Adaptive-Neighborhood Histogram Equalization of Color Images

V. Buzuloiu, M. Ciuc, R. M. Rangayyan, C. Vertan.
Abstract

- **Histogram equalization of color images**
  - Enhances the image quality

- **Proposed method**
  - Uses **global** and **local** histogram equalization
Adaptive Neighborhood HE

- **Overview of ANHE**

  - **Global Histogram Equalization**
    - Compute the intensity image $I$
    - 1-D intensity histogram

  - **Local Histogram Equalization**
    - Adaptive region growing
    - Modification of the region intensity Histogram

**Fig. 1. An overview of adaptive neighborhood HE.**
Main Ideas

1. The hue must be preserved

2. To consider the neighboring values is useful in HE
   - The neighborhood must be chosen adaptively
   - Local details are emphasized

3. Global histogram equalization
   - Implements well-balanced image
1. Global histogram equalization

- **Global HE**
  - Intensity image: \( I = (R+G+B)/3 \)
  - 1-D intensity histogram
    \[
    h_I(i) = \frac{1}{MN} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} \delta(I(m,n) - i), \quad i = 0, \ldots, L-1
    \]
  - Global HE function
    \[
    F_I(i) = \left( (L-1) \times \sum_{j=0}^{i} h_I(j) \right), \quad i = 0, \ldots, L-1
    \]
2. Local histogram equalization

- Adaptive region growing

  - Region

  $$d_{kl} = |I(k,l) - I(i,j)| \leq T,$$

  $$I(i, j): Seed,$$

  $$I(k,l): Eight \ connected \ connected \ neighbors \ of \ the \ seed$$

  $$T \in [20,40]$$
Modification of the region intensity histogram

- Intensity histogram of region: $h_{reg}$
- Stretch the intensity histogram of the region: $[i_{min}, i_{max}]$

\[
i_{min} = F_1(\mu_{reg}) - \kappa\sigma_{reg} \quad \text{and} \quad i_{max} = F_1(\mu_{reg}) + \kappa\sigma_{reg}\]

$\mu_{reg}$: The mean of the population of pixels within the region

$\sigma_{reg}$: The standard deviation of the population of pixels within the region
New intensity value of the seed pixel

\[ I'(i, j) = [i_{\text{min}} + (i_{\text{max}} - i_{\text{min}}) \times F_{\text{reg}}(I(i, j))] \]

\( F_{\text{reg}} : The \ CDF \ of \ the \ region \ computed \ from \ the \ h_{\text{reg}} \)

New values of the color component

\[ R' = (I' / I) \times R \]
\[ G' = (I' / I) \times G \]
\[ B' = (I' / I) \times B \]
Fig. 2. Results of histogram equalization: (a) The original “03” image. (b) The image after histogram equalization on each channel independently. (c) The image after 3-D histogram equalization. (d) The image after histogram decimation. (e) The image after histogram explosion. (f) The image after ANHE.
Fig. 3. Histograms of intensities of the images in image “03”: (a) original; (b) after histogram equalization on each channel independently; (c) after 3-D histogram equalization; (d) after histogram decimation; (e) after histogram explosion; (f) after ANHE.
Conclusion

- **Histogram equalization of color images by using an adaptive neighborhood**
  
  - The new intensity of a pixel is computed
    
    - With respect to the **global histogram equalization function**
    
    - With respect to the **values of pixels in a neighborhood** that is adaptively determined for each pixel individually