

5.1 彩色图像

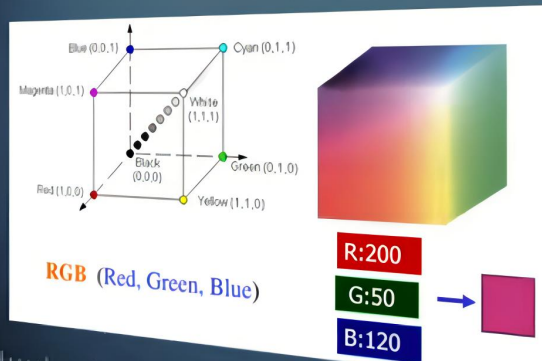
5.1.1 视觉系统基础 (Visual System)

Color Image Processing

- Color Image Processing
 - Color Vision: pp.548
 - human eye; photoreceptor cells
 - primary colors: R, G, B
 - Tricolor image:
 - Tricolor system: e.g. color photography, color TV
 - Tricolor digital image is usually more convenient to treat as an ordinary image having three gray levels at each pixel
 - An overlay of three monochrome digital images

Color Image Processing

- Color Specification



RGB (Red, Green, Blue)

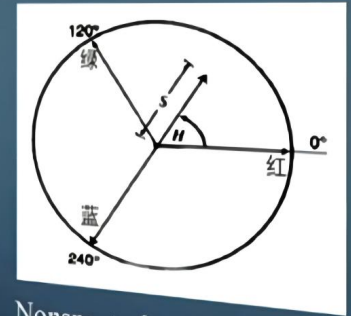
R:200
G:50
B:120

Color Image Processing

- Color Specification
 - RGB Format: 直角坐标系
 - scaled between 0,1; Three of corners correspond to the primary colors. The reminding three corners represent the secondary colors: yellow, cyan and magenta(purple)

Color Image Processing

- HIS Format:
 - Intensity: overall brightness 亮度
 - Hue : expressed as an angle 色度
 - Saturation 饱和度



极坐标系

Nonspectral (purple) colors

Color Image Processing

Color Coordinate Conversion:

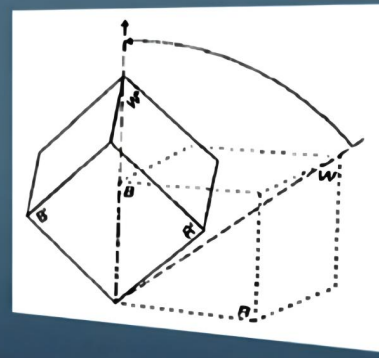
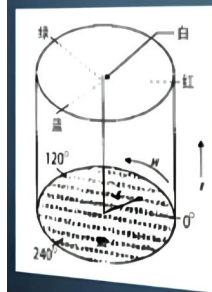
RGB to HIS:

- Establishing an (x,y,z) coordinate system in which the RGB cube is rotated so that its diagonal lies along the z-axis and its R-axis lies in the xz-plane.

$$x = \frac{1}{\sqrt{6}}[2R - B - G] \quad y = \frac{1}{\sqrt{2}}[G - B]$$

$$z = \frac{1}{\sqrt{3}}[R + G + B]$$

$$\rho = \sqrt{x^2 + y^2} \quad \phi = \text{ang}(x, y)$$



HIS 中的 I 在这里用圆柱体垂直于圆心的轴来表示。Cylindrical coordinates) 以黑色像素点和白色像素点的连线为转轴来旋转正方体, 旋转360°, 它就描述了整个极坐标系。

Color Image Processing

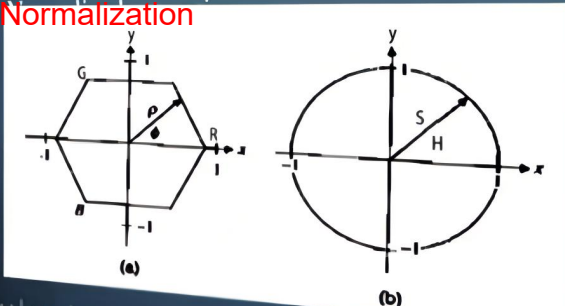
Color Coordinate Conversion:

RGB to HIS:

- Cylindrical coordinates (θ, ρ, z) corresponds to (H, S, I)

Normalization

六边形需要经过 normalization, 才能形成圆。
对饱和度 S 进行。



Color Image Processing

$$S = \frac{\rho}{\rho_{\max}} = 1 - \frac{3 \min(R, G, B)}{R + G + B} = 1 - \frac{\sqrt{3}}{I} \min(R, G, B)$$

$$\theta = \cos^{-1} \left[\frac{\frac{1}{2}[(R - G)] + (R - B)}{(R - G)^2 + (R - B)(G - B)} \right]$$

$$H = \begin{cases} \theta & G \geq B \\ 2\pi - \theta & G < B \end{cases}$$

Color Image Processing

Color Coordinate Conversion:

HIS to RGB:

- Converting formulas are different depending on the H:

Color Image Processing

$$0^\circ \leq H < 120^\circ$$

$$R = \frac{1}{\sqrt{3}} \left[1 + \frac{S \cos(H)}{\cos(60^\circ - H)} \right] \quad B = \frac{1}{\sqrt{3}}(1 - S) \quad G = \sqrt{3}I - R - B$$

$$120^\circ \leq H < 240^\circ$$

$$G = \frac{1}{\sqrt{3}} \left[1 + \frac{S \cos(H - 120^\circ)}{\cos(180^\circ - H)} \right] \quad R = \frac{1}{\sqrt{3}}(1 - S) \quad B = \sqrt{3}I - R - G$$

$$240^\circ \leq H < 360^\circ$$

$$B = \frac{1}{\sqrt{3}} \left[1 + \frac{S \cos(H - 240^\circ)}{\cos(300^\circ - H)} \right] \quad G = \frac{1}{\sqrt{3}}(1 - S) \quad R = \sqrt{3}I - G - B$$

5.1.2 彩色图像表示方法 (Color Image Formats)

Color Image Enhancement

Color Balance:

- Color images often do not appear properly when display:
"out of balance"
- The remedy for color imbalance is to use linear gray-scale transformations on each of the R,G and B images. Usually only two of them need to be transformed to match the third:
 1. Select relatively uniform light and dark gray areas
 2. Compute the mean gray level of both areas in all three component images
 3. Use a linear contrast stretch on two of them matching the third.

Color Image Enhancement

Contrast and Color Enhancement:

- Saturation Enhancement
 - We can make the colors more bold by multiplying the saturation at each pixel by a constant greater than 1
 - A constant less than 1 reduces the apparent intensity of the colors
- Hue Alteration:
 - Since hue is an angle, a constant can be added to it
 - If the added or subtracted angle is only a few degree, the process will "cool" or "warm" the color images
 - Larger angles will drastically alter its appearance

Color Image Enhancement

Color Image restoration:

1. Use a linear point operation to ensure that the RGB image fits properly within gray scale and color balance
2. Convert to HIS format
3. Use a median filter on the hue and saturation images to reduce the random color noise
4. Use a linear filter to restore the intensity, sharpens edges and enhance detail
5. Use linear point operations on all three components to ensure proper utilization of the gray scale
6. Convert to RGB format

Color Image Enhancement

Pseudocolor

- This term refers to generating a color image from a monochrome image by mapping each of the gray levels to a point in color space.
- Lookup table



Gray level image



Pseudocolor color image

Color Image Analysis

Color Image Analysis

Color Compensation

- Color spread: since color image digitizers have broad and overlapping sensitivity spectra, one seldom obtains complete isolated objects in three component images.

- Color spread can be modeled as a linear transformation. Matrix C specifies how the colors are spread among the three channels. C_{ij} is the proportion of brightness of point j that appears in channel i . X be the 3 by 1 vector of actual brightness at a particular pixel:

$$Y = CX + b \quad b: \text{black-level offset}$$

And

$$x = C^{-1} [y - b]$$

Color Image Analysis

Color Compensation

- Let E specify the relative exposure time set in each channel,
 $y = ECx + b$

And

$$x = C^{-1} E^{-1} [y - b]$$

- $C^{-1} E^{-1}$: modified color compensation matrix.

- A simple way to modify the color compensation matrix to account for variation in exposure time.

Color Image Segmentation

Color Image Segmentation:

- Segmenting a color image by thresholding becomes a process of partitioning color space
- Different objects often fall into separate clusters of points in a 3D histogram defined in RGB or HIS space.
- The intensity is seriously effected by illumination and viewing angle
- It's more productive to segment the image in the hue-saturation plane than that in 3D color space.



彩色图像的分割相对来说容易一些，因为我们可以利用它的彩色信息在不同的 channel 里的表达方式的差异。另外，我们经常也可以将RGB格式的彩色图像转换成HIS格式的，在HIS的 channel 里进行分割也时候也会得到意想不到的效果。

Color Image Measure

Color Image Measure:

- Measurements of size and shape are the same as a monochrome image
- New aspect of color:
 - Average hue
 - Average saturation
 - Average intensity

完成了彩色图像的分割之后，彩色图像中还有一个重要的概念，就是如何去表达彩色图像的特征。这个被成为 Measure。

5.2 三维图像

5.2.1 三维图像的由来与表示 (Origin and Representation of 3D Image)

Background

二维图像实际上是三维图像投影的结果。

- Spatially three dimensional image:
 - Images have gray levels are a function of three spatial variables
 - For example, Ocean water temperature as a function of x,y and depth etc.
- Two-dimensional (2D) images have been derived from the three-dimensional (3D) world by camera systems that employ a perspective projection to reduce the dimensionality from three to two.

Computer Tomography

- X-ray
 - Human body is opaque to light in visible spectrum, except in very thin sections, however it does transmit X rays.
 - Some structures of body (e.g. bones) absorb X ray more heavily than the other structures.
 - Conventional radiography produces an image in which the 3D structures are projected on to a plane and superimposed shadows on the film.
 - Radiologists frequently use multiple views (X rays taken at different angles) to resolve ambiguities

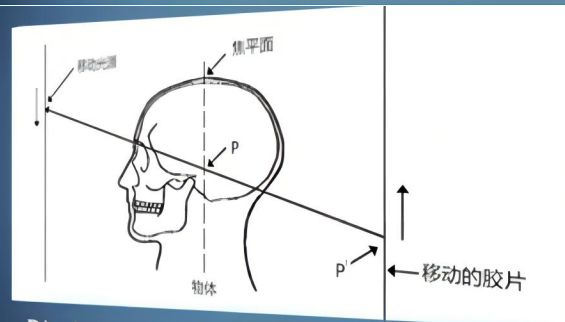
3D Imaging

• Optical Sectioning 切片

- Serial sectioning: slice the specimen to produce a series of thin sections that may be studied individually to develop an understanding of the 3D structure of the specimen.
- Two major disadvantage:
 1. Loss of registration that occurs when the sections become separated after slicing
 2. Unavoidable geometric distortion including stretching, curling, folding, and tearing of the thin section.

Computer Tomography 计算机立体成像学 CT

- Tomography
 - Tomography employs a source and film that move during the exposure.
 - The technique is useful where image detail is required in deeply imbedded structures

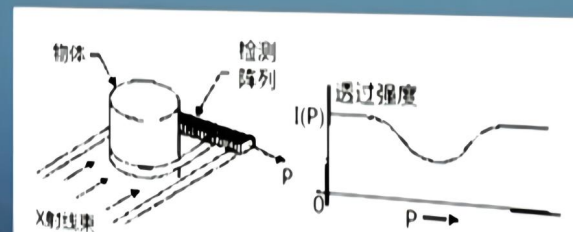


- Disadvantage:
 - Require higher X-ray dosage than in normal radiography.

Computer Tomography

- Axial Tomography
 - Computerized axial tomography (CAT or CT)
 - A technique that incorporates digital image processing to obtain 3D images.
 - The devices involved, commonly called CAT (CT) scanners, reconstruct the 3D image of the X-ray-absorbing object.
 - A planar X-ray beam penetrates the object, and the transmitted beam intensity is measured by a linear array of X-ray detectors.

- Axial Tomography
 - A series of intensity functions is recorded as the apparatus rotates about the object through a small angle between each exposure which cover 180 degree of rotation in steps of 2 to 6 degrees.

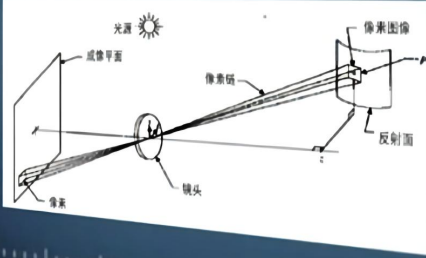


经常听到多少排的CT是指在一次旋转过程中，我们的传感器可以采集多少个层面，比如又64排、180排等等，这样成像的速度更快，或者成像更精细。

5.2.2 三维图像的处理 (3D Image Processing)

Stereometry 立体成像素

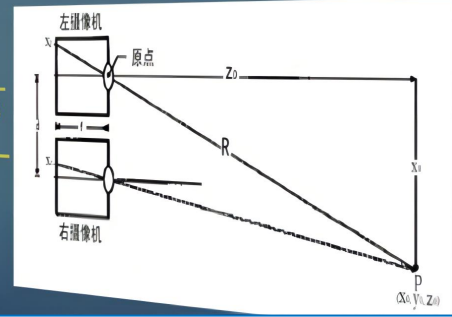
- Stereometry:
 - a technique by which one can deduce the three-dimensional shape of an object from a stereoscopic image pair.
- Model the geometry of image formation.



Stereometry

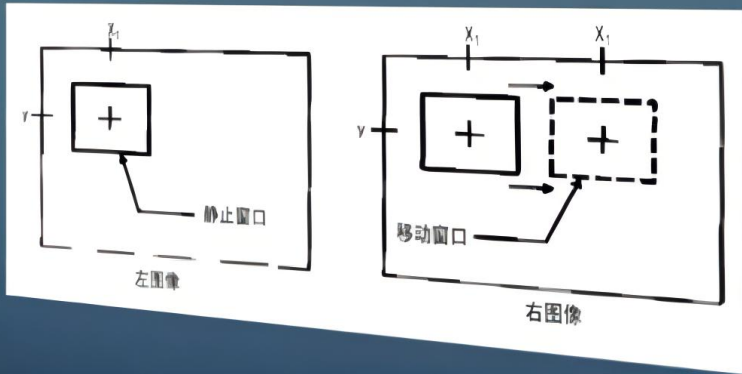
- Stereoscopic Imaging:
 - Dual camera configuration suitable for stereoscopic imaging
 - Range Equations:

$$R = \frac{d\sqrt{f^2 + x_l^2 + y_l^2}}{x_r - x_l}$$



Stereometry

- Stereo Matching:
 - A technique that can be used to locate the right image pixel position that corresponds to a particular left image pixel
 - To obtain accurate range information, one have to do this with sub-pixel accuracy



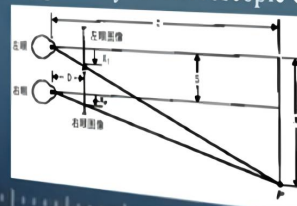
Stereometry

- Stereo Matching procedure:
 1. Fit imaginary windows around a pixel having the same coordinates in another image
 2. Compute a measure of the agreement (cross-correlation, a sum of squared difference etc.) between the images inside the two windows

- Stereo Matching procedure:
 3. Repeat the process as the window in the right image moves toward the right. At some point, the moving window will contain essentially the same details as the fixed window in the left image. When this happens, the image content in the two windows is approximately the same, and the measure of image agreement is maximized

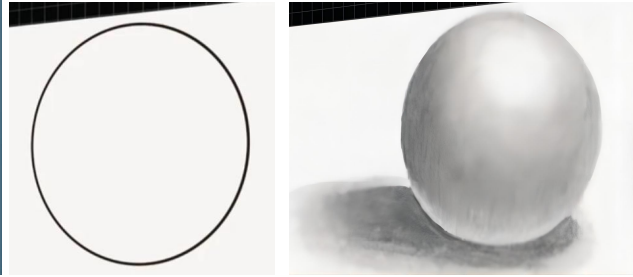
Stereometry

- Stereoscopic Image Display:
 - A 3D scene can be re-created for a viewer through stereoscopic display techniques. This is the basis of the "3D" movie and stereoscopic photography
 - Display Geometry:
 - viewing geometry for stereoscopic display



Shaded Surface Display

- Shaded Surface Display :
 - A technique used to generate an image of a 3D object that exists only as a mathematical description.
 - This technique requires modeling of three things:
 1. The spatial description of the surface
 2. The light-reflecting phenomenon at the surface
 3. The geometry of the light sources and the imaging projection.



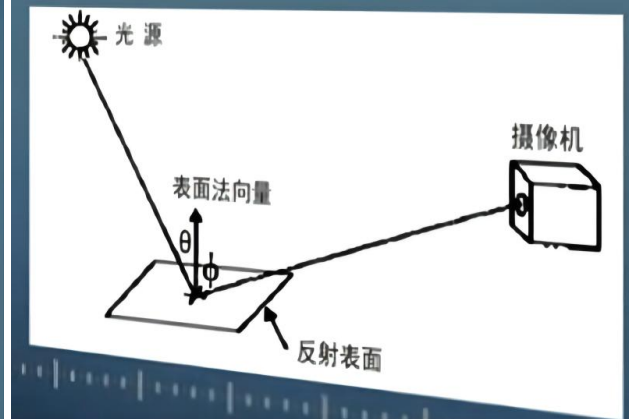
Shaded Surface Display

- Surface Reflection Phenomenon
 - Two important types of reflection:
 - Diffuse scattering: characteristic of matte or chalky
 - specular reflection: characteristic of shiny or metallic surface
 - Reflected intensity

$$I = A \frac{\cos(\theta)}{r^2} \frac{1}{\cos(\phi)} \{B \cos(\phi) + (1-B)[\cos(\theta + \phi)]^n\}$$

B and n: reflectance parameters
A: constant of proportionality

r: light distance from surface
 $0 \leq B \leq 1$



Shaded Surface Display

- Image Geometry:
 - The model for computing the image of the object's surface
 - If the normal vector to the surface of the polygon is known, the gray level of the pixel can be computed

