

Lecture 2



Digital Image Processing

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<http://www.ee.columbia.edu/dvmm>

Most images are downloaded from the web site of the Gonzalez/Woods textbook



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HIS color space



- Last week:
 - introduction and tri-color representation
 - HSI perceptual color space
 - Readings: G&W 6.1-6.2, Jain 3.7-3.8
- This week:
 - Review and MATLAB demo of HSI conversion
 - More Color Coordinate Systems (Jain 3.7-3.9)
 - Pseudo-Coloring (G&W 6.3)
 - Optimal Quantization (G&W 2.4, Jain 4.5-4.8)

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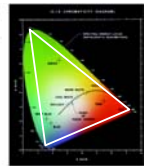
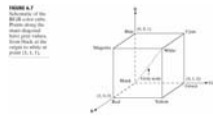
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Chromaticity Diagram



- Convert 3D cube to 2D diagram
- Each RGB is normalized by dividing the color values by SUM(R,G,B)
- Coordinate of each point indicates the proportion of R,G,B in the composition
- Only shows the chromaticity of the color, does not specify the intensity
- Boundary points are spectral colors
- Equal energy point is the white color
- Points on a line are all the mixed colors using two colors on the ends
- Points in a triangle are mixed by colors on three vertices
→ reproducible colors by RGB



$$r = R / (R + G + B)$$

$$g = G / (R + G + B)$$

$$b = B / (R + G + B)$$



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Understanding HSI from RGB



- Turn the RGB cube so that Black-White axis is vertical
- Each plane containing the B-W axis and any color point contains all the colors of the same hue (because of the mixing property)
- Hue can be represented as angle between the plane and a reference plane (e.g. Red)
- Color of the same hue can be made less saturated by mixing more grey colors (shift closer to the b-w axis)
- Intensity can be measured by the intersection position between the horizontal plane (containing the point) and the B-W axis.

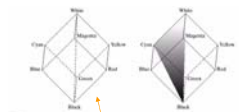


FIGURE A.12 Conceptual relationship between the RGB and HSI color models.

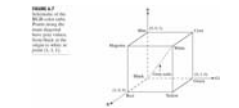


FIGURE A.7 Conversion of the RGB color model to the HSI color model.



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Formation of the HIS color cone

- Cross sections of the RGB cube along the B-W axis
- The cross section shape changes from hexagon to triangle
- Hue is represented by the angle from Red line
- Saturation is represented by the distance to the origin
- The hexagonal shape can be approximated by a circle or a triangle.

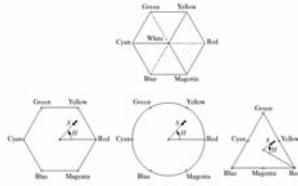


FIGURE 6.13 Hue and saturation in the HIS color model. The dot is an arbitrary color point. The angle from the red axis gives the hue, and the length of the vector is the saturation. The intensity of all colors in any of these planes is given by the position of the plane in the vertical intensity axis.

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Colors on the HIS color cone

- Saturated colors on the outer points
- The maximum saturation values occur at the intermediate intensity levels.
- Note the different equations used in the textbook and the reference book
(Mathematical proof on the Web site)

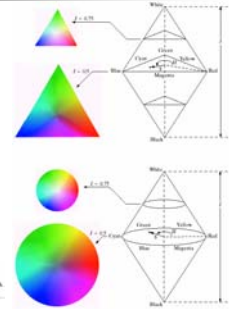


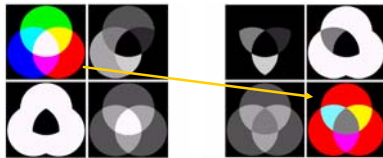
FIGURE 6.14 The HIS color model based on a triangle and its circular color planes. The triangles and circles are perpendicular to the vertical intensity axis.

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Manipulations in the HSI space



- Hue of Green and Blue regions are set to 0.
- Saturation of Cyan is reduced by half.
- Intensity of the White color pixels are reduced by half.

- HSI allows independent manipulations of colors
- See Matlab demo

FIGURE 6.17 Color and Modified HIS component images. (a) Original RGB image. (b) Fig. 6.17 for the original HIS image.

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Other Issues of Color Spaces

- Uniform Color Spaces and MacAdam Ellipses (see hand notes)
- Subtractive color space for printing
- Pseudo Coloring

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Additive vs. Subtractive Colors

- Additive colors for display
- subtractive colors for printing
- See hand notes for equations



FIGURE 6.6 Primary and secondary colors of light and pigments. (Courtesy of the General Electric Co., Lamp/Business Division.)

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Color Gamut

- Triangle includes all the colors producible by CIE RGB primaries
- Irregular region includes all the printable colors

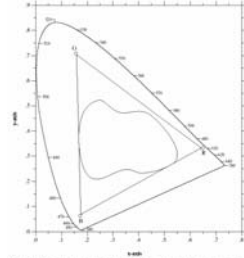


FIGURE 6.6 Typical color gamut of color monitors (triangle) and color printing devices (irregular region).

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Pseudo Coloring

Reading: G&W Sec. 6.3

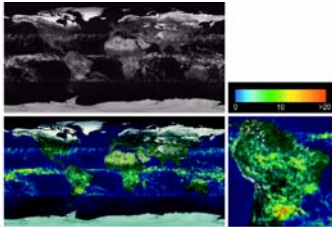


FIGURE 6.27 (a) Grayscale image in which intensity (in the lighter horizontal band above) corresponds to average monthly rainfall. (b) Colors assigned for intensity values. (c) Color-coded image. (d) Zones of the South America region. (Courtesy of NASA.)

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Intensity Slicing

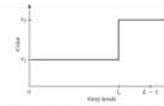


FIGURE 6.19 An alternative representation of the intensity-slicing technique.

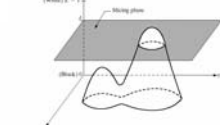


FIGURE 6.18 Geometric interpretation of the intensity-slicing technique.

- How to decide the mapping function?

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Example of intensity slicing

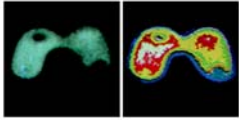
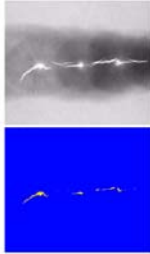


FIGURE 6.21
A grayscale image of a
Pickering Phantom
with a grayscale
intensity slicing
operation applied.
Courtesy of
S. YAN, of
SRI, Inc.,
SRI, Inc.,
SRI, Inc.



- Map gray level 255 to yellow
- The rest to blue
- 255 corresponds to cracks or porosities in the weld
- Mapped to 8 colors
- Note the color variations in the left lobe of the radiation test pattern

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Gray level to color transformation

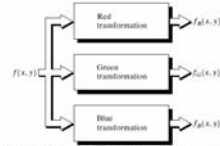


FIGURE 6.23 Functional block diagram for pseudocolor image processing. f_r , f_g , and f_b are fed into the corresponding red, green, and blue inputs of an RGB color monitor.

- How to design the transformation functions?

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Example of Gray-Color Transformation

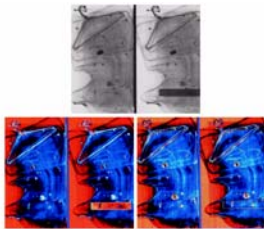


FIGURE 6.24 Pseudocolor enhancement by using the gray-level-to-color transformations in Fig. 6.25. (Original image courtesy of Dr. Mike Harwitz, Westinghouse.)

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How does it work?

- 3 channels use sinusoidal functions with the same frequency but different phases.
- Adjust the frequency to obtain the best quality/information.

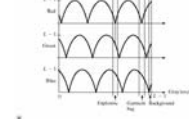
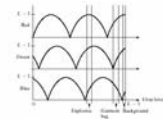
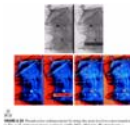


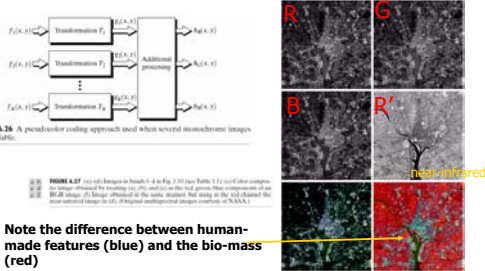
FIGURE 6.25 Three sinusoidal functions used to obtain the images in Fig. 6.24.

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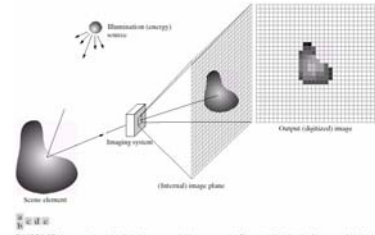
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Pseudocoloring using multiple monochrome images



Sampling & Quantization

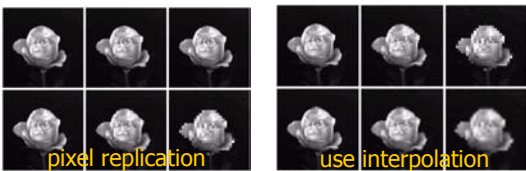


Reading:
G&W Sec. 2.4
Jain 4.5-4.8

Sampling – Spatial Resolution

- Concept of the Nyquist Rate
- Non-uniform sampling and Interlaced sampling used in digital video

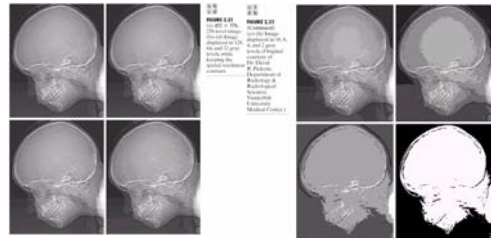
See hand notes



Varying spatial resolution

Quantization – Grey-Scale Resolution

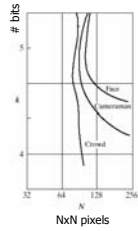
- Varying # of bits per pixel



Tradeoff between gray-level resolution and spatial resolution



Figure 1.22 (a) Image with a low level of detail. (b) Image with a medium level of detail. (c) Image with a relatively large amount of detail. (Image (b) courtesy of the Massachusetts Institute of Technology.)



- Curves show isopreference points
- For low-, moderate-detail images, increasing K or N will help perceptual quality
- For high-detail images, increasing N is more important.

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