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:

$$R(x,y) = \log(I(x,y)) - \log(I(x,y) * M(x,y))$$

$$= \log\left(\frac{I(x,y)}{I(x,y) * M(x,y)}\right)$$

where $M(x,y) = \exp\left((x^2 + y^2)/\sigma^2\right)$, $\sigma$ 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

\[
R(x, y) = \log \left( \frac{I_o\rho(x, y)}{I_o\rho(x, y) \ast M(x, y)} \right) \\
= \log \left( \frac{\rho(x, y)}{\rho(x, y) \ast M(x, y)} \right)
\]
• By performing the same operation on each color channel, the output color image can be written as

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

• \( R_i(x, y) \) is dependent upon the size of the surround mask \( M(x, y) \) which is parameterized by \( \sigma \).

• Different values of \( \sigma \) enhance different features of the input image: large values provide good spectral information, and small values provide good spectral information.

• So,

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

Retinex
Retinex – Examples – X-rays

Original

Retinex
Retinex – Examples – Mammograms
Retinex – Examples – Mammograms
Retinex – Examples – CT Scans

Original

Retinex
Retinex – Examples – CT Scans

Original

Retinex
Retinex – Examples – Comparisons

Photoshop levels  Photoline

Retinex  DCEnhance
Retinex – Examples – Other

Original

Retinex
Retinex – Examples – Other

Original

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Retinex – Examples – Other

Original

Retinex
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