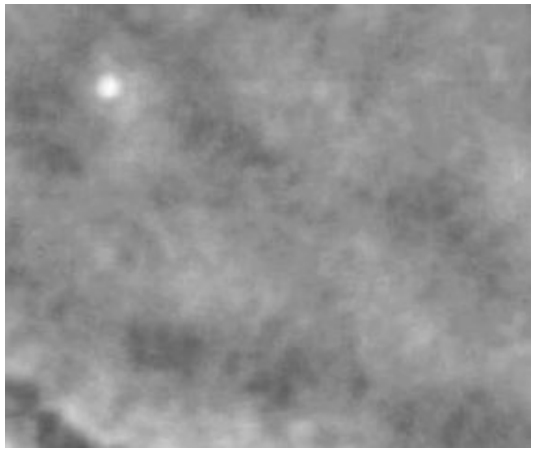
Geometric (Bio-) Modeling and Visualization

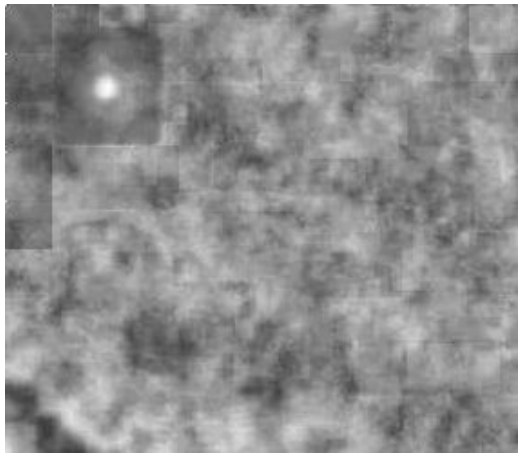
http://www.cs.utexas.edu/~bajaj/c3s84R10/

Lecture 19a

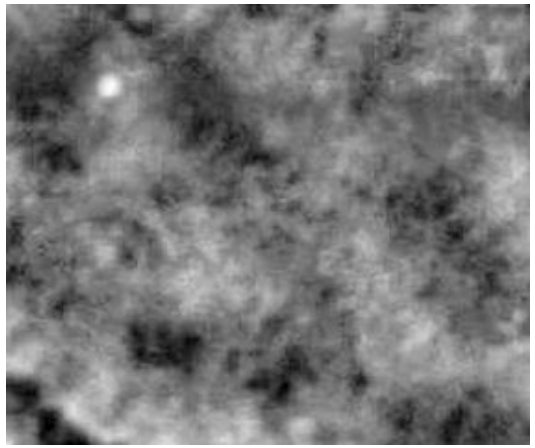
Maps IIa: Image/Map Processing - Contrast Enhancement



Original image



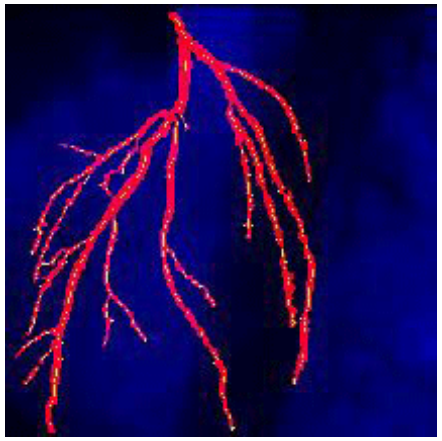
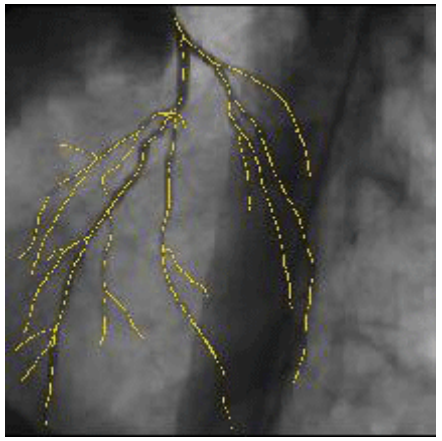
Contrast enhanced



Final Contrast enhanced

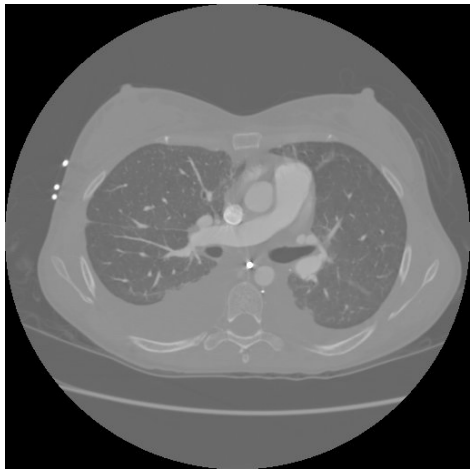
Selected Topics in Image Processing

- Image contrast enhancement
  - A fast and adaptive method
- Image Filtering
  - Anisotropic Diffusion
- Image segmentation
  - Multi-seeded fast marching method
- Image skeleton extraction
  - Boundary-free, boundary-based approach

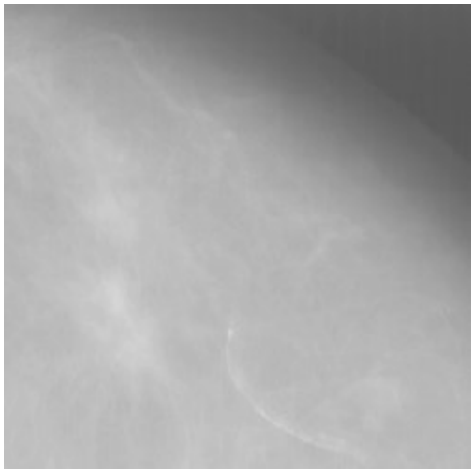




J. F. OBrien and N. F. Ezquerra, *Proc. SPIE Conf. Visualization in Biomed. Computing*, 1994

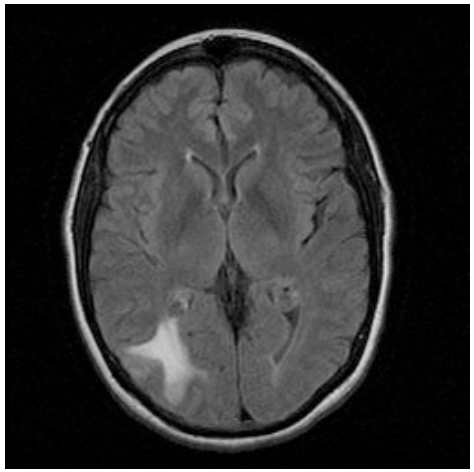
Contrast Enhancement (1): Examples



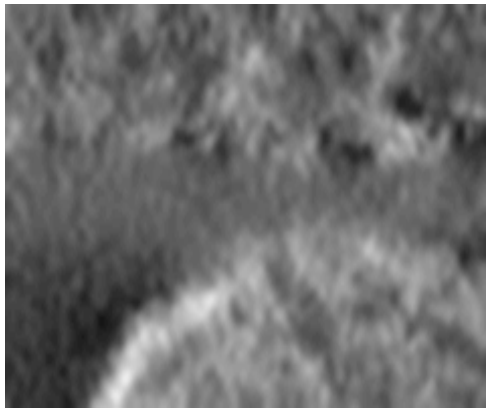
CT image



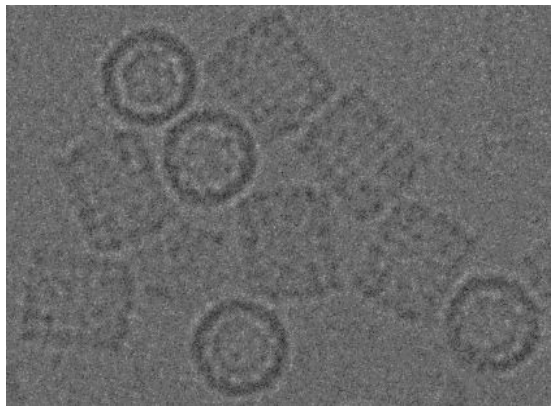
Mammography image



MRI image



Cell image

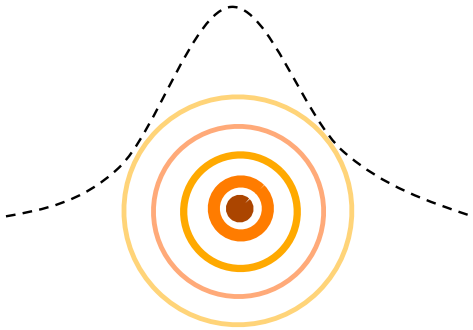


Virus image

Contrast Enhancement (2): Prior Work

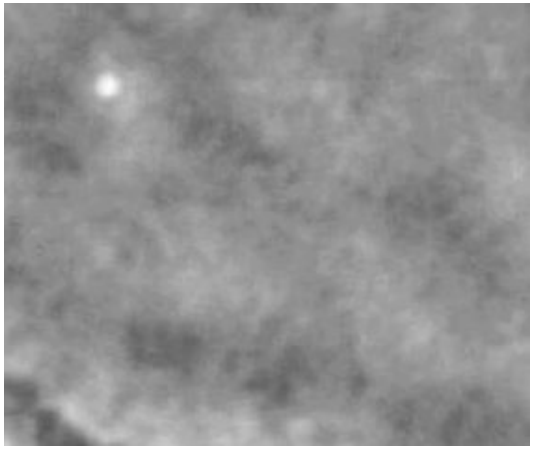
- Global contrast manipulation
  - Linear
  - Nonlinear
- Histogram equalization (Pizer'87; Caselles'98; Stark'00)
  - Global
  - Local
- Retinex model (Jobson'97)
  - Single scale
  - Multi-scale

$$R = \log \frac{I(x,y)}{I(x,y) * G_{\sigma}(x,y)}$$

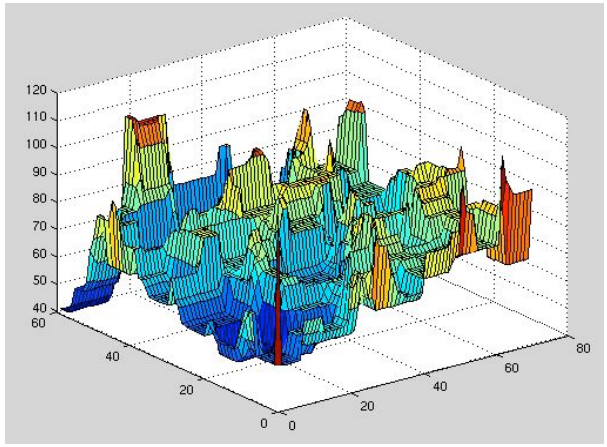


Contrast Enhancement (1): Algorithm

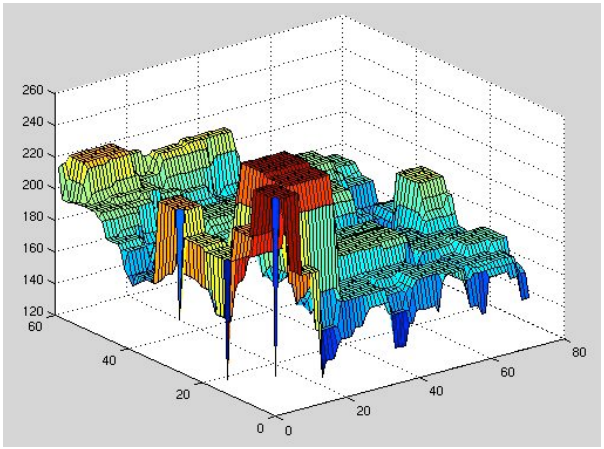
- Motivation
  - Local contrast manipulation
  - Adaptive transfer function
  - Multi-scale contrast enhancement
- Steps
  - Compute local statistics (min/max/avg)
  - Design transfer function
  - Update the intensity pixel-by-pixel



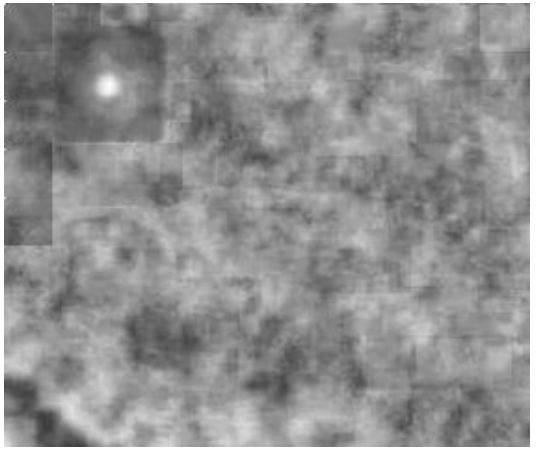
Original image



Local minimum



Local maximum



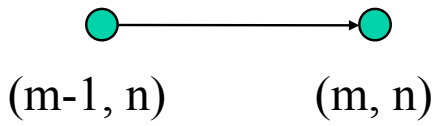
Contrast enhanced

Z. Yu and C. Bajaj, Proc. Intl. Conference on Image Processing, 2004

Contrast Enhancement (2): Algorithm

- Propagation scheme for average (Deriche'90; Young'95)

$$\text{lavg}_{m,n} = (1 - C) \times \text{lavg}_{m,n} + C \times \text{lavg}_{m-1,n}$$



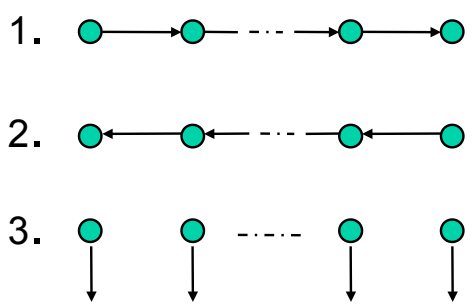
- Conditional propagation scheme for local minimum/maximum (Yu'04)

$$\begin{cases} if(\text{lmin}_{m-1,n} < \text{lmin}_{m,n}) \\ \quad \text{lmin}_{m,n} = (1 - C) \times \text{lmin}_{m,n} + C \times \text{lmin}_{m-1,n} \\ \\ if(\text{lmax}_{m-1,n} > \text{lmax}_{m,n}) \\ \quad \text{lmax}_{m,n} = (1 - C) \times \text{lmax}_{m,n} + C \times \text{lmax}_{m-1,n} \end{cases}$$

C: conductivity $\in [0, 1]$

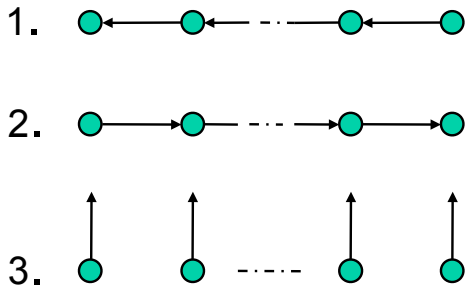
Top-down

For each row:



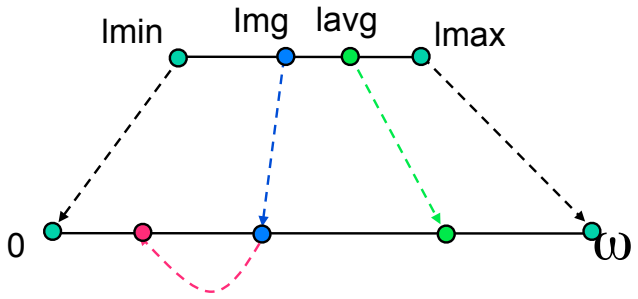
Bottom-up

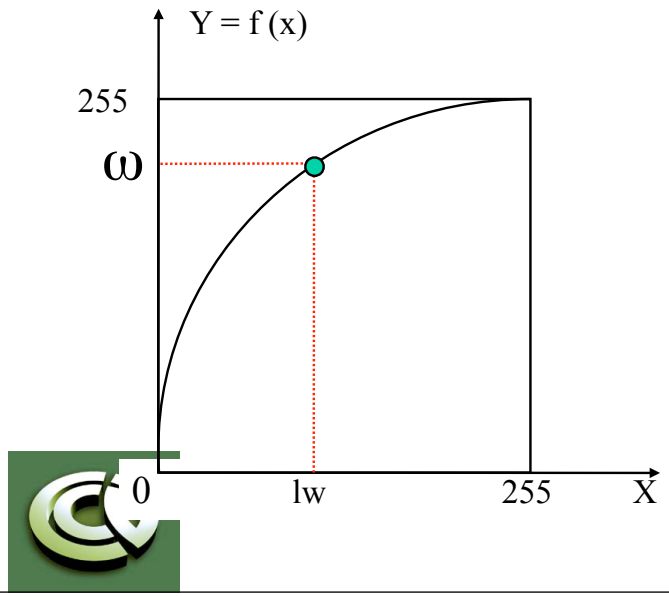
For each row:



Contrast Enhancement (3): Algorithm

- Adaptive (per pixel) Range Stretching
  - Local contrast manipulation



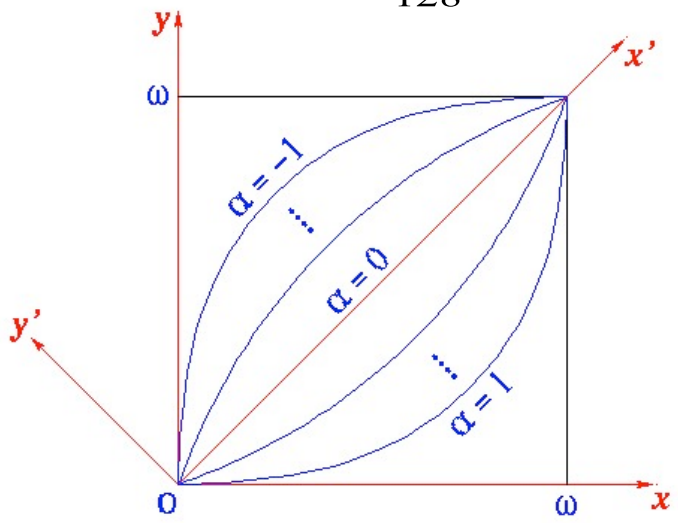


- If I(x,y) < A(x,y),
  - choose concave transfer function
- If I(x,y) > A(x,y),
  - choose convex transfer function

$$I_{new} = \omega(\alpha) * (I_{old} - \mathrm{Im}\,in) / (\mathrm{Im}\,ax - \mathrm{Im}\,in)$$

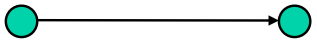
$$A_{new} = \omega(\alpha) * (A_{old} - \mathrm{Im}\,in) / (\mathrm{Im}\,ax - \mathrm{Im}\,in)$$

$$\alpha = \frac{A_{new} - I_{new}}{128}$$



Contrast Enhancement (4): Algorithm

- Anisotropic propagation

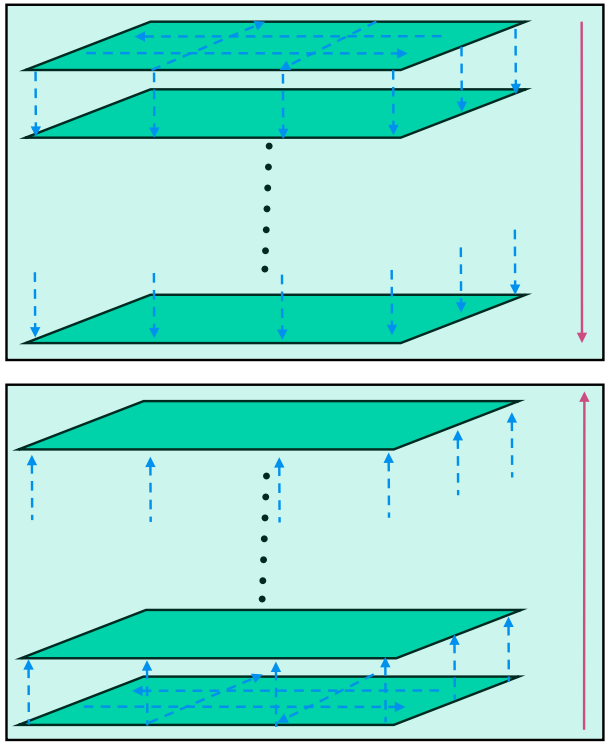


(m-1, n) (m, n)

$$
\begin{cases}
if(\text{lmin}_{m-1,n} < \text{lmin}_{m,n}) \\
\quad \text{lmin}_{m,n} \mathrel{+}= (\text{lmin}_{m-1,n} - \text{lmin}_{m,n}) \\
\qquad * exp(-R * |\text{lmin}_{m-1,n} - \text{lmin}_{m,n}|) \\
\\
if(\text{lmax}_{m-1,n} > \text{lmax}_{m,n}) \\
\quad \text{lmax}_{m,n} \mathrel{+}= (\text{lmax}_{m-1,n} - \text{lmax}_{m,n}) \\
\qquad * exp(-R * |\text{lmax}_{m-1,n} - \text{lmax}_{m,n}|) \\
\\
\text{lavg}_{m,n} \mathrel{+}= (\text{lavg}_{m-1,n} - \text{lavg}_{m,n}) \\
\qquad * exp(-R * |\text{lavg}_{m-1,n} - \text{lavg}_{m,n}|)
\end{cases}
$$

R: resistance $\in [0.01,\ 0.1]$

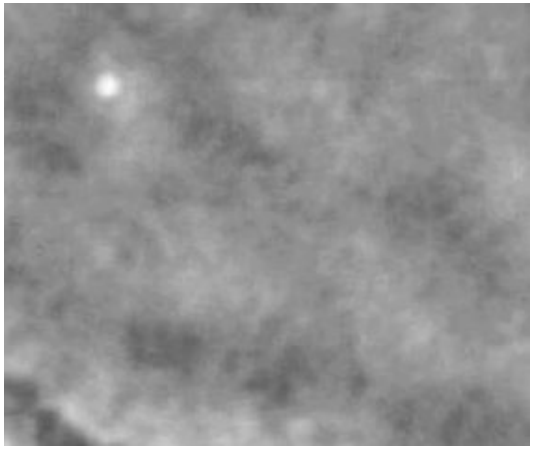
- 3D contrast enhancement



- Color contrast enhancement
  - RGB, HSV

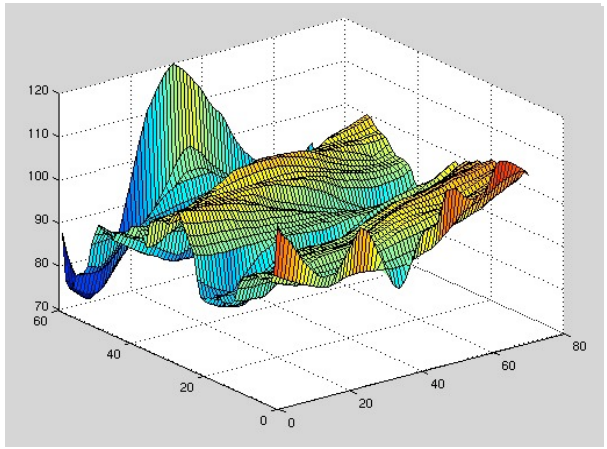
Contrast Enhancement (5): Comparisons

- Advantages
  - Fast to calculate
  - Smooth results

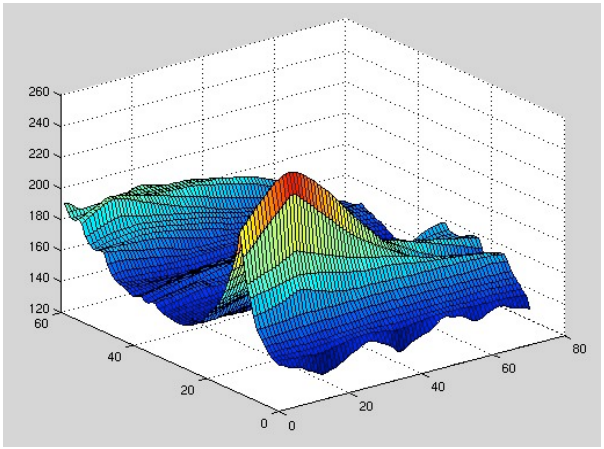


Original image

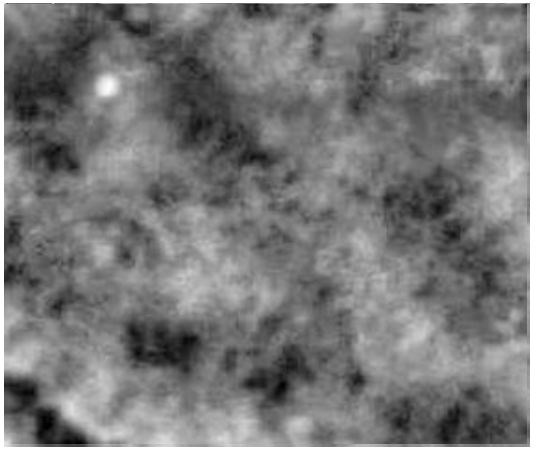
Results by propagation:



Local minimum

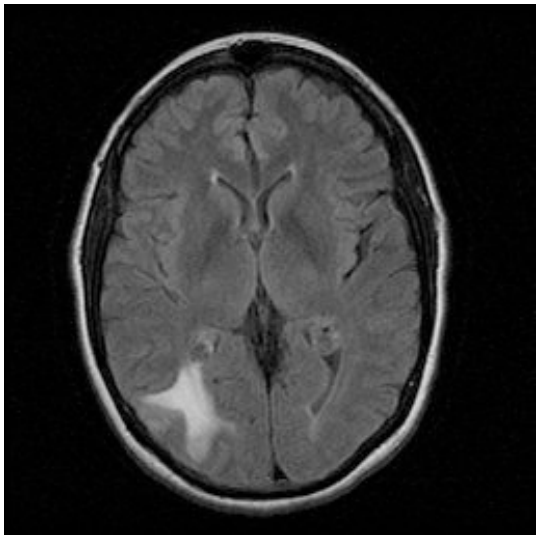


Local maximum

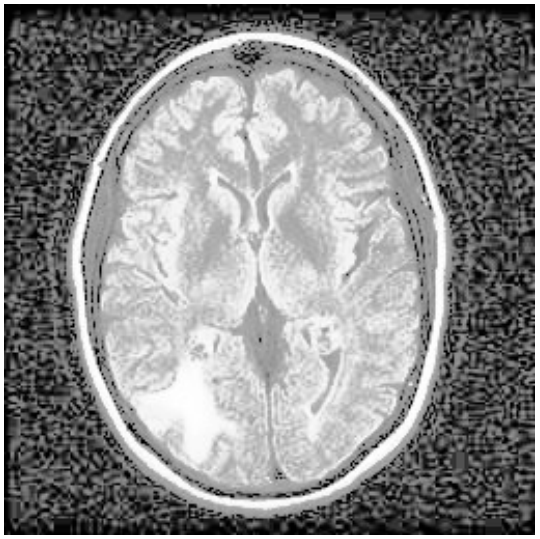


Contrast enhanced

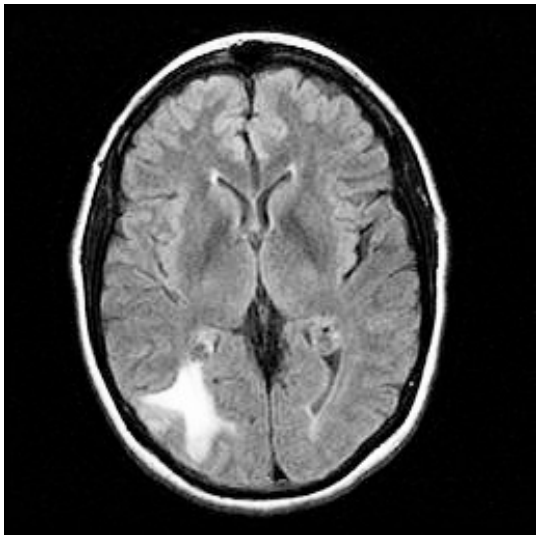
Contrast Enhancement (6): Results



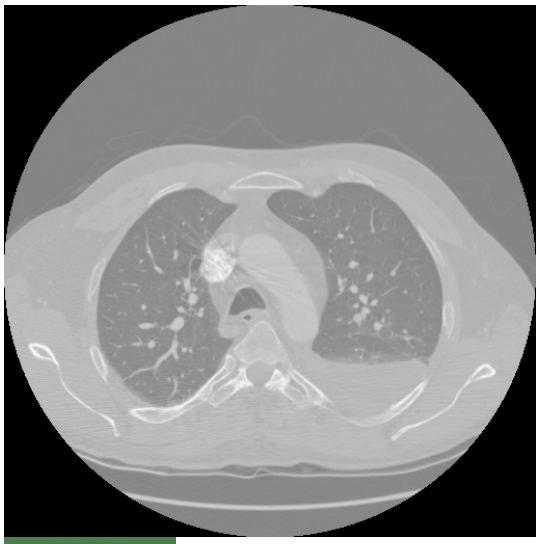
Original image



Histogram equalization



This method (isotropic)

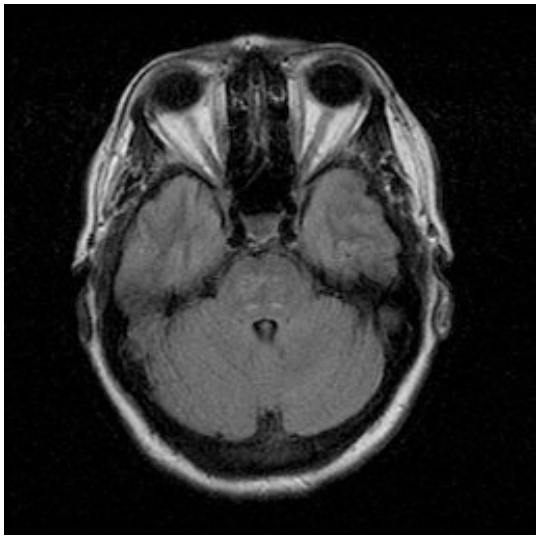


Original image

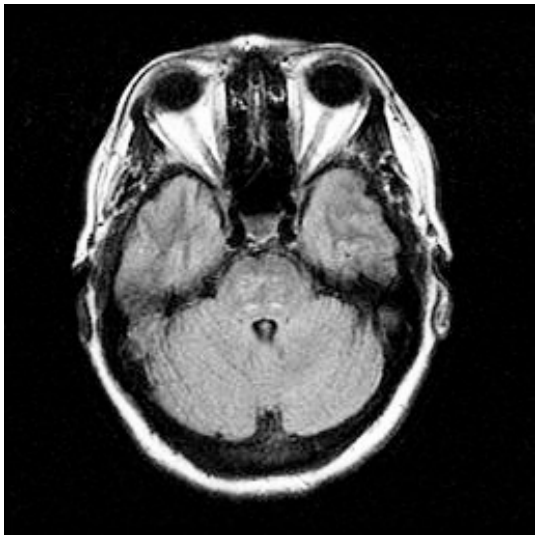
Histogram equalization

This method (anisotropic)

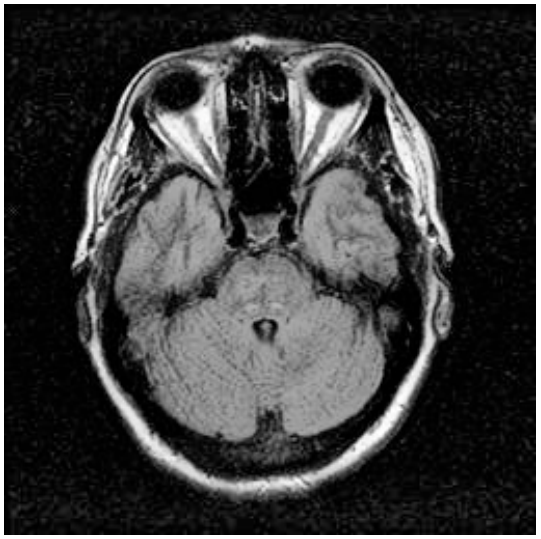
Contrast Enhancement (9): Results-2



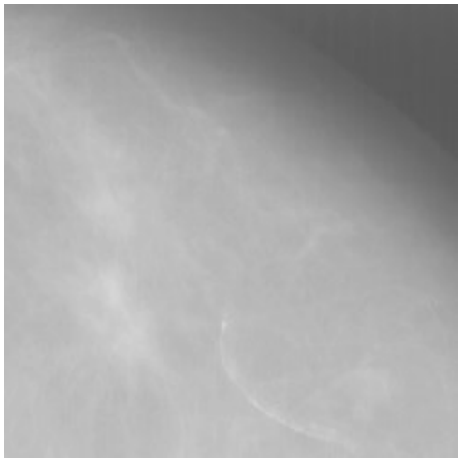
Original image



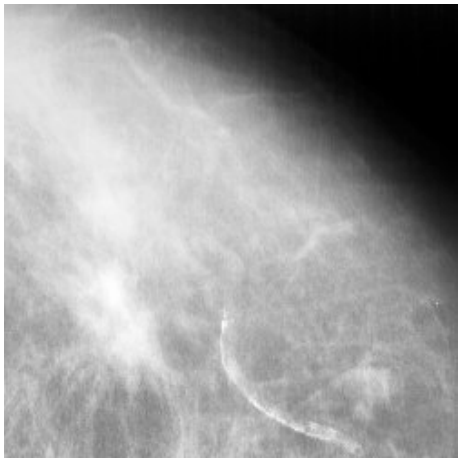
Isotropic propagation



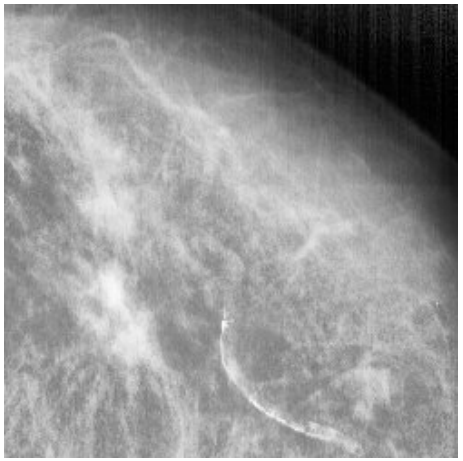
Anisotropic propagation



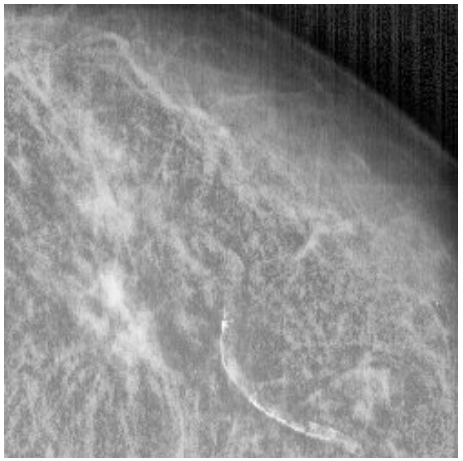
Original image



$C = 0.95$

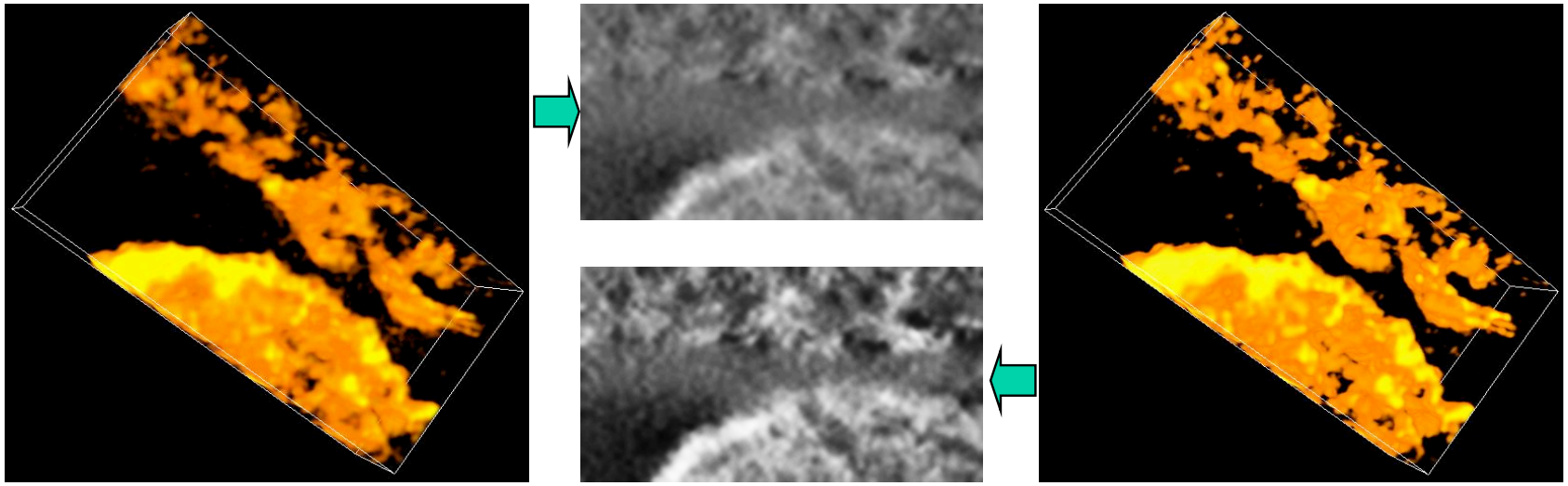


$C = 0.85$

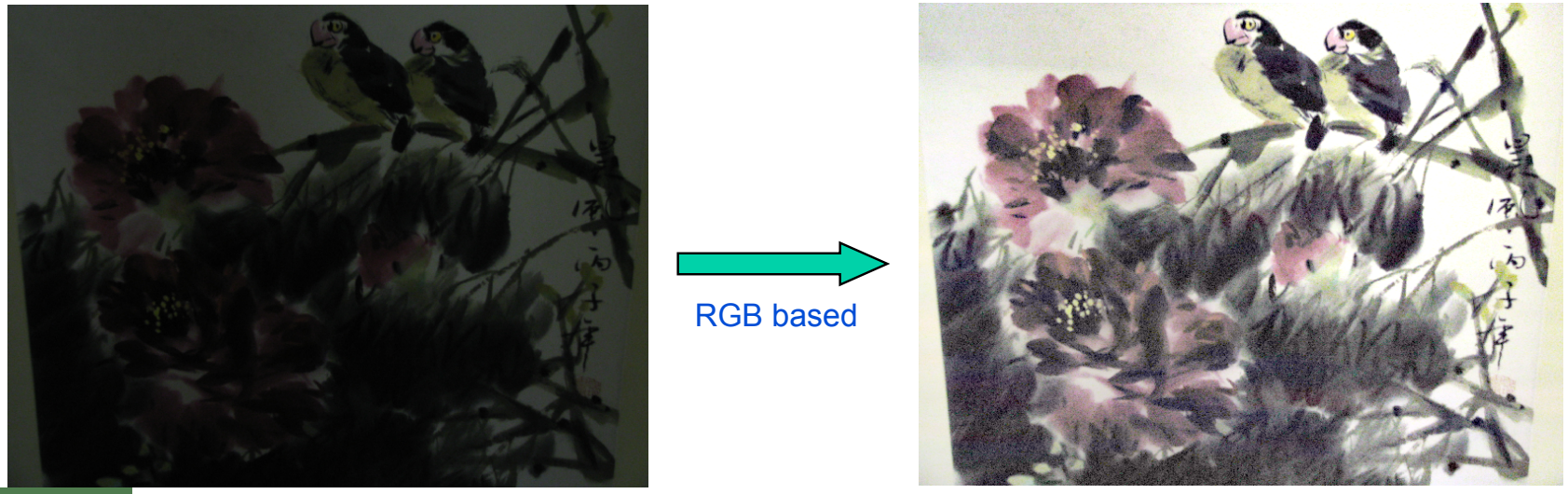


$C = 0.75$

Contrast Enhancement (10): Results-3



3D example: Hair bundle cellular image (left: original right: enhanced)



Color example: Painting (left: original right: enhanced)

Additional Reading

- The references given below include the ones cited in the lecture slides. Please check for pdf's of these additional references on university computers from http://cvcweb.ices.utexas.edu/cvc/papers/papers.php
- C.Bajaj **Tutorial Notes on "Multiscale, Bio-Modeling and Visualization",** Chap 2, 2010.