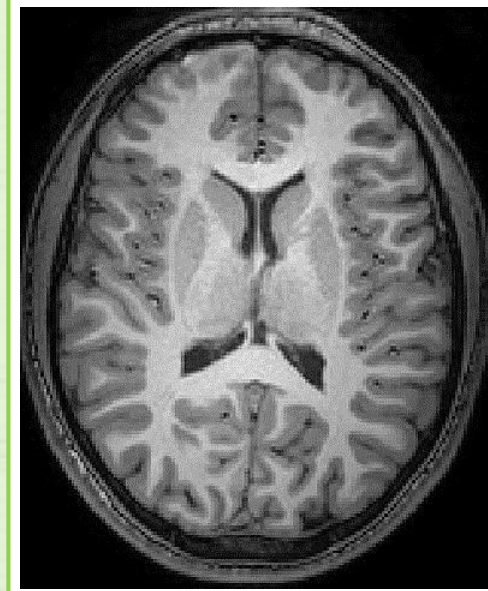
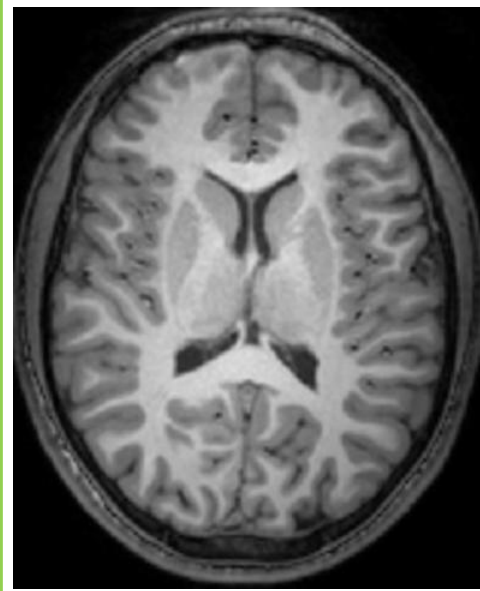
$-1/9$	$-1/9$	$-1/9$
$-1/9$	$17/9$	$-1/9$
$-1/9$	$-1/9$	$-1/9$



Spatial Filtering



Original



Nonlinear Filtering



Original

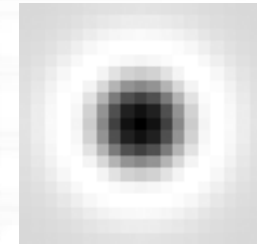
Isotropic Diffusion Filtering



Anisotropic Diffusion Filtering

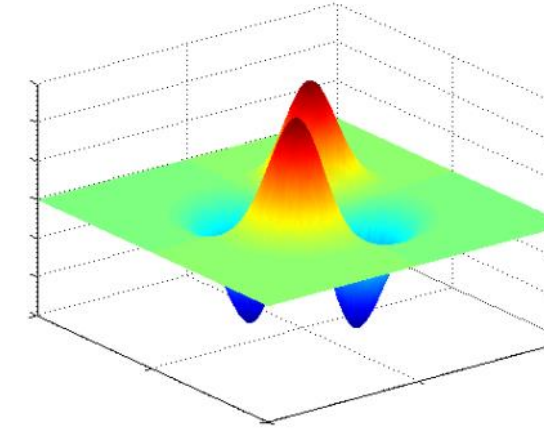
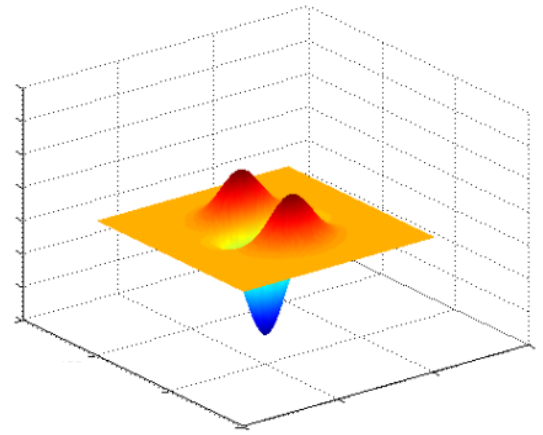
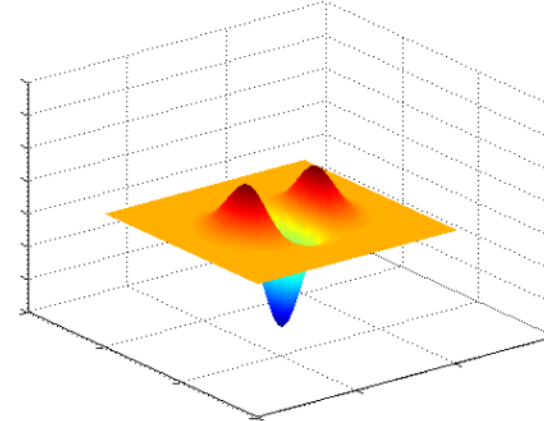
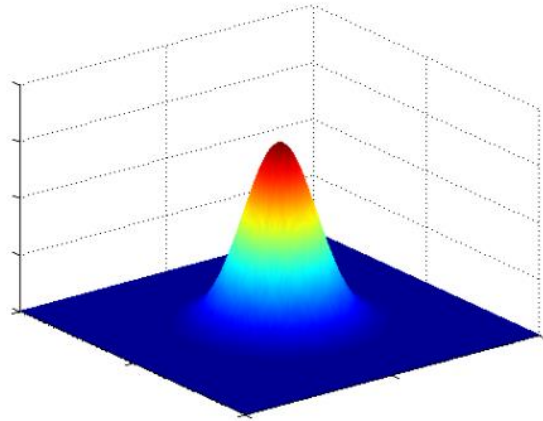
$$I_{i,j}^{t+1} = I_{i,j}^t + \lambda [c_N \cdot \nabla_N I + c_S \cdot \nabla_S I + c_E \cdot \nabla_E I + c_W \cdot \nabla_W I]_{i,j}^t$$

Laplacian of Gaussian Filter



$$g(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

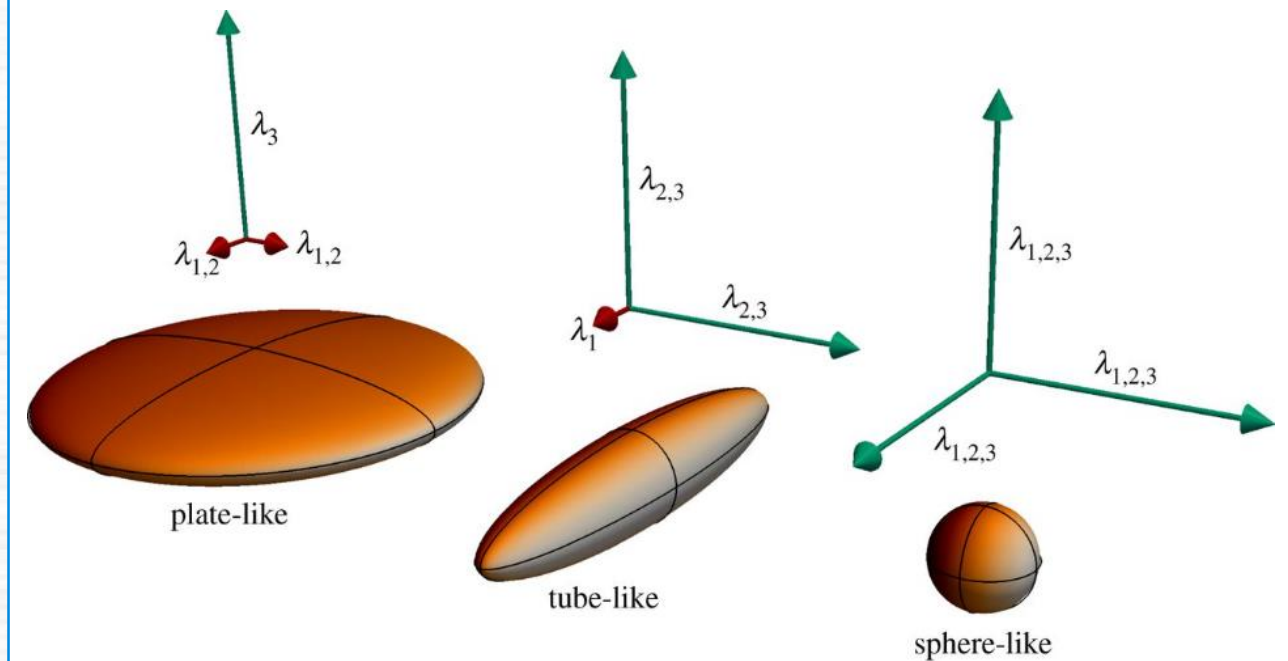
Vessel Enhancement Filtering



Vessel Enhancement Filtering

$$H(v) = \begin{pmatrix} g_{xx}(v) & g_{xy}(v) & g_{xz}(v) \\ g_{yx}(v) & g_{yy}(v) & g_{yz}(v) \\ g_{zx}(v) & g_{zy}(v) & g_{zz}(v) \end{pmatrix}$$

$$(|\lambda_1| \leq |\lambda_2| \leq |\lambda_3|)$$



Vessel Enhancement Filtering

$$\begin{aligned}
 |\lambda_1| &\approx 0 \\
 |\lambda_1| &\ll |\lambda_2| \\
 \lambda_2 &\approx \lambda_3
 \end{aligned}$$

2D		3D			orientation pattern
λ_1	λ_2	λ_1	λ_2	λ_3	
N	N	N	N	N	noisy, no preferred direction
		L	L	H-	plate-like structure (bright)
		L	L	H+	plate-like structure (dark)
L	H-	L	H-	H-	tubular structure (bright)
L	H+	L	H+	H+	tubular structure (dark)
H-	H-	H-	H-	H-	blob-like structure (bright)
H+	H+	H+	H+	H+	blob-like structure (dark)

Vessel Enhancement Filtering

$$R_B = \frac{Volume/(4\pi/3)}{(Largest\ Cross\ Section\ Area/\pi)^{3/2}} = \frac{|\lambda_1|}{\sqrt{|\lambda_2\lambda_3|}}$$

Blob-like structure

$$R_A = \frac{(Largest\ Cross\ Section\ Area)/\pi}{(Largest\ Axis\ Semi-length)^2} = \frac{|\lambda_2|}{|\lambda_3|}$$

Plate-like structure

$$S = \|H\|_F = \sqrt{\sum_{j \leq D} \lambda_j^2}$$

Second-order structureness

Vessel Enhancement Filtering

$$V_0(s) = \begin{cases} 0 \\ \left(1 - \exp\left(-\frac{R_A^2}{2a^2}\right)\right) \exp\left(-\frac{R_B^2}{2b^2}\right) \left(1 - \exp\left(-\frac{S^2}{2c^2}\right)\right) \end{cases} \quad \text{if } \lambda_2 > 0 \text{ or } \lambda_3 > 0,$$

Vessel Enhancement Filtering

