Image Processing in Remote Sensing

Color Processing

Present by:

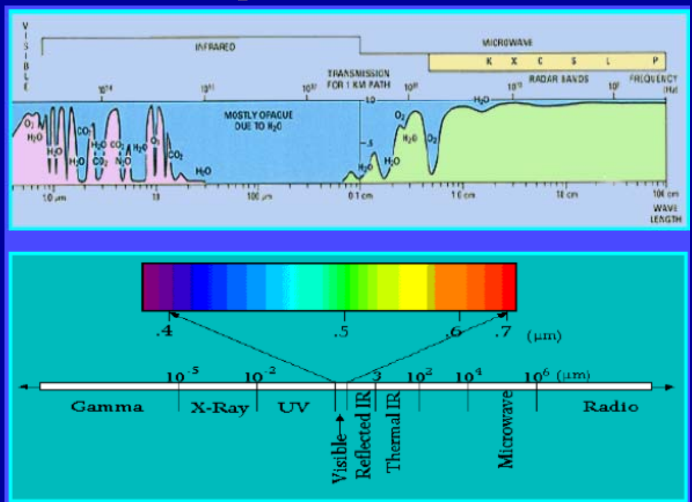
Dr.Weerakaset Suanpaga

D.Eng(RS&GIS)

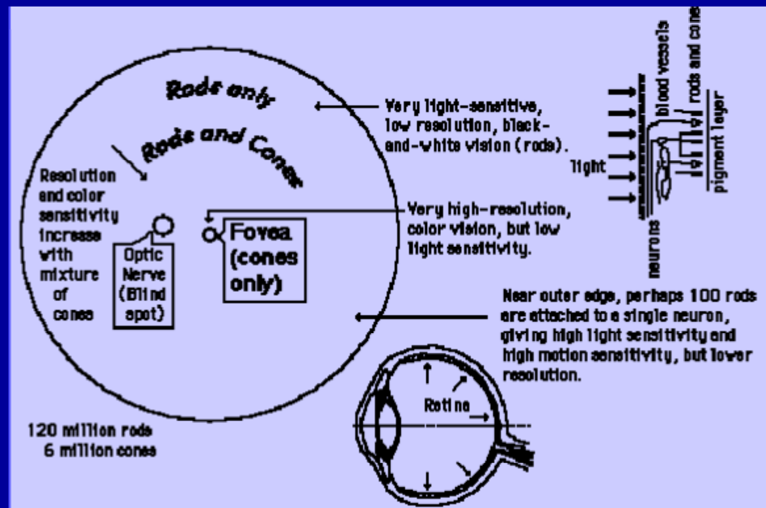
3.2 Color Processing

- Spectral information perceived by human eye
  - visible wavelength ; 380-700nm
  - Cone: good spatial resolution, low sensitivity for daylight, 3 types for r g b)
  - Rod : High sensitivity, but b/w
- Physiopsycological Phenomena
- Image Interpretation
  - human beings perceive thousands of color shades and intensities, compared to only two-dozen shades of gray.

Electromagnetic Spectrum



Rods and Cones



Rods and Cones

- The retina contains two types of photoreceptors, rods and cones. The rods are more numerous, some 120 million, and are more sensitive than the cones.
- The experimental evidence suggests that among the cones there are three different types of color reception. Response curves for the three types of cones have been determined. Since the perception of color depends on the firing of these three types of nerve cells, it follows that visible color can be mapped in terms of three numbers called tristimulus values. Color perception has been successfully modeled in terms of tristimulus values and mapped on the CIE chromaticity diagram.

http://hyperphysics.phy-astr.gsu.edu/hbase/vision/rodcone.html

Cone Details

•Current understanding is that the 6 to 7 million cones can be divided into red" cones (64%), "green" cones (32%), and "blue" cones (2%) based on measured response curves. They provide the eye's color sensitivity. The green and red cones are concentrated in the fovea centralis . The "blue" cones have the highest sensitivity and are mostly found outside the fovea, leading to some distinctions in the eye's blue perception.

•The cones are less sensitive to light than the rods, as shown a typical day-night comparison. The daylight vision (cone vision) adapts much more rapidly to changing light levels, adjusting to a change like coming indoors out of sunlight in a few seconds. Like all neurons, the cones fire to produce an electrical impulse on the nerve fiber and then must reset to fire again. The light adaption is thought to occur by adjusting this reset time.

•The cones are responsible for all high resolution vision. The eye moves continually to keep the light from the object of interest falling on the fovea centralis where the bulk of the cones reside.

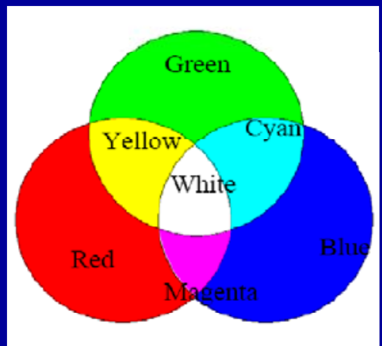
Color Representation

•Color Mixing System
  •All Color can be created by mixing 3 primary colors in appropriate proportions
  •Physical Approach
  •Easy for machines to compose color
  •Typical Primary Color
    → Red, Green, Blue
  •Additive color composite for light
  •Subtractive color composite for pigments

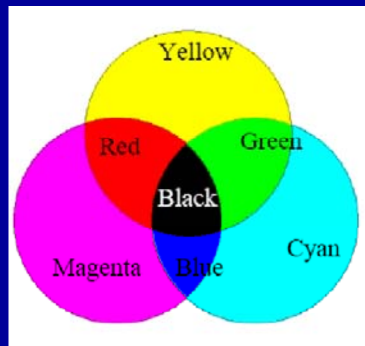
- Color Appearance System
  - Describe Color Qualitatively using Color Code
  - Easy for human beings to describe or control color
  - Munsell Color System
  - HSI

Color mixing system Light and pigment

Mixture of light (Additive primaries)



Mixture of Pigments (Subtractive primaries)



CIE RGB Color Matching Function

- defined by CIE in 1931
- color matching function is defined through color matching experiment.

$\bar{r}(\lambda), \bar{g}(\lambda), \bar{r}(\lambda)$: ColorMatchingFunctioi

$L_e(\lambda)$: SpectralIrradiance

$\boldsymbol{C} = R\boldsymbol{R} + G\boldsymbol{G} + B\boldsymbol{B}$

$\boldsymbol{C}$: Color Stimulus

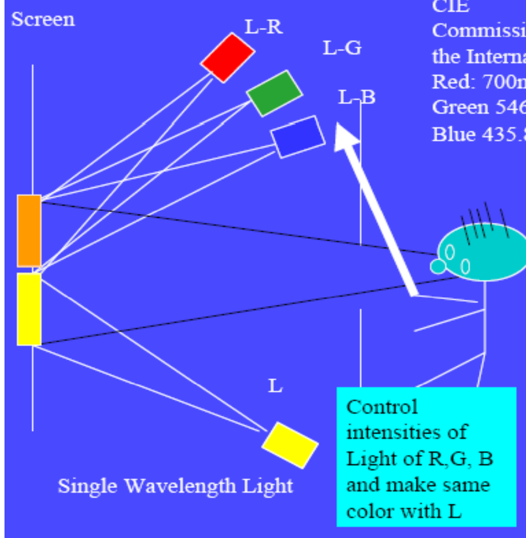
R,G,B: Tristimulus Value

$$R = \int_{380}^{780} \bar{r}(\lambda)\, L_e(\lambda)\, d\lambda$$

$$G = \int_{380}^{780} \bar{g}(\lambda)\, L_e(\lambda)\, d\lambda$$

$$B = \int_{380}^{780} \bar{b}(\lambda)\, L_e(\lambda)\, d\lambda$$

Color matching Experiment and function



CIE
Commission Internationale de l'Eclairage
the International Commission on Illumination
Red: 700nm
Green 546.1nm
Blue 435.8nm

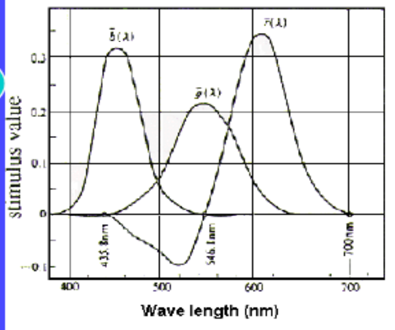


Figure 10.5.1 Color matching function of CIE 1931 RGB

CIE XYZ Color System

- Mathematically Derived from CIE RGB System
  - RGB system includes negative in color matching function
  - Derived virtual color matching Function is always positive

$$X = 0.49000R + 0.31000G + 0.20000B$$

$$Y = 0.17697R + 0.81240G + 0.01063B$$

$$Z = \quad 0.01000G + 0.99000B$$

XYZ Color system

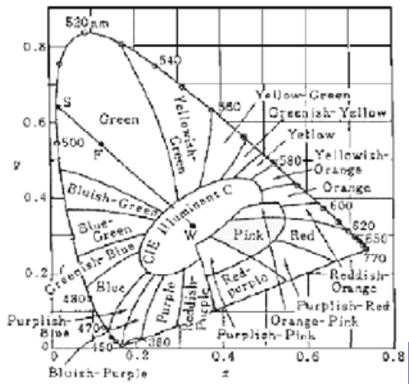


Figure 10.5.3 XYZ color system

XYZ Color System

- Mathematically Derived from CIE RGB System
  - RGB system includes negative in color matching function
  - Derived virtual color matching Function is always positive

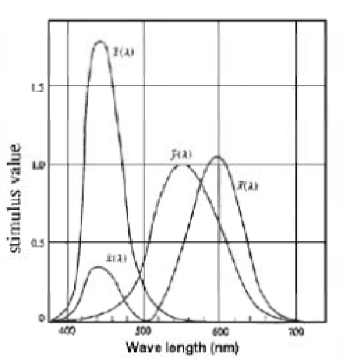


Figure 10.5.2 Color matching function of CIE1931XYZ

$\bar{r}(\lambda), \bar{g}(\lambda), \bar{r}(\lambda)$: Color Matching Functior

$L_e(\lambda)$: Spectral Irradiance

$$R = \int_{380}^{780} \bar{r}(\lambda) L_e(\lambda)\, d\lambda$$

$$G = \int_{380}^{780} \bar{g}(\lambda) L_e(\lambda)\, d\lambda$$

$$B = \int_{380}^{780} \bar{b}(\lambda) L_e(\lambda)\, d\lambda$$

Stimulus Component –> Chromaticity Diagram

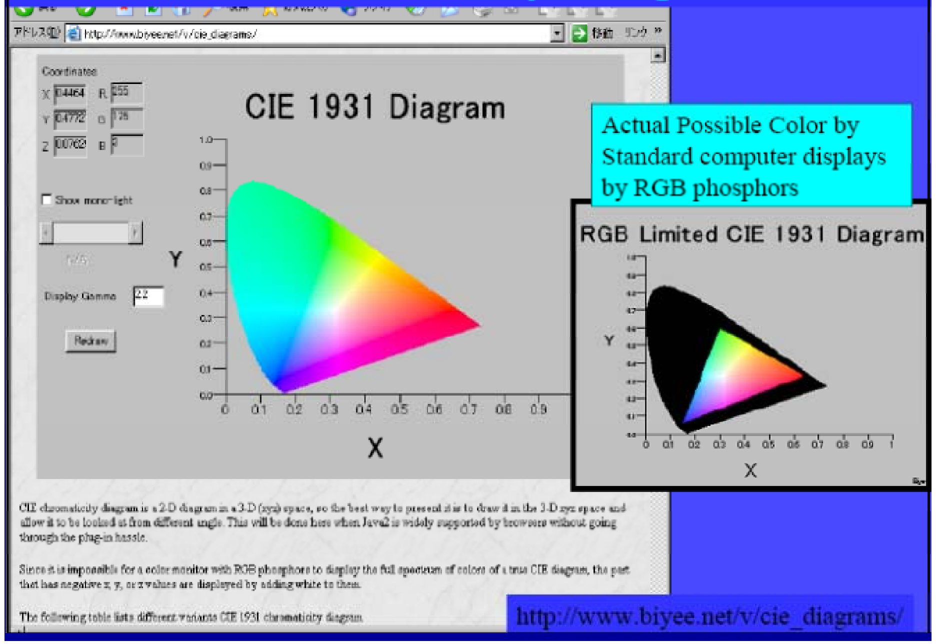
$x = X/(X+Y+Z)$

$y = Y/(X+Y+Z)$

$z = Z/(X+Y+Z)$

$x+y+z=1$

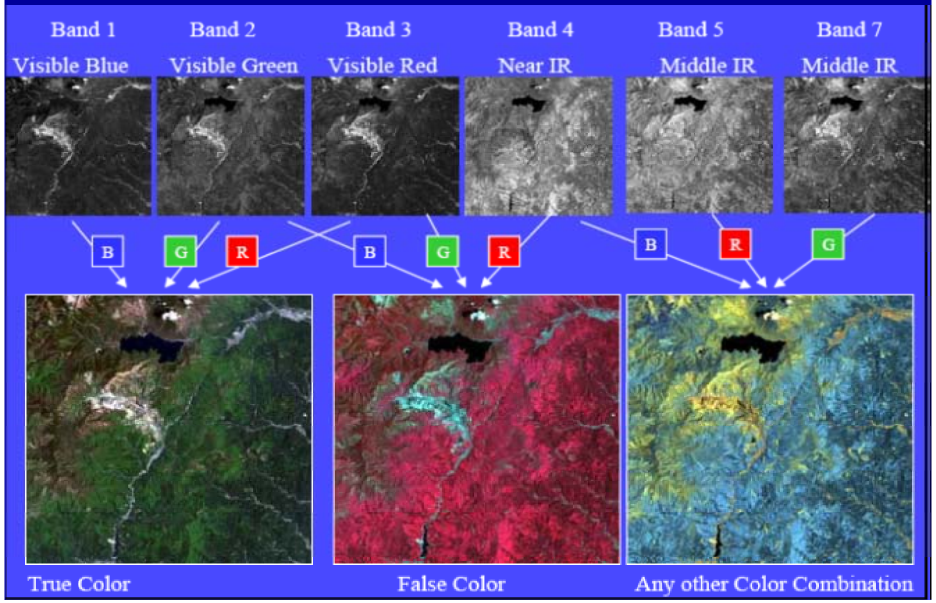
CIE Chromaticity Diagram



3.3 color composite

- Allocate RGB to 3 gray scale images
- True Color Composite
  - reproduction of color image
    - visible Red band -> R
    - visible Green band -> G
    - visible Blue band -> B
- False Color Composite
  - Allocate invisible band to RGB or any other color combination other than True Color
    - Infrared band -> R
    - visible Red band -> G
    - visible Green band -> B
  - Any other band combination for R,G,B

Color composite example :LANDSAT

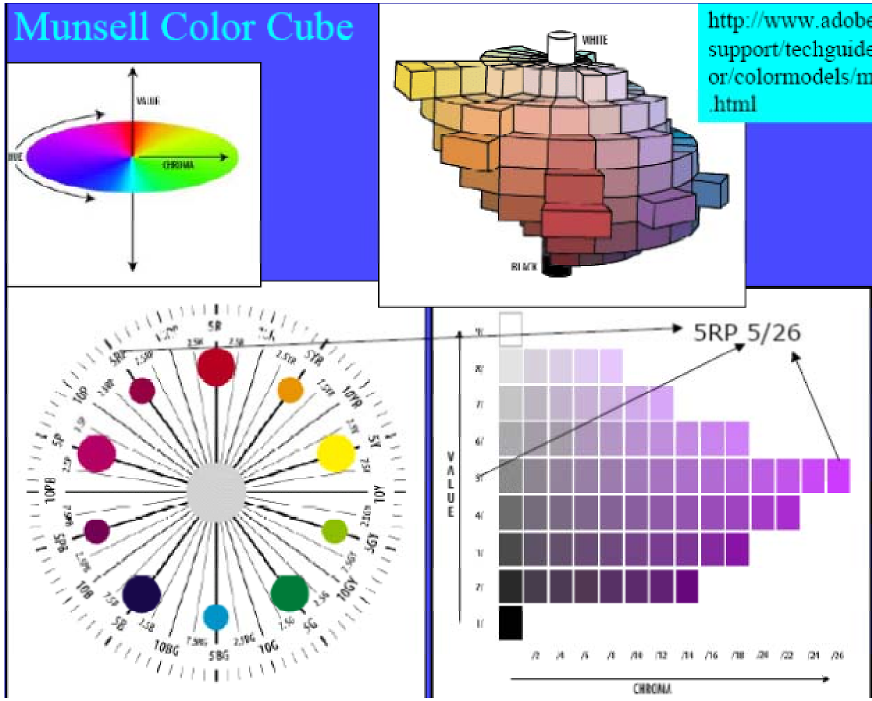


color composite 2

- Natural Color Composite
  - looks like a true color image using infrared band
  - allocate G to infrared that is strongly reflected by vegetation
    - visible Red band -> R
    - Infrared band -> G
    - visible Green band -> B

Munsell Color Cube

http://www.adobe.com/support/techguides/color/colormodels/munsell.html



Conversion between RGB and HSI

Mathematical conversion between RGB Color cube and HSI model

Specify color in HSI

- easy for human beings to get color

Color Enhancement Operation in HSI color space

- RGB -> HSI -> Operation -> H'S'I' -> R'G'B'
  - Data Fusion between RGB and B/W(Highreso, Radar …)
  - Overlay one image on an original image.
    - To keep the color of original image, replace only I
  - SPOT : HSI Composite of 20m False Color image and 10m Monochrome color image
    - Spectral Info. 20m Multi-band false color H&S
    - Texture Info 10m Monochrome band I
  - IKONOS-Pan Sharpened (Algorithm ?)

Conversion between RGB and HSI

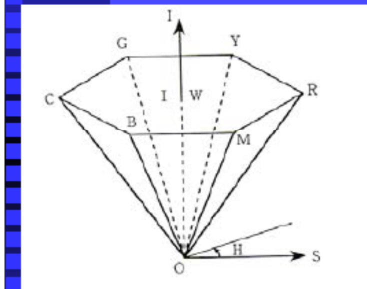
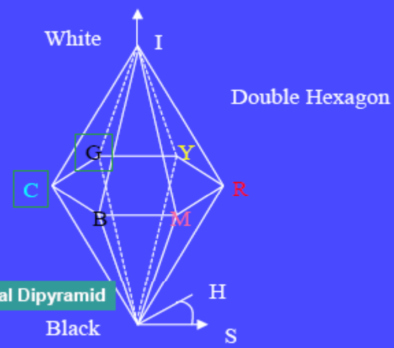
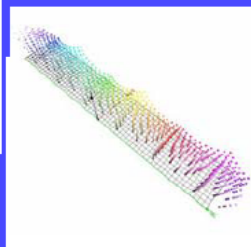


Figure 10.6.3 Relationship between RGB space and HSI space

Hexagonal Pyramid



Hexagonal Dipyramid



$$\begin{cases} H = arctan(\frac{\beta}{\alpha}) \\ S = \sqrt{\alpha^2+\beta^2} \\ I = (R+G+B)/3 \end{cases}$$

$$\begin{cases} \alpha = R - \frac{1}{2}(G+B) \\ \beta = \frac{\sqrt{3}}{2}(G-B) \end{cases}$$

http://www.couleur.org/index.php?page=transformations#HSI

3.4 Pseudo-color

- Allocate different color to each gray level in one gray scale image
- Enhance gray scale image using human being's good sensitivity for colors
  - distinguish small gray level difference
  - grasp same gray scale level area
- Same as index color images
  - Easy to create and implement your own color palette

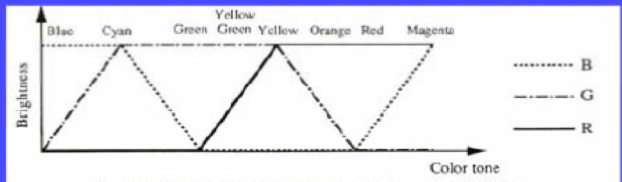
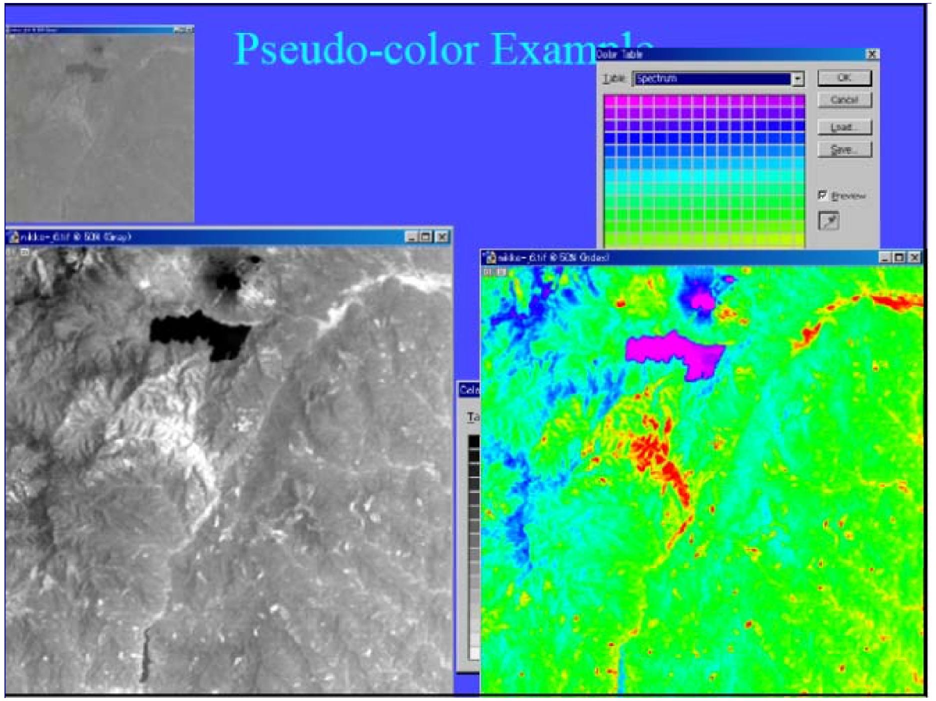


Figure 10.4.3 Example of pseudo color display

Pseudo-color Examp



Creating Color Table

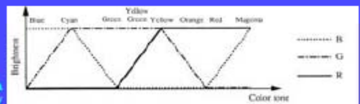
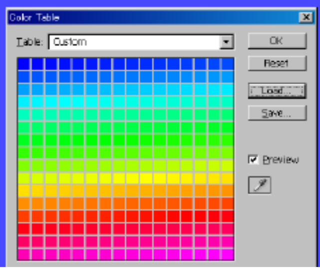


Figure 10.4.3 Example of pseudo color display

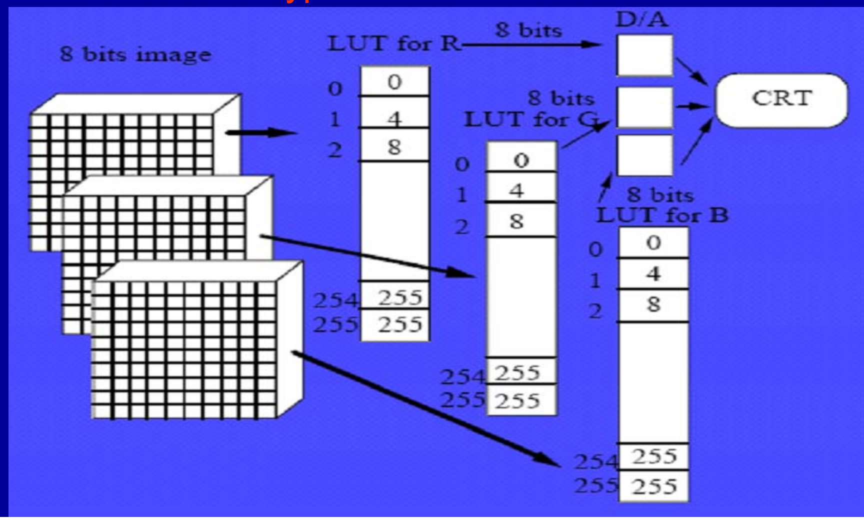
- ENVI, ERMapper –Color Table is in text format
  - R G B for Level 1
  - R G B for Level 2
  - ….
- Photoshop Simple binary RGB for Level0, RGB for Level1,….




```
for(i=0;i<256;i++){
  if( i<=lim1 ){
    r[i]=0;
    g[i]=(double)(255-0)/(lim1-lim0)*(i-lim0);
    b[i]=255;
  } else if( i<=lim2 ) {
    r[i]=0;
    g[i]=255;
    b[i]=(double)(0-255)/(lim2-lim1)*(i-lim1)+255;
  } else if( i<=lim3 ) {
    r[i]=(double)(255-0)/(lim3-lim2)*(i-lim2);
```

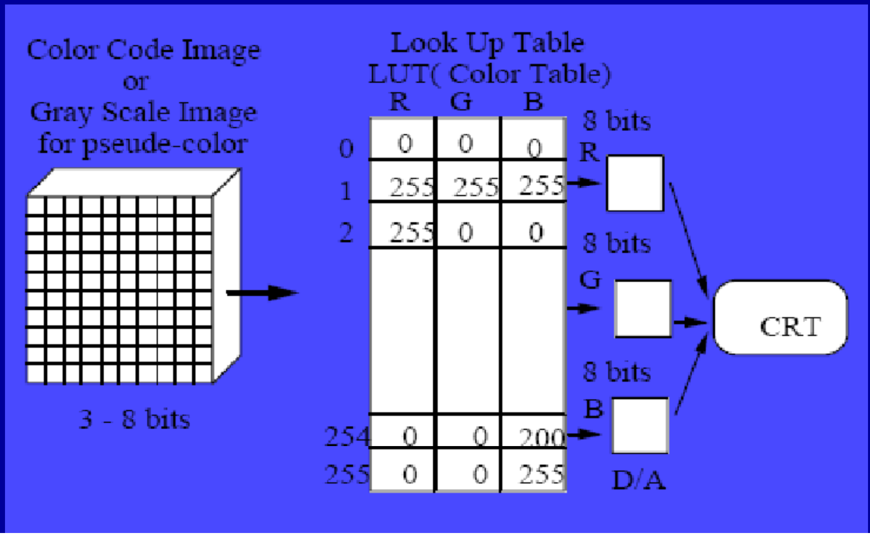

RGB Color Image Display

Full Color Type



RGB Color Image Display

Color Map Type



4.Image Conversion
4.1 Math Operation:NDVI

- Arithmetic operation is possible because the mage
- Is nothing more than numerical data
  - + - * / , log
  - Single Band/Band Math
  - B1/B2
- Contrast enhancement , Radiometric correction
- Change detection, Calculate Index
  (Vegetation Index,etc)

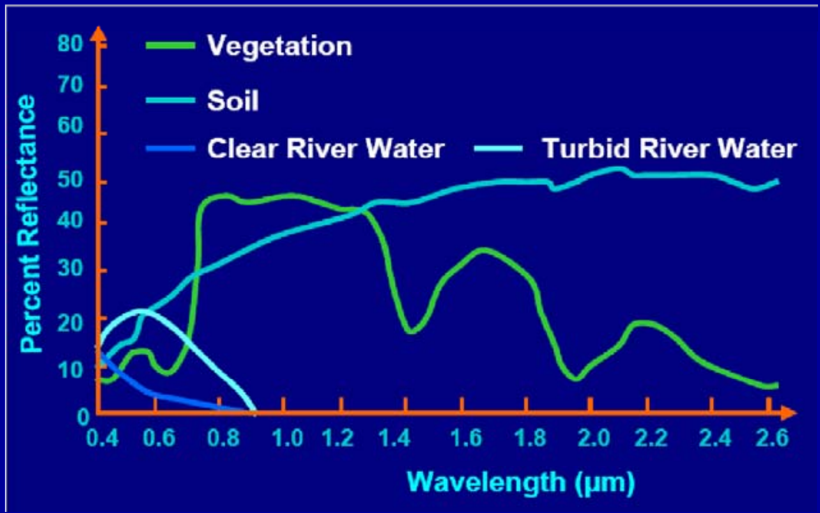
4.Image Conversion
4.1 Math Operation:NDVI

- Arithmetic Operation
  - + - * / ,log,. . .
  - Single Band/Band Math
  - Contrast Enhancement, Radiometric Correction
  - Change detection, Calc. Index(Vegetaion Index, etc.)
- Logical Operation
  - Operation for binary image(False or True)
  - NOT, AND, OR, XOR
  - Creat new regions

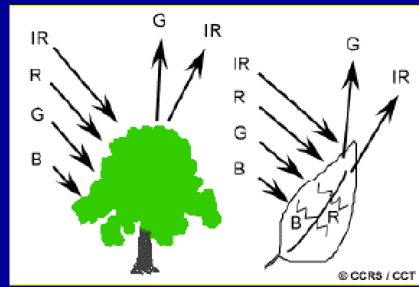
Vegetation Index

- Vegetation absorbs Visible Red, reflects Near Infrared
- ratio of NIR and VR
- NIR/VR
- log(NIR/VR)
- (NIR - VR) / (NIR+VR)

Spectral reflectance



Interactions with Surfaces

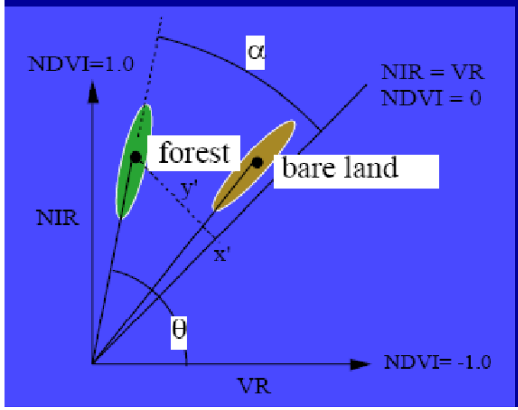


There are three (3) forms of interaction that can take place when energy strikes, or is **incident (I)** upon the surface. These are: **reflection (R)**; **transmission (T)**; and **absorption (A). Interactions**

NDVI:Normatlized differential vegetation index

NDVI =(NIR-VR)/(NIR+VR)

= tan α = y'/x'



$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} \cos\pi/4 & \sin\pi/4 \\ -\sin\pi/4 & \cos\pi/4 \end{pmatrix} \begin{pmatrix} VR \\ \text{NIR} \end{pmatrix}$$

$$\tan\alpha = \frac{y'}{x'} = \frac{NIR - VR}{NIR + VR}$$

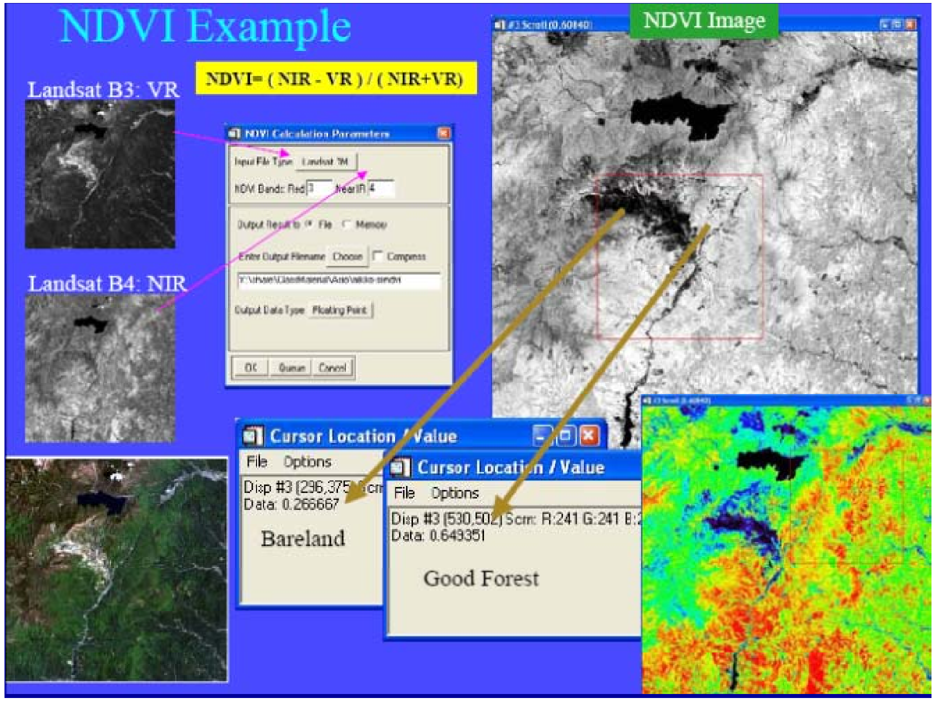
Bands used for NDVI

NDVI =(NIR-VR)/(NIR+VR)

= tan α = y'/x'

	NIR	VR
LANDSAT MSS	B7	B5
LANDSAT TM	B4	B3
SPOT XS	B3	B2
NOAA AVHRR	B2	B1

NDVI Example

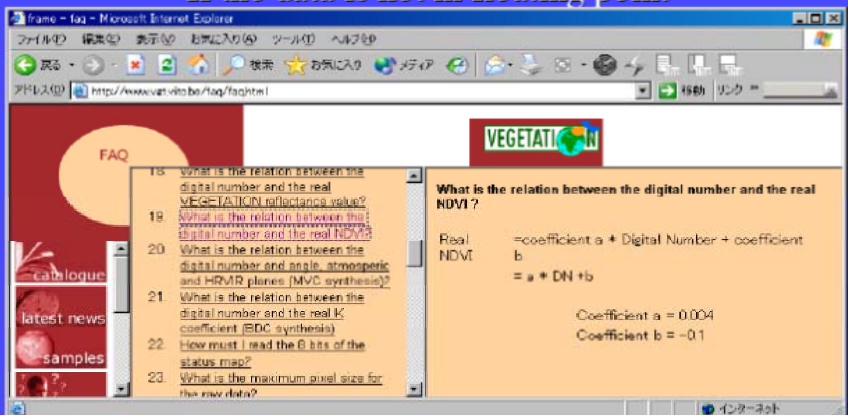


Scaling of NDVI

- -1.0 < NDVI < 1.0
- Save as Floating Point Value, or
- Save as 8 bit Integer for easy handling, but with an appropriate scaling factors.
- Adjust -1.0 to 1.0 to 8 bit Integer 0-255
  1. 0 < (NDVI+1.0)*100 < 200
  2. 0 < (NDVI+1.0)*128 < 256
- Some Application Software automatically decide scaling factors, which makes it impossible to retrieve original NDVI value.
- We should always consider Scaling Factors

DN to Real Value

- Always check scaling factor
  - NDVI, Reflectance, Temperature, Radiance …. If the data is not in floating point



Accuracy of NDVI Calculation

- Dividing sometimes enhances noise
- NDVI
  - If NIR and VR are near to 0, the operation will enhances noise.
  - Exclude low level area from calculation
    - water, shade area

Logical operator and operation

- Indicate area by binary image
  - False or True
- Operation on binary Image
  - Logical Operator(NOT,AND,OR,XOR)
- Create New Regions
  - Broad-leave Tree OR Conifer Tree -> Forest
  - Bare-land AND Steep Area -> Slope Failure Area

Logical operator

NOT		AND			OR			XOR		
0	1	0	0	0	0	0	0	0	0	0
1	0	1	0	0	1	0	1	1	0	1
		0	1	0	0	1	1	0	1	1
		1	1	1	1	1	1	1	1	0

0: False
1: True

Clear Image
Cursol Display

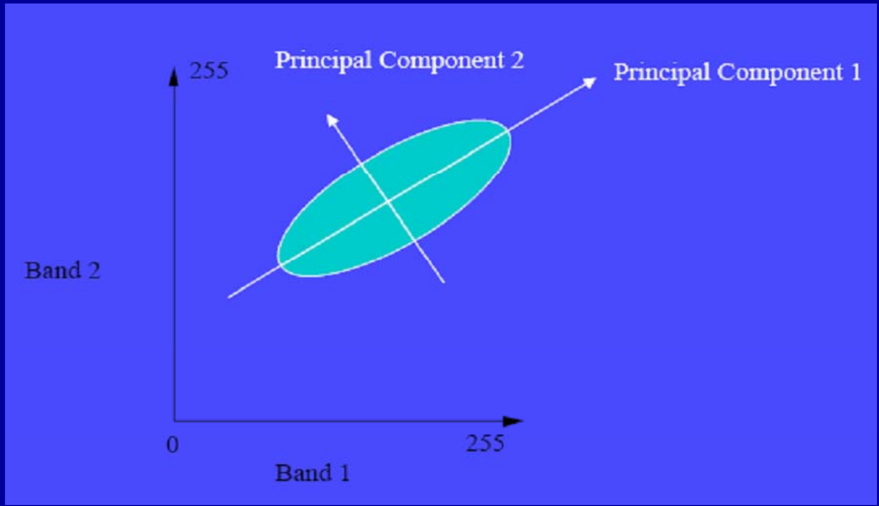
Logical image

- ROI
  - Region of Interest
  - Destination area for operations
    - Get statistics
    - Class definition
- Mask Image (e.g. Cloud Mask, Land Mask …)
  - 0 : False, not 0 (usually 255):true
- Bit Plane Image (Nowadays not using so much)
  - treat each bit in 8 bit image as a image.

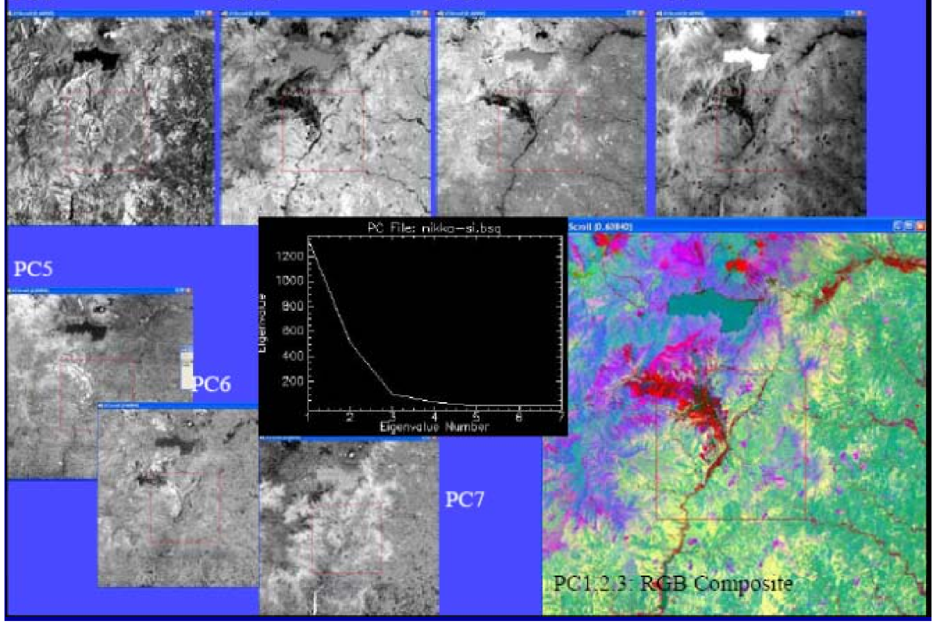
4.3 principle component analysis

- Individual bands of a multispectral image are commonly highly correlated.
- Principal components transformation is a technique for removing or reducing this spectral redundancy.
- The principal component images are uncorrelated each other.
- Principal components are used for color composite to visualize more than 3 band data using first 3 PC bands, where almost of information is being concentrated.

Principle of component analysis



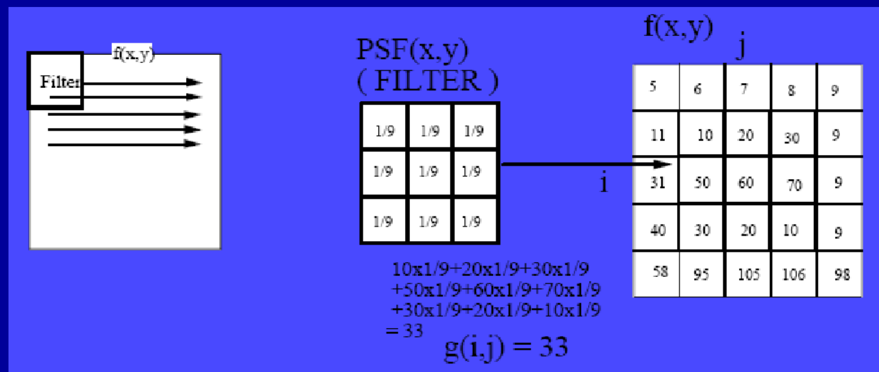
Principal Component Example



4.4 Filtering :Edge Enhancement

- Image feature extraction
- Noise suppression
- Image enhancement

Spatial filter and operations



$$g(i,\ j) = \sum_{m=i-W/2}^{i+W/2} \sum_{n=j-W/2}^{j+W/2} f(m,n)\,PSF(i-m,\ j-n)$$

Various Filters

Smoothing

	1	1	1
1/9*	1	1	1
	1	1	1

Laplacian

-1	-1	-1
-1	1	-1
-1	-1	-1

Sharpening

	1	-8	1
1/9*	-8	37	-8
	1	-8	1

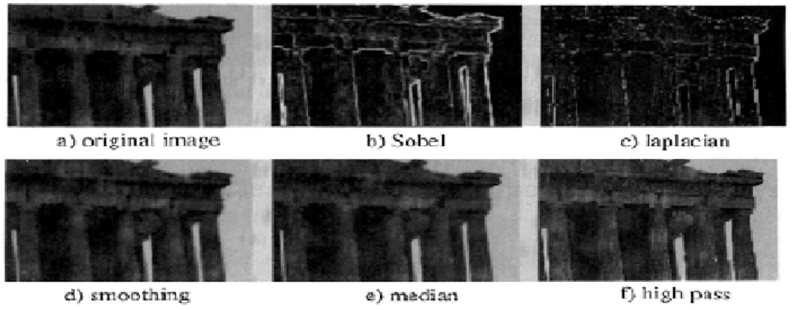


Figure 10.9.2 Image enhancement with use of 3x3 operators

END