计算机辅助手术讲座（12）
Image Guided Surgery (12)

Color Image and 3D Image

彩色图像和三维图像处理

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2009.11

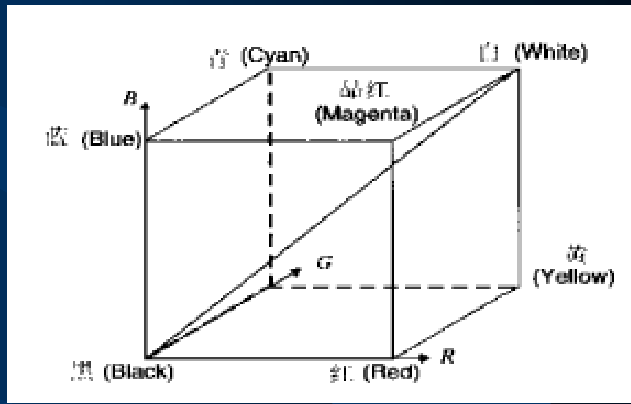
Color Image Processing

Color Image Processing

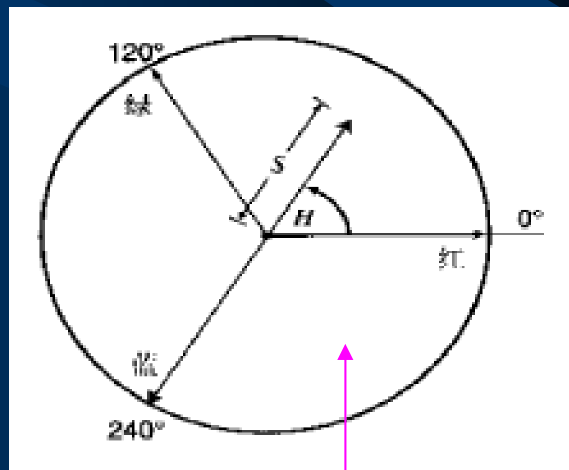
- Color Image Processing
  - Color Vision: pp.548
    - human eye; photoreceptor cells;
    - primary colors: R, G, B
  - Tricolor image:
    - Tricolor system: e.g. color photography, color TV
    - Tricolor digital image is usually more convenient to treat as an ordinary image having three gray levels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

Color Image Processing

- Color Specification
  - RGB Format:
    - color cube: 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).



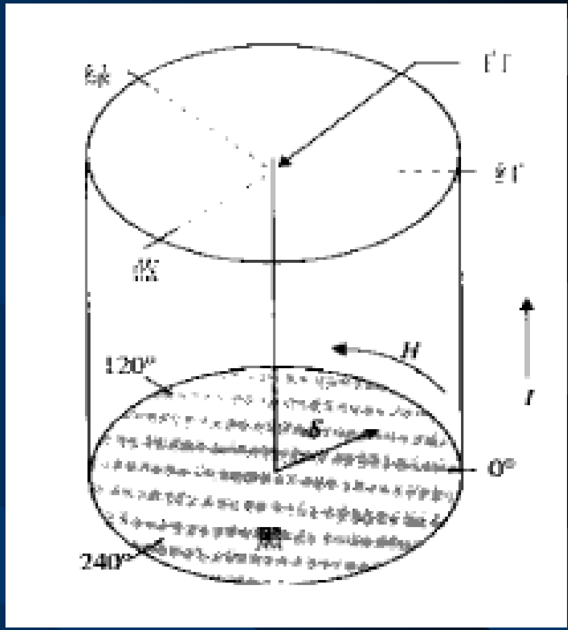
  - HIS Format:
    - Intensity (I): overall brightness
    - Hue (H,色度): expressed as an angle
    - Saturation(S，饱和度):



Nonspectral (purple) colors

Color Image Processing

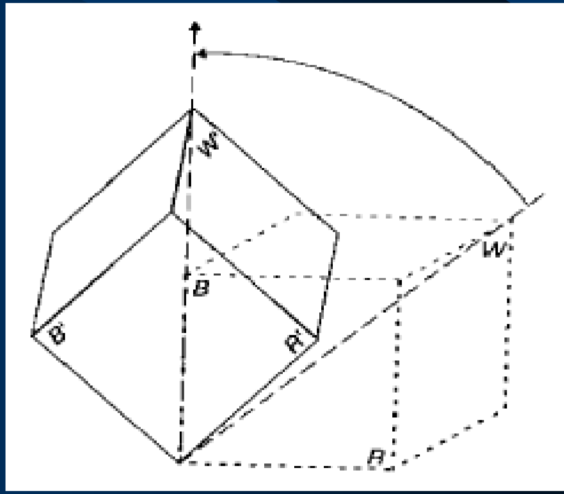
- Color Coordinate Conversion:
  - RGB to HIS:
    - Establishing an (x,y,z) coordinate system in which the RGB cube is rotated so that its diagonal lies along the z-axis and its R-axis lies in the xz-plane.



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

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

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



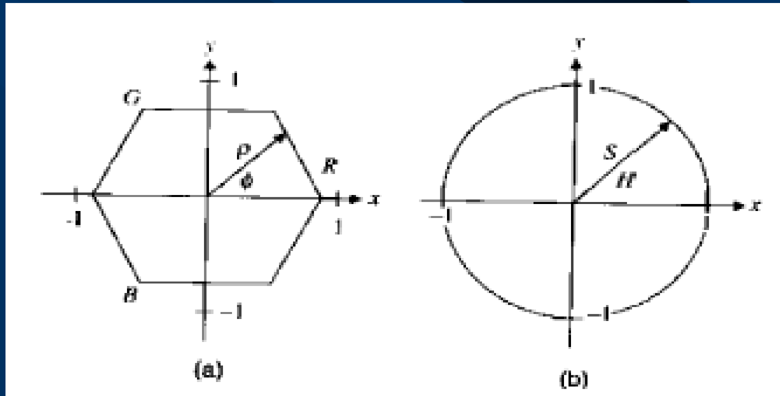
Color Image Processing

- Color Coordinate Conversion:
  - RGB to HIS:
    - Cylindrical coordinates (θ,ρ,z) corresponds to (H,S,I)
    - Normalized saturation:

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

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

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



Color Image Processing

- Color Coordinate Conversion:
  - HIS to RGB :
    - Converting formulas are different depending on the H:

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

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

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

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

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

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

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

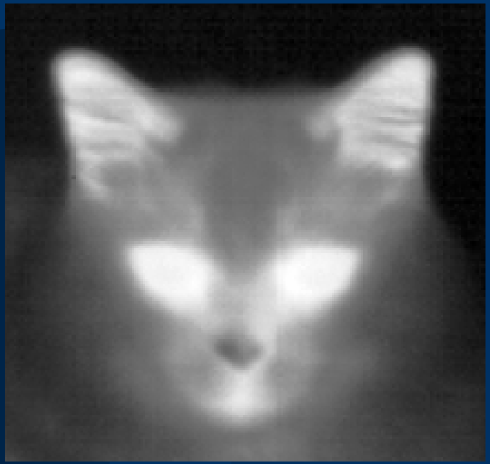
- Contrast and Color Enhancement:
  - Saturation Enhancement
    - We can make the colors more bold by multiplying the saturation at each pixel by a constant greater than 1
    - A constant less than 1 reduces the apparent intensity of the colors.
  - Hue Alteration:
    - Since hue is an angle, a constant 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 blance
  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 digitizer s 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** specify 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:

$$\mathbf{Y = Cx + b}$$ b: *black-level offset*

And

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

Color Image Analysis

- Color Image Analysis
  - Color Compensation
    - Let E specify the relative exposure time set in each channel,

$$\mathbf{y = ECx + b}$$

And

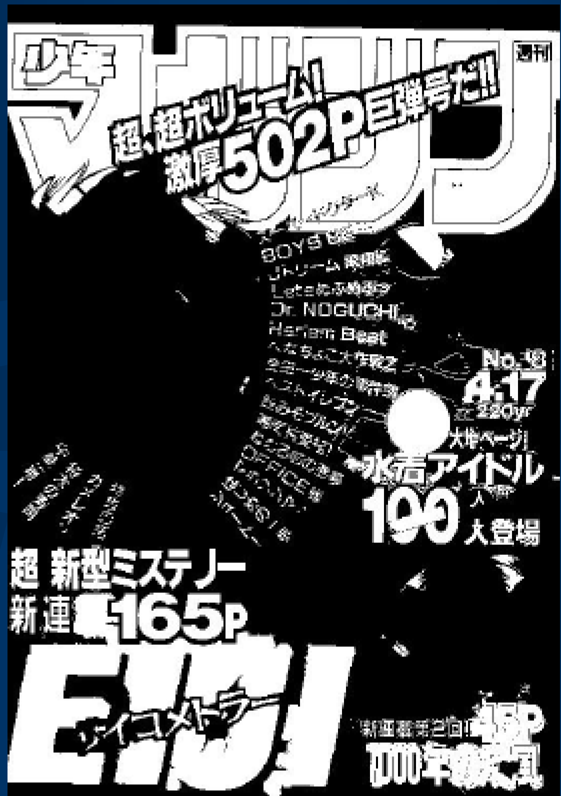
$$\mathbf{x = C^{-1}E^{-1}[y-b]}$$

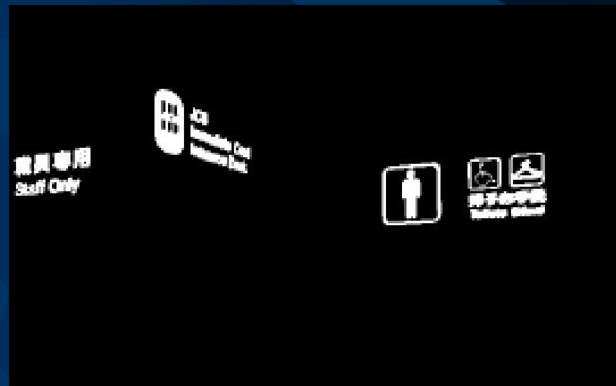
- $C^{-1}E^{-1}$: modified color compensation matrix.
- A simple way to modify the color compensation matrix to account for variation in exposure time.

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.

Color Image Segmentation





Color Image Segmentation

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

Three-Dimensional Image Processing

Background

- 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.

3D Imaging

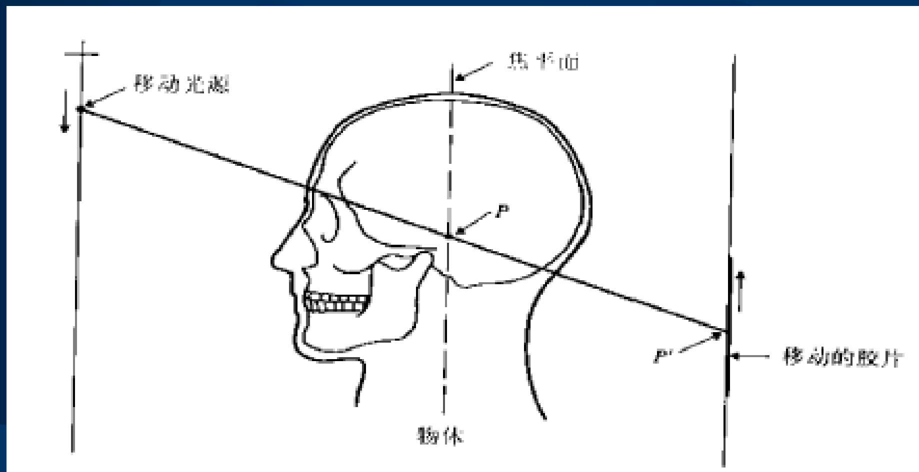
- Optical Sectioning
  - Serial sectioning: slice the specimen to produce a series of thin sections that may be studied individually to develop an understanding of the 3D structure of the specimen.
  - Two major disadvantage:
    1. Loss of registration that occurs when the sections become separated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

Computer Tomography

- X-ray
  - Human body is opaque to light in visible spectrum, except in very thin sections, however it does transmit X rays.
  - Some structure of body (e.g. bones) absorb X ray more heavily 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

Computer Tomography

- 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.

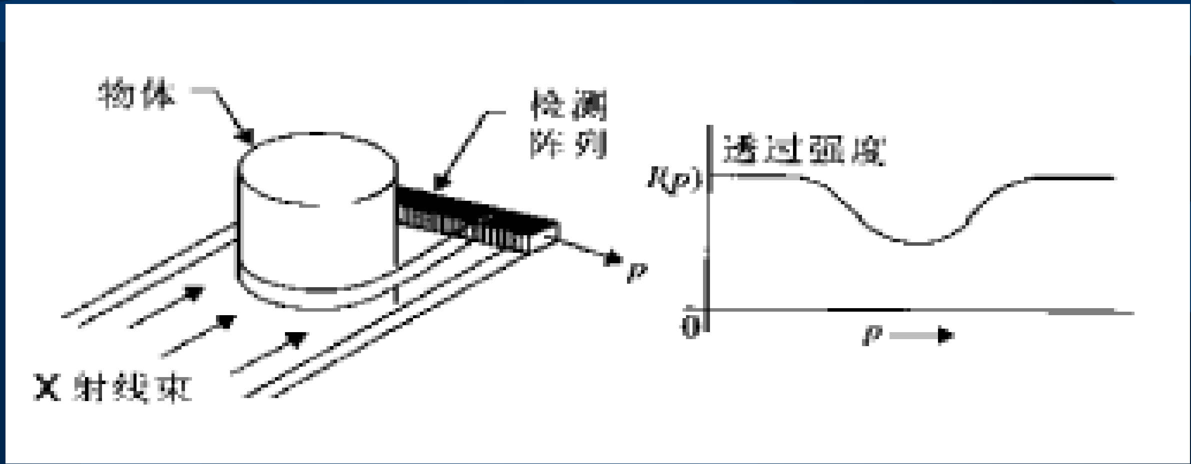


Computer Tomography

- **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.

Computer Tomography

- **Axial Tomography**
  - A serials 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.

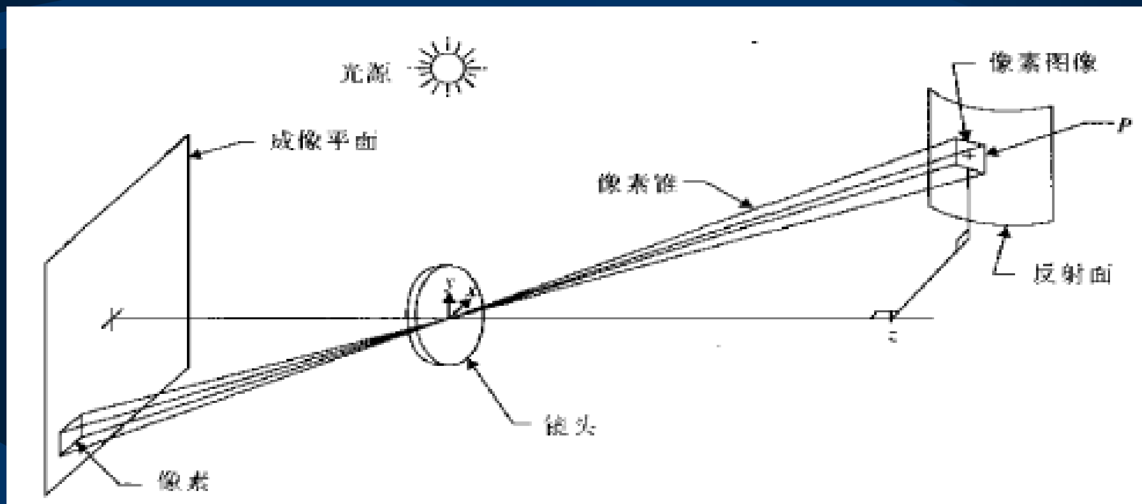


Computer Tomography

- **Axial Tomography**
  - The resulting set of one-dimensional intensity functions is used to compute a 2D cross sectional image of the object at the level of the beam
  - The process is repeated as the beam-detector unit is moved down the object in small steps. Producing a set of cross-sectional images that can be "stacked" to form a 3D image of the object

Stereometry

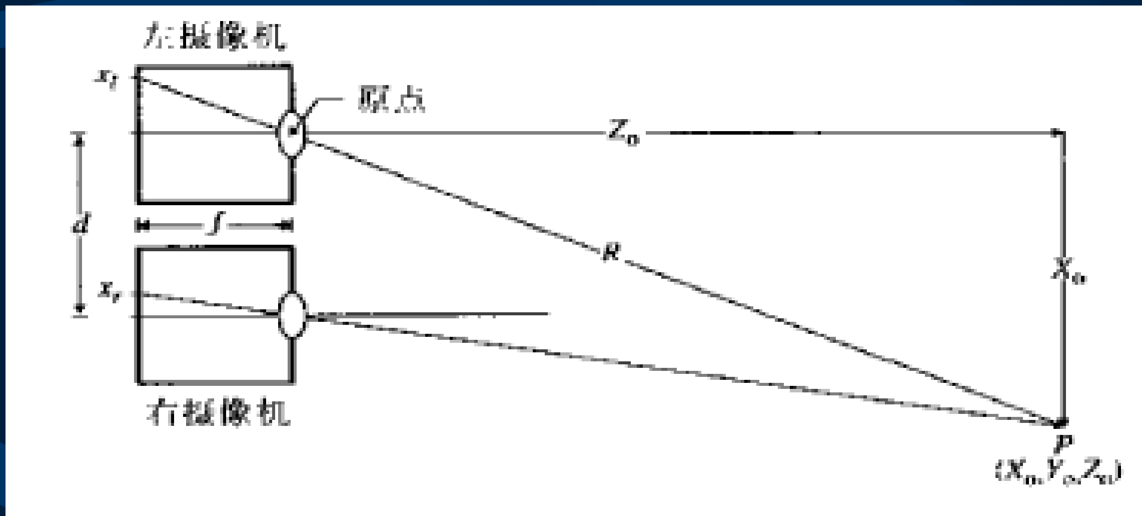
- **Stereometry**:
  – a technique by which one can deduce the three-dimensional shape of an object from a stereoscopic image pair.
- Model the geometry of image formation.



Stereometry

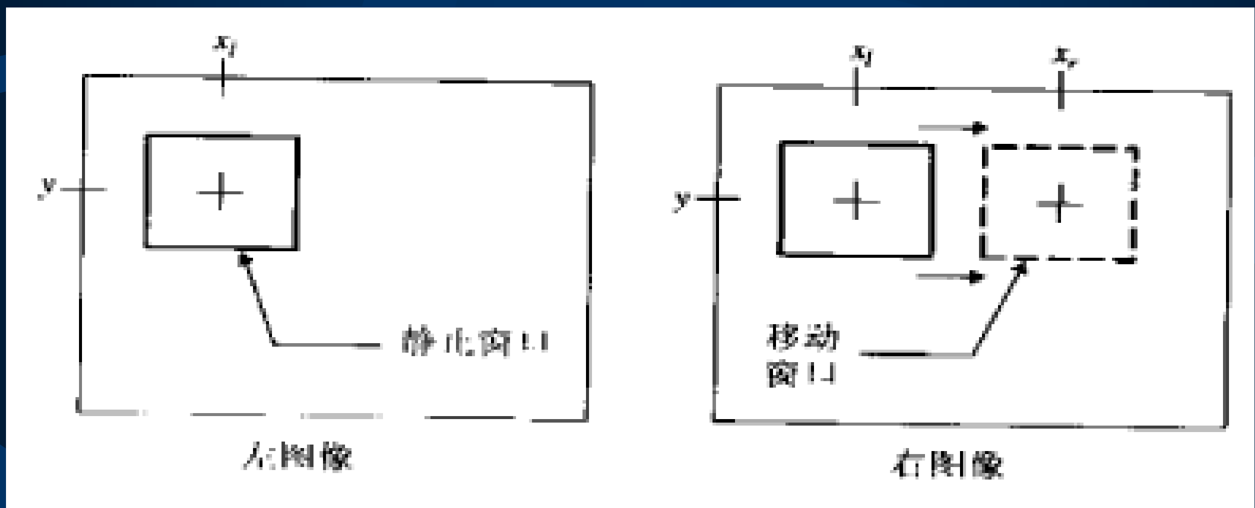
- **Stereoscopic Imaging:**
  - Dual camera configuration suitable for stereoscopic imaging
  - Range Equations:

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



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

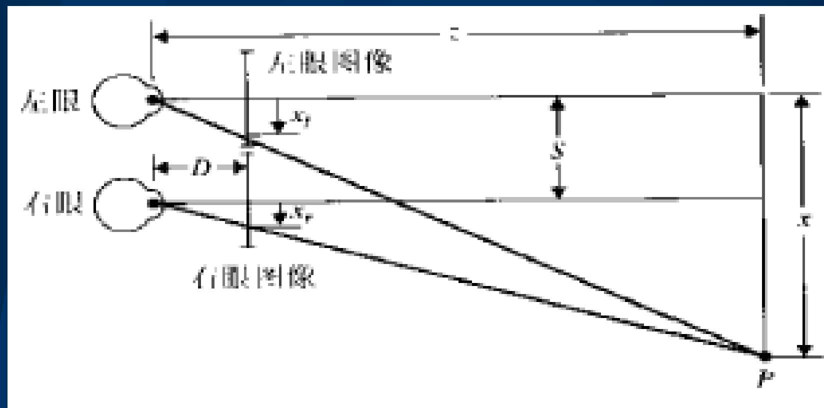


Stereometry

- **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.
  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 Description
  - The 3D surface of the object is ordinarily described by a polyhedral (多面的) approximation
  - Selected points on the object's surface form the vertices of the polygonal faces of the polyhedron
  - Triangles are commonly used for the faces
  - The description of the surface may be in the form of a list of its vertex points

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

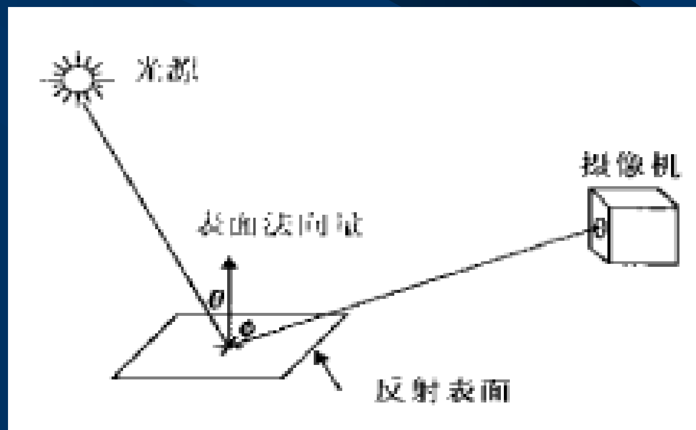
$$I = A\frac{\cos(\theta)}{r^2}\frac{1}{\cos(\phi)}\{B\cos(\phi) + (1-B)[\cos(\theta+\phi)]^n\}$$

B and *n*: reflectance parameters

A: constant of proportionality

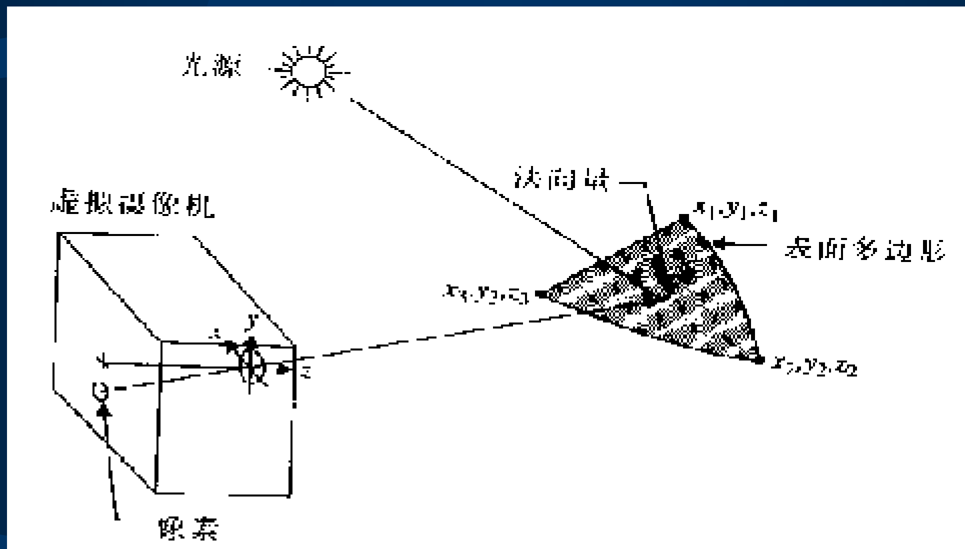
r: light distance from surface

$0 \le B \le 1$



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.



Discussion