

Retinex Image Enhancement: Application to Medical Images

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Retinex Image Enhancement – General Information

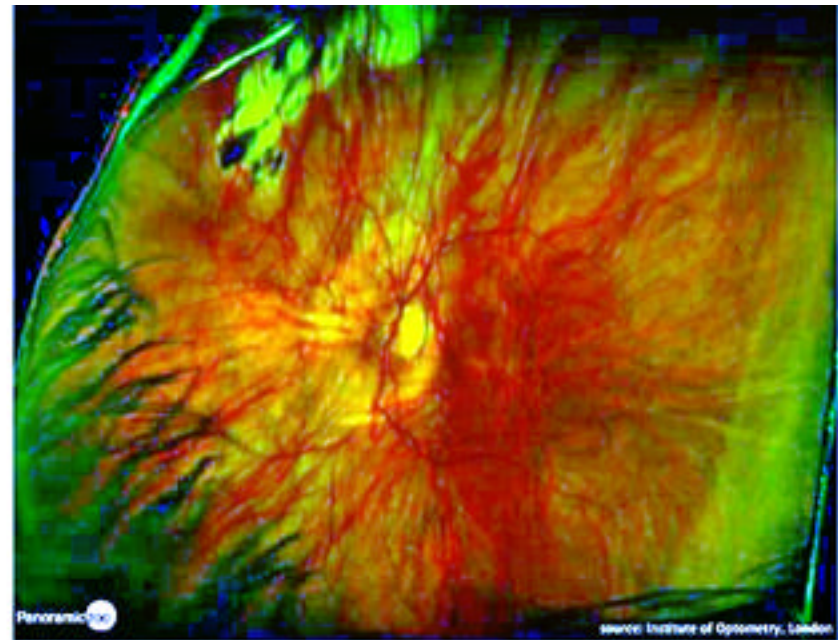
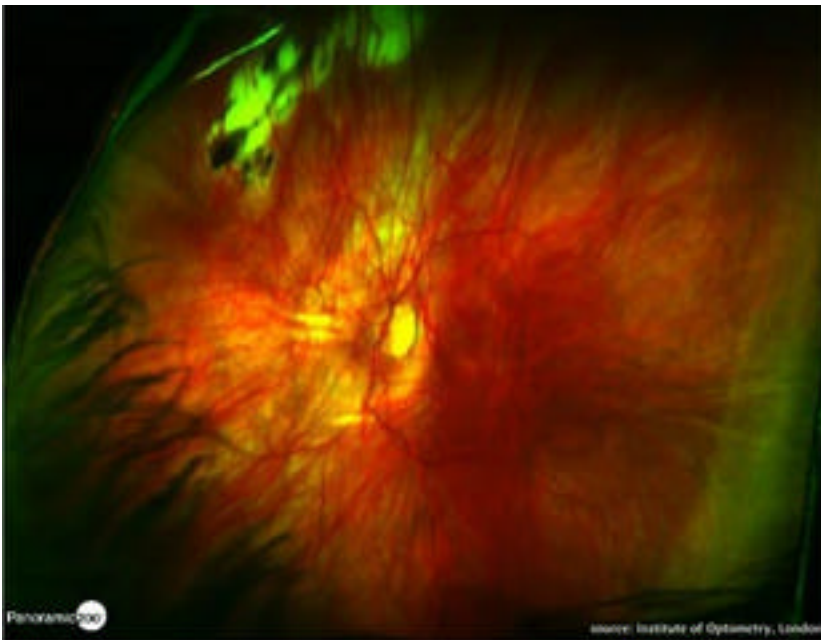
- The Multiscale Retinex with Color Restoration – Retinex for short – is a general-purpose image enhancement algorithm.
- It is patented:
 - US patent #5,991,456, and two others pending
 - Australia patent #713706 (International #US97/07996)
 - Pending in several other Asian and European countries
- TruView Imaging Company, Hampton, Virginia, holds the exclusive licensing rights.

Retinex Image Enhancement – Potential Applications

- Any medical imaging application where automatic contrast enhancement and sharpening is needed. Potential areas of impact may include:
 - Digital X-ray
 - Digital mammography
 - CT scans
 - MRI
- Telemedicine applications where bandwidth between doctor and patient poses a potential bottleneck. The Retinex compacts the high input dynamic range, potentially reducing the high bandwidth requirement.

Retinex Image Enhancement – Background

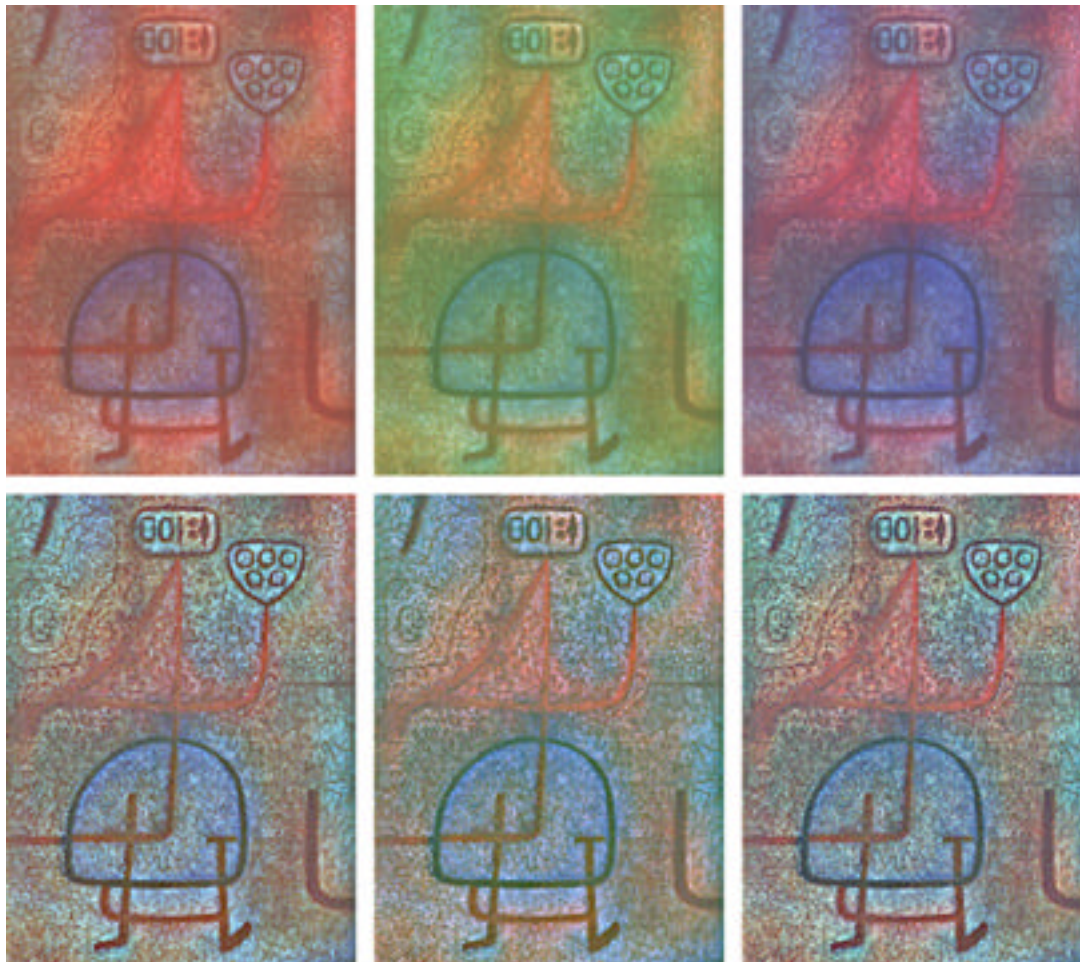
- The Retinex provides automatic
 - Dynamic range compression: i.e., the ability to represent large input dynamic range into relatively small output dynamic range.



– Sharpening: i.e., compensation for the blurring introduced into the image by the image formation process. This allows fine details to be seen more easily than before.



– Color constancy: i.e., the ability to remove the effects of the illumination from the subject. This allows consistency of output as illumination changes.



Retinex Image Enhancement – Technical

- The Retinex takes an input digital image I and produces an output image R on a pixel by pixel basis in the following manner:

$$\begin{aligned} R(x, y) &= \log (I(x, y)) - \log (I(x, y) * M(x, y)) \\ &= \log \left(\frac{I(x, y)}{I(x, y) * M(x, y)} \right) \end{aligned}$$

where $M(x, y) = \exp \left(-\frac{(x^2 + y^2)}{\sigma^2} \right)$, σ

is a constant which controls the extent of M , and $*$ represents spatial convolution

- This non-linear transform has some interesting properties:
 - It mimics the spatial aspect of color perception by setting the output value as a function of the center (numerator in the equation) and its surround (denominator in the equation).
 - The ratioing operation in conjunction with the log function inherently performs dynamic range compression.
 - The output is independent of the illumination source.

- The input image can be written as the product of two components:

$$\rho(x,y)$$

the reflectance component which represents the light reflected from all the objects in the scene being imaged, and $i(x,y)$ which represents the illumination component: That is,

$$I(x,y) = i(x,y)\rho(x,y).$$

- Since the illumination component varies very slowly across the scene, $I(x,y) \approx I_o\rho(x,y)$, and

$$\begin{aligned} R(x,y) &= \log \left(\frac{I_o\rho(x,y)}{I_o\rho(x,y) * M(x,y)} \right) \\ &= \log \left(\frac{\rho(x,y)}{\rho(x,y) * M(x,y)} \right) \end{aligned}$$

- By performing the same operation on each color channel, the output color image can be written as

$$R_i(x, y) = \log \left(\frac{I_i(x, y)}{I_i(x, y) * M(x, y)} \right) \quad i \in \{R, G, B\}$$

- $R_i(x, y)$ is dependent upon the size of the surround mask $M(x, y)$ which is parameterized by σ .

- Different values of σ enhance different features of the input image: large values provide good spectral information, and small values provide good spatial information.

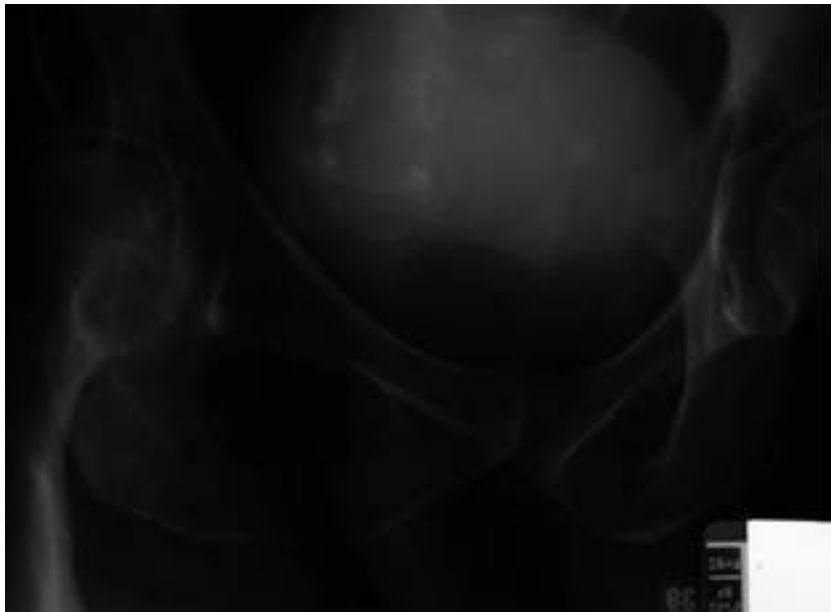
- So,

$$R_i(x, y) = \frac{1}{K} \sum_{k=0}^K \log \left(\frac{I_i(x, y)}{I_i(x, y) * M_k(x, y)} \right), i \in \{R, G, B\}$$

Retinex – Examples

- Many digital medical images suffer from lack of contrast and sharpness.
- The Retinex automatically provides both enhanced contrast and sharpness.
- The following slides show the application of the Retinex image enhancement algorithm to
 - X-rays
 - Mammograms
 - CT scans
 - Other medical images

Retinex - Examples - X-rays

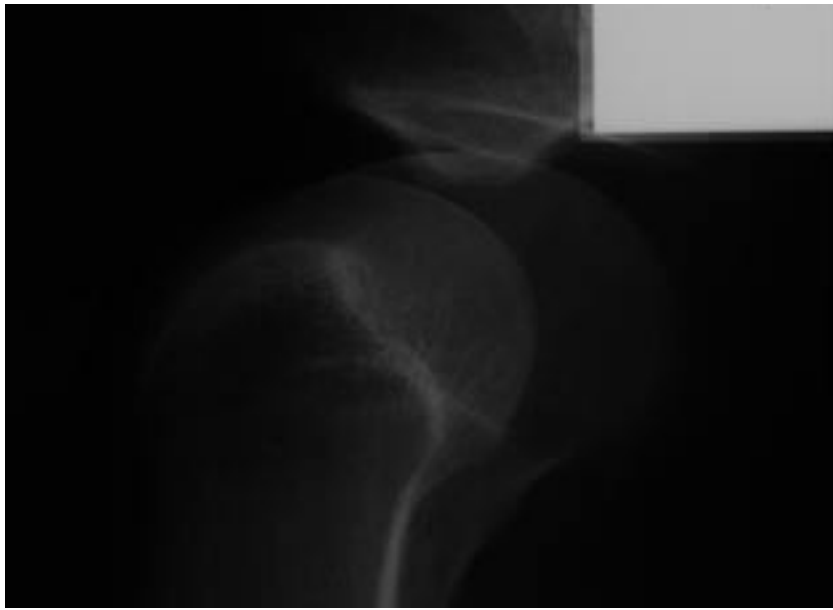


Original



Retinex

Retinex - Examples - X-rays

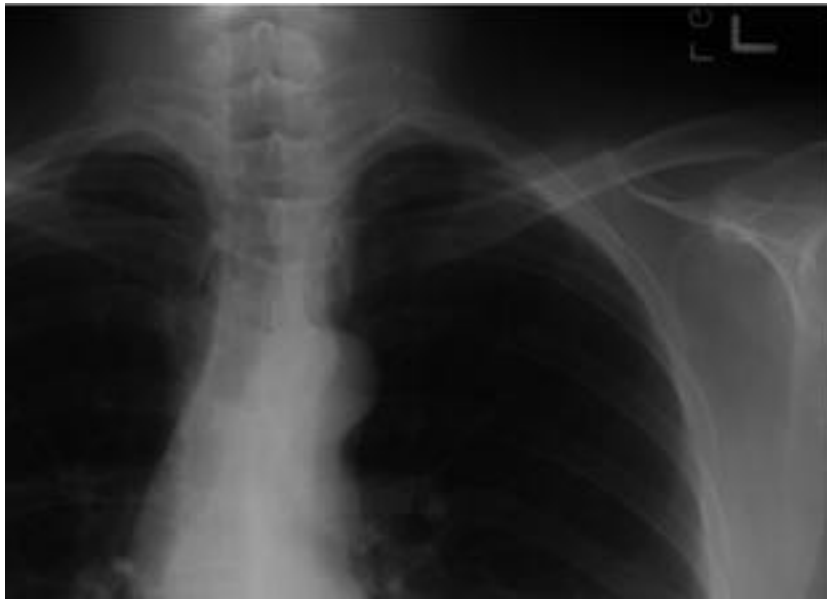


Original



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Retinex - Examples - X-rays

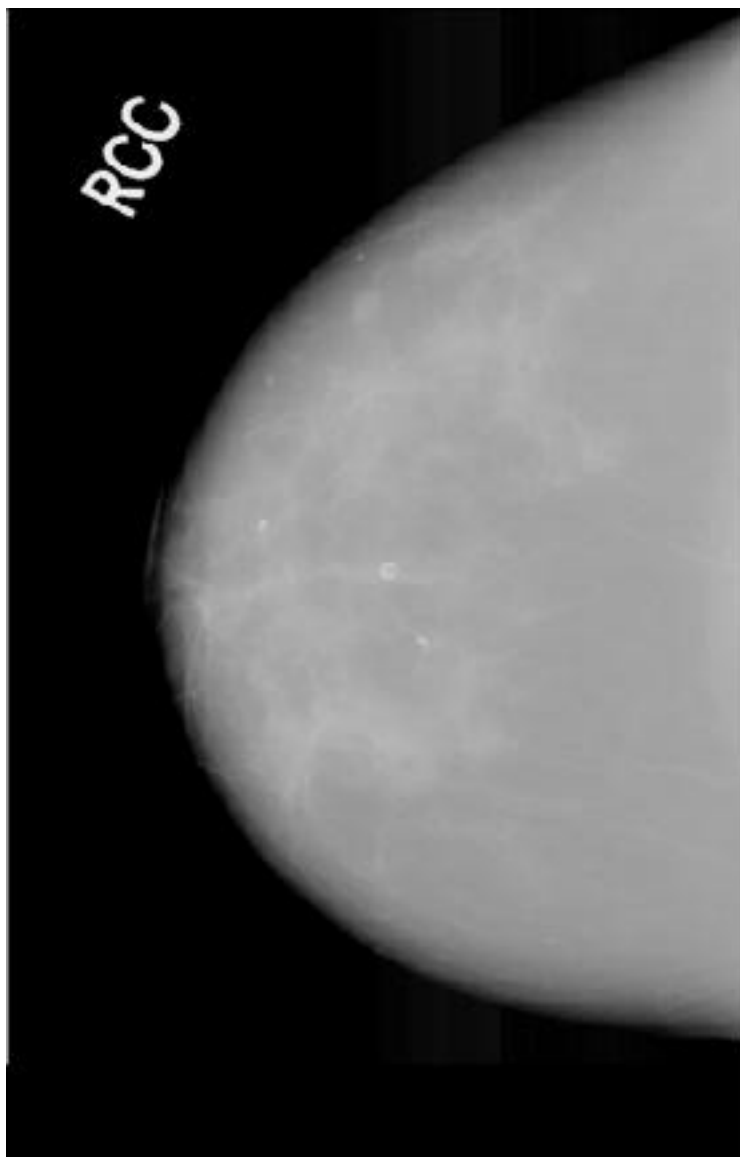


Original

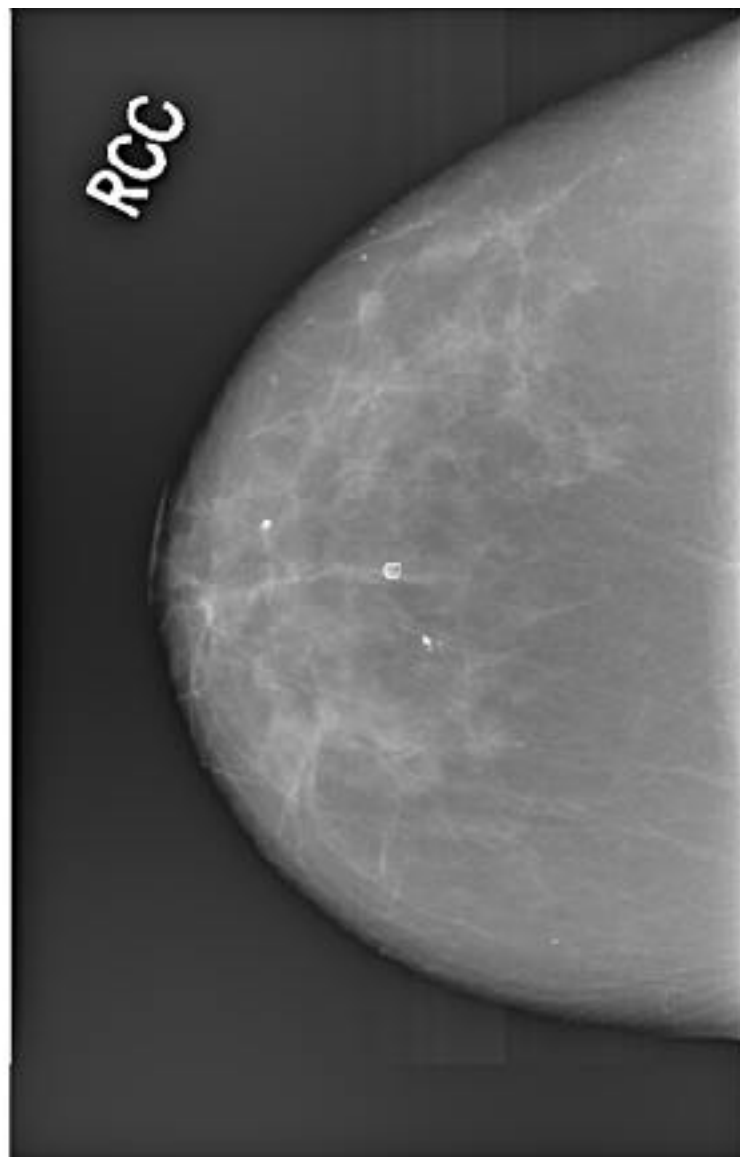


Retinex

Retinex - Examples - Mammograms

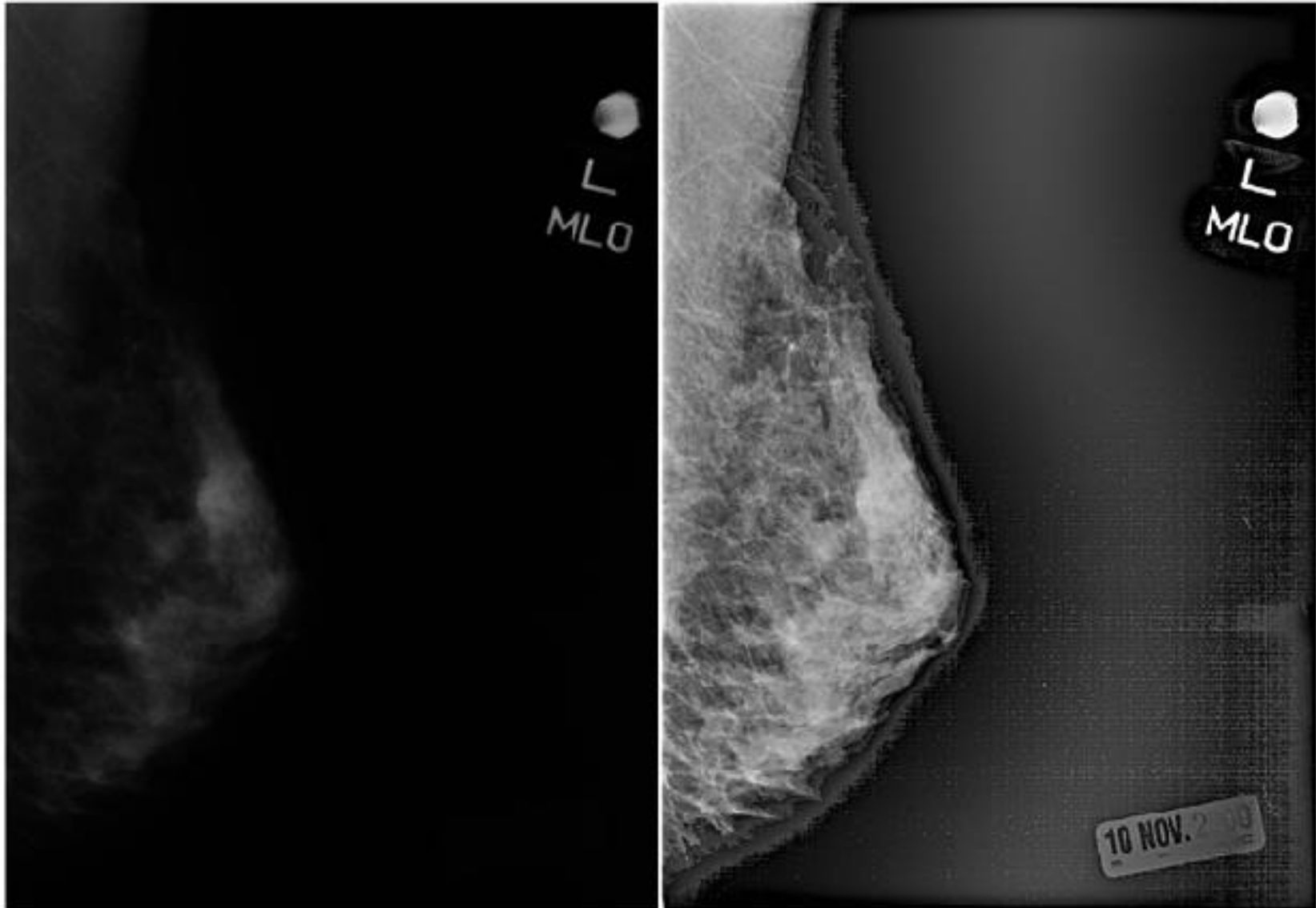


Original



Retinex

Retinex - Examples - Mammograms



Original

Retinex

Retinex - Examples - CT Scans

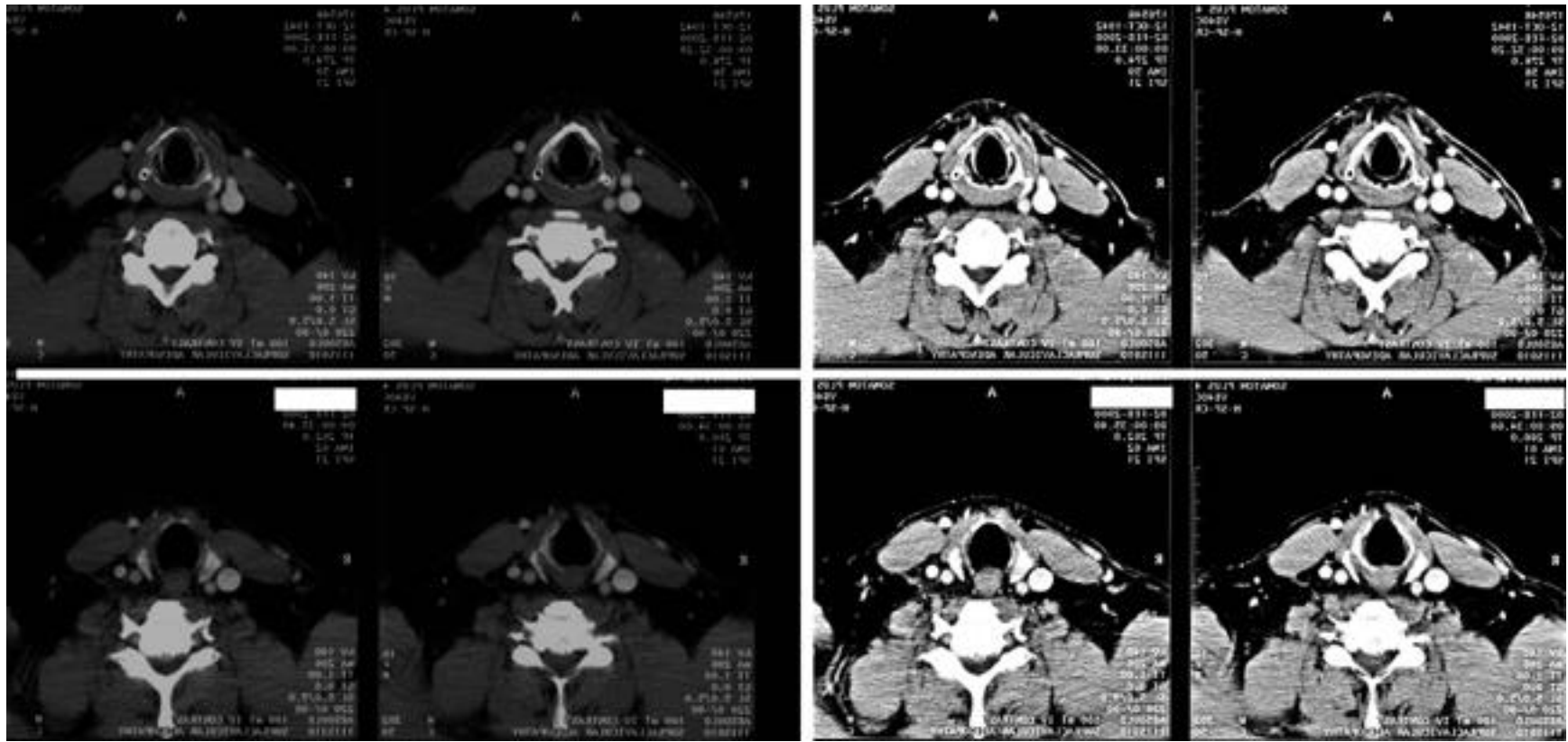


Original



Retinex

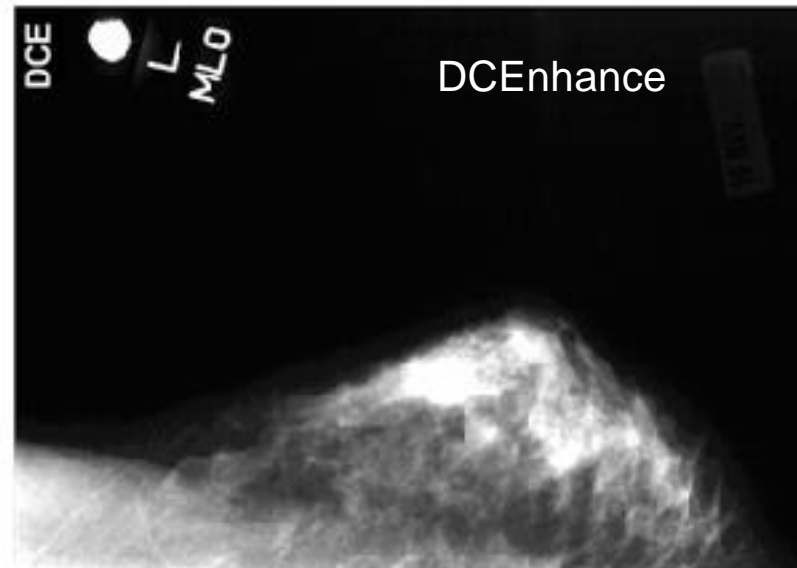
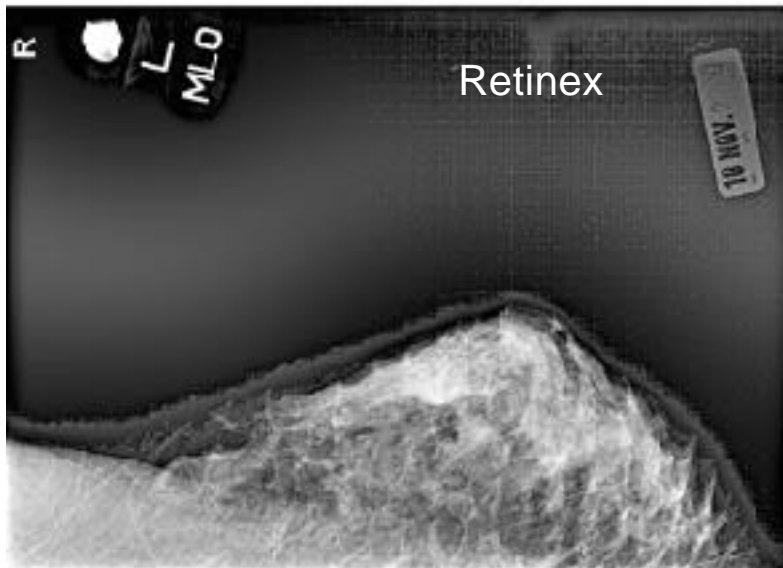
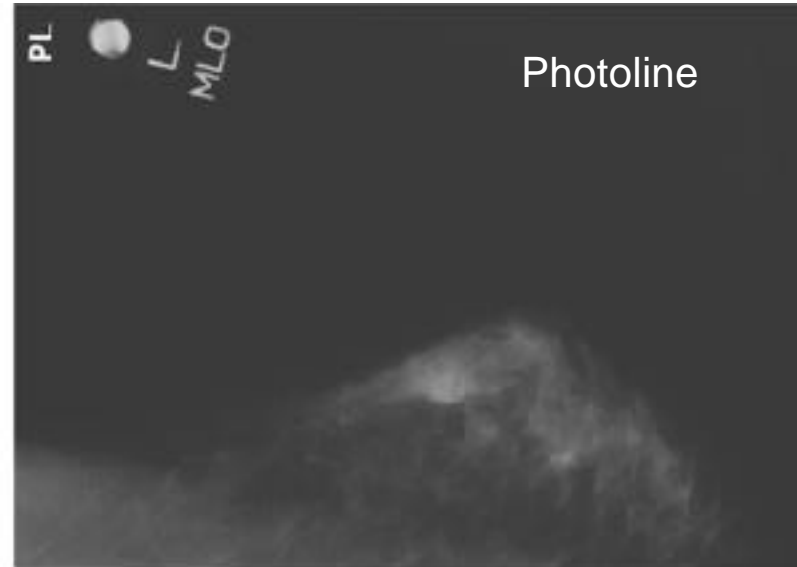
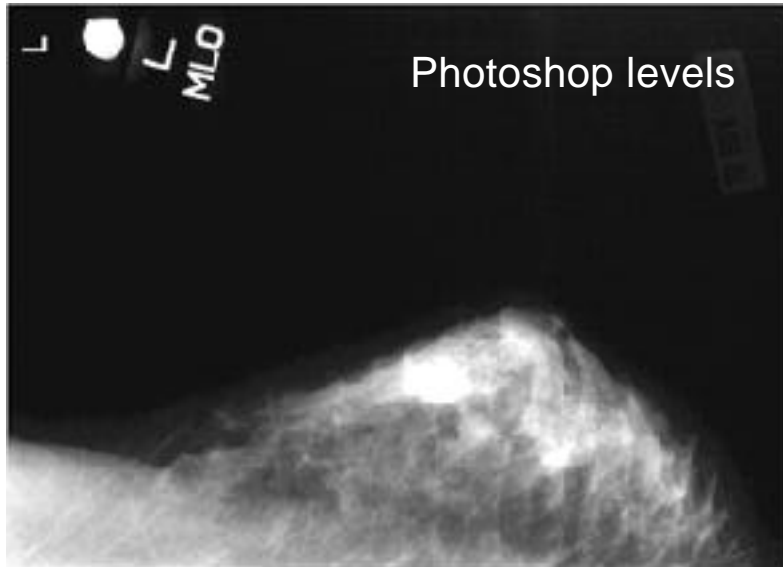
Retinex - Examples - CT Scans



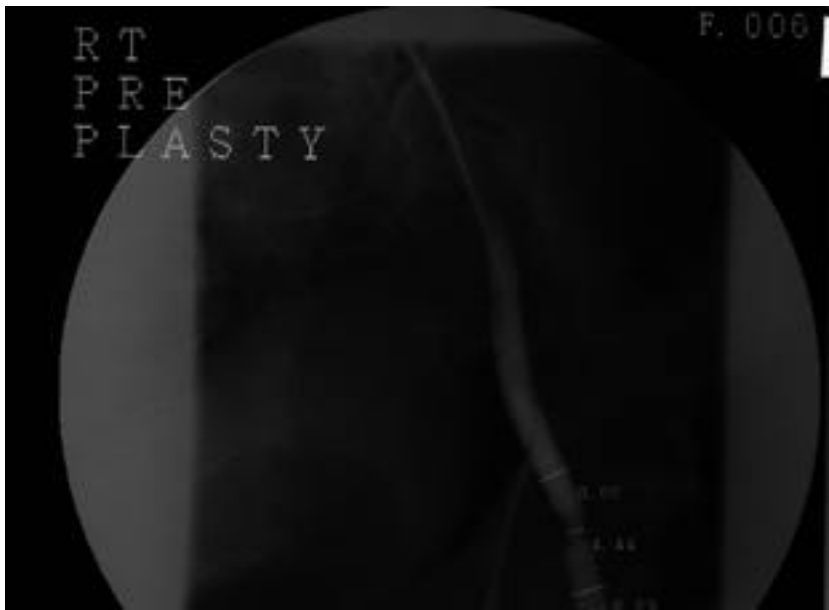
Original

Retinex

Retinex - Examples - Comparisons



Retinex - Examples - Other



Original

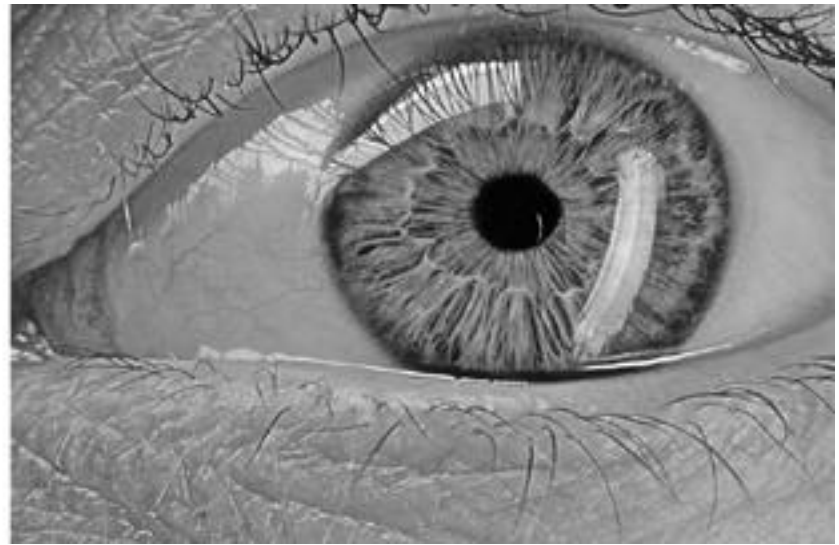


Retinex

Retinex - Examples - Other



Original



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Retinex - Examples - Other



Original



Retinex

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