SYDE 575: Introduction to Image Processing

Adaptive Color Enhancement for Color vision Deficiencies

Color vision deficiencies

- Statistics show that color vision deficiencies affect 8.7% of the male population and 0.4% of the female population.
- Dichromacy is a form of color vision deficiency that severely affects an individual's ability to differentiate hues.
- Dichromacy has no known cure.

Types of dichromatic color vision deficiencies

- **Protanopia:** L cones are absent or defective
- **Deuteranopia:** M cones are absent or defective
- **Tritanopia:** S cones are absent or defective (rare)

Types of dichromatic color vision deficiencies

- Protanopia and deuteranopia are often referred to as red-green color blindness.
- Tritanopia is often referred to as blue-yellow color blindness.

So what may dichromats see?

- From top-left (Clockwise): a) Trichromat, b) Protanope, c) Tritanope , d) Deuteranope

Color Correction Approaches

- There are two main approaches to color correction for helping individuals cope with the medical condition:
  - Fixed color correction
  - Adaptive color correction

Fixed Color Correction Approach

- Perform a fixed color transformation on the image
- Improves color differentiation to make details more visible
- Problem: The aesthetics of the original scene is poorly captured

Adaptive Color Correction Approach

- Solution: Adapt color transformation based on the underlying hue characteristics of the image
- Advantages:
  - Improves color differentiation
  - Preserves aesthetic appeal of the original scene

Color space transformation

- The main difficulty encountered by those suffering from dichromacy is the inability to differentiate between certain hues.
- An effective approach to color enhancement is to alter the hue distribution of an image in such a way that hue discrimination is improved and details within an image become more perceivable by those suffering from dichromacy.

Color space transformation

- To preserve the aesthetic properties of the original image, it is also desired that other characteristics of the image such as illumination and saturation are left unchanged.
- To accomplish this goal, the image is converted from the RGB colorspace to the HSV colorspace.

Hue Remapping

- A simple method of improving hue discrimination within the indistinguishable hue range is to perform a circular hue shift such that hues that can be easily discriminated are used to represent this hue range.
- One of the major disadvantages of this technique is that such a uniform hue shift results in highly unnatural images.

Hue Remapping

- The reason for this is that most of the hues that are actually correctly recognized by those suffering from dichromacy are now misrepresented by the hue shift.
- What if we do a hue compression instead?
  - Allows some of the hues that can be correctly recognized to be assigned much of the same hue as before

Hue Remapping

- How about a linear hue compression?
- Improves hue discrimination and maintains some of the distinguishable hues
- Problem: the uniform nature of such transforms result in significant loss of dynamic range in the distinguishable portions as well as unnatural color remappings in many areas given the fixed redistribution.

Non-linear Hue Remapping

- First, rotate hue space such that the two hues that were indistinguishable are at the front of the spectrum while the third hue is at the end.
- For example, in the case of protanopia and deuteranopia, the hue range containing the red and green hue components are rotated to the front of the spectrum while the blue hue range is at the end.

Non-linear Hue Remapping

- A hue remapping can then be performed on the rotated hue space in the form of a power transformation function:

$$f(h) = h^{\phi}$$

Non-linear Hue Remapping

- This hue remapping does two things:
  - The range of hues that are indistinguishable (e.g., red-yellow-green range) are stretched over a wider dynamic range, thereby increasing the hue discrimination for that range of hues.
  - The range of the hue that is distinguishable from the rest of the spectrum (e.g., blue) is compressed, thereby having part of its dynamic range being redistributed to the indistinguishable range.

Non-linear Hue Remapping

- By using a nonlinear remapping function, the range re-distribution is varied over the spectrum and therefore allows for greater flexibility in maintaining the aesthetic feel of the original image.
- After the hue remapping, the hue space is rotated back to its original position.

Adaptive Hue Remapping

- The parameter Φ controls the curvature of the power function.
- A simple approach is to set the control parameter at a fixed value.
- The main problem to this approach is that hue distribution varies greatly from one image to another.

Adaptive Hue Remapping

- For example, an image may consists of only blue hues. Therefore, a fixed value of will compress the blue hue range and stretch the other hue ranges without any perceptual benefit.
- As such, it is necessary to adaptively adjust the value of Φ based on the underlying image content to achieve enhanced perceptual quality.

Adaptive Hue Remapping

- If the hue distribution resides mostly in the indistinguishable range, then the control parameter should be increased to stretch this range to improve hue discrimination and attenuate image details.
- However, if the hue distribution resides mostly outside this range, then the control parameter should be decreased to preserve the original hue distribution.
- This can be determined based on histogram

Examples of Color Correction