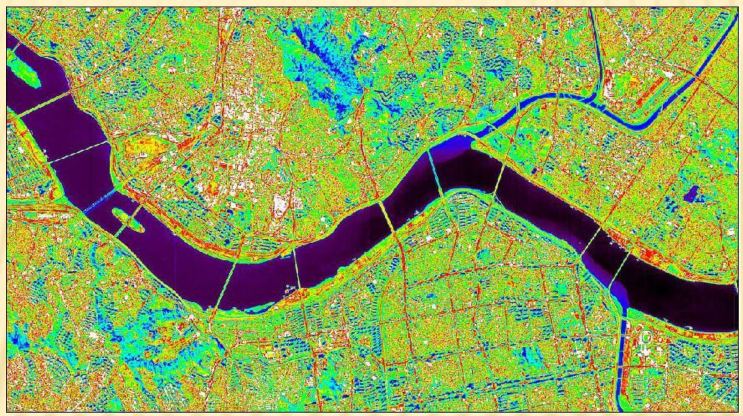
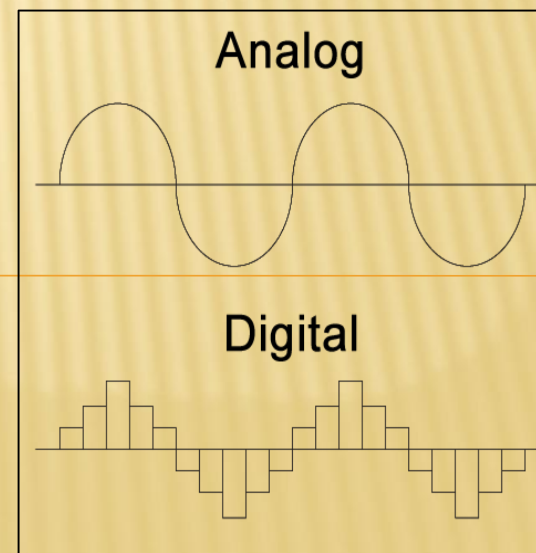
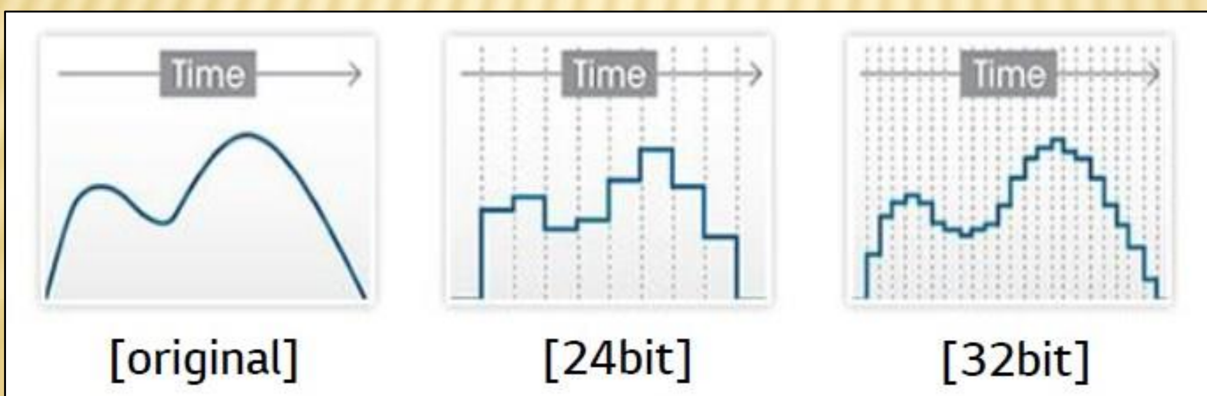
SATELLITE IMAGES - FUNDAMENTALS

- Image → Two dimensional representation of objects in a real scene
- Images can be of Analog or Digital in nature







ANALOG IMAGE

Image → Representation of reflection from an object (target)

• Aerial survey results in a photographic image

• A photographic image will be in the form of a physical record *[piece of paper (or) a film]* and records patterns of the image

• Works within Visible range of the spectrum (most generally)

• Photographic images are ANALOG in nature *[brightness within a photograph is analog or proportional to brightness within the scene]*

• Analog images have the following difficulties:

Storage; Transmission; Searching; Analysis

DIGITAL IMAGE

- Digital image consists of an array of individual pixels *[picture elements]*
- Each pixel stores a discrete number *[digital number]* in binary format to represent brightness of the image at pixel location
- Easy for data storage; transmission; searching; analysis
- Satellite image consists of photograph of earth (or, other planets) made by means of artificial satellites
- Images used in remote sensing can be ANALOG (Aerial image) or DIGITAL (Satellite images) in nature
- The reflecting (emitting) EM radiations from individual patches of the ground will be stored in digital format.
- Colour images are composed of several such arrays of same ground area, each representing brightness in a separate region of spectrum

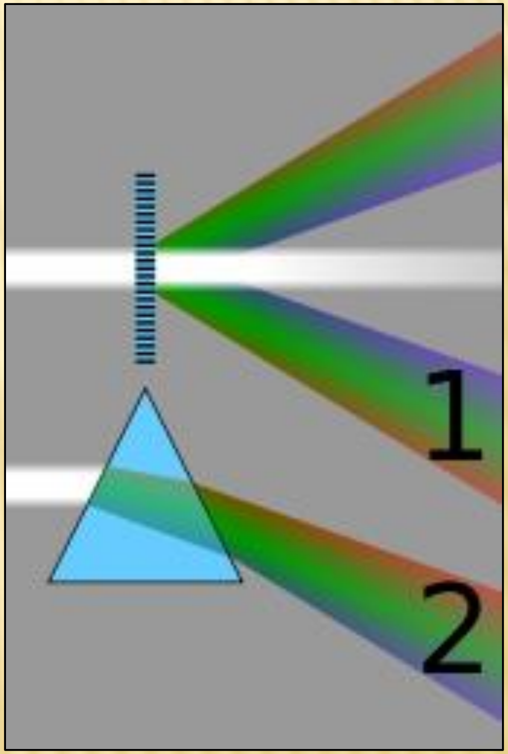
ANALOG VS DIGITAL IMAGE

- **Analog images** are the type of images that we, as humans, look at
- They include such things as photographs, paintings, TV images, and medical images recorded on film or displayed on various display devices, like computer monitors
- What we see in an analog image is various levels of brightness (or film density) and colors
- It is generally continuous and not broken into many small individual pieces
- **Digital images** are recorded as many numbers
- The image is divided into a matrix or array of small picture elements, or pixels.
- Each pixel is represented by a numerical value
- Digital Images are easily processed using computer systems.

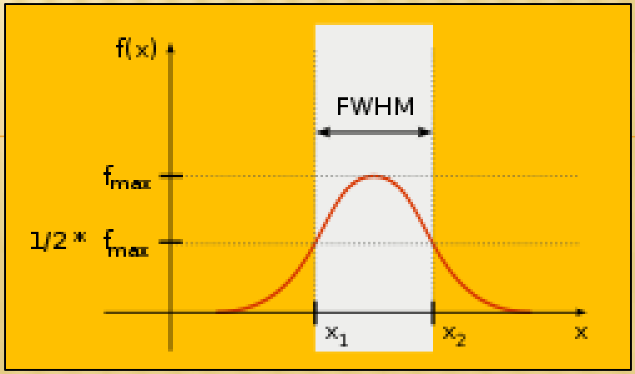
SPECTRAL SENSITIVITY

- An optical sensor converts light into electronic signals
- Optical sensors use prisms / filters to separate the light into spectral regions
- Filters are specialized glass materials that pass certain wavelengths and absorb / block all other wavelengths
- Filters are manufactured by adding DYES to glass
- In Visible region, filters are generally used to separate out BLUE (due to shorter wavelength – higher scattering)
- A deep red filter blocks all visible radiation, but allows to pass infra red radiation (for vegetation growth)
- More than filters, DIFRACTION GRATINGS are used in satellite sensors due to their effectiveness, small size, light weight

SPECTRAL SENSITIVITY



- Diffraction grating is an optical component with a periodic structure, which splits and diffracts light (EM wave) into several beams travelling in different directions
- Due to the use of filters / diffracting gratings used by sensors to define spectral limits, spectral sensitivity varies across a specified defined interval
- Spectral sensitivity is the relative efficiency of detection of light as a function of wavelength
- Spectral sensitivity of a sensor is generally specified using "Full Width Half Maximum
- Beyond the limits of FWHM, the response (measurement) is so weak



SPECTRAL SENSITIVITY

1) Panchromatic Sensing system

   - Sensor is a single channel detector sensitive to radiation within a broad wavelength range
   - If the wavelength range coincide with the visible range, then the resulting image resembles a "black-and-white" photograph taken from space
   - The spectral information or "colour" of the targets is lost

2) Multispectral Sensing system

   - Sensor is a multichannel detector with a few spectral bands
   - Each channel is sensitive to radiation within a narrow wavelength band
   - The resulting image is a multilayer image which contains both the brightness and spectral (colour) information of the targets being observed

3) Hyperspectral Sensing system

   - Acquires images in about a hundred or more contiguous spectral bands
   - Enables better characterization and identification of targets

DIGITAL DATA

- Output from electronic sensors reaches the analyst as a set of digital values
- Each digital value is recorded as a series of binary (0 – 1) values known as *bits*
- Each *bit* records an exponent of power 2, with value of the exponent determined by position of the bit in the sequence
- Ex: A system is designed such that, each digital value is recorded using 7 bits
- Digital number 75 is recorded as 1001011
- Eight *bits* constitute one *byte*
- *1 kb = 2^{10} bytes (= 1024 bytes); 1 Mb = 2^{20} bytes; 1 Gb = 2^{30} bytes*

DIGITAL DATA

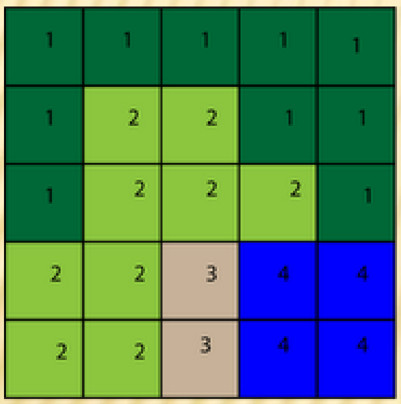
- The discrete value stored in each pixel in the digital format is called as DIGITAL NUMBER – DN
- The DN value for a pixel do not represent the true brightness (radiance) from the scene, but represents the relative brightness (scaled values)
- Number of brightness (DN) values within an image are determined by the number of *bits* available
- DNs are not comparable between two different scenes as DN value changes with *bits* available
- DNs are to be converted into radiance for comparison
- The sensitivity of a sensor (to represent brightness in terms of DN) has to be frequently calibrated with targets of known brightness

DATA FORMATS

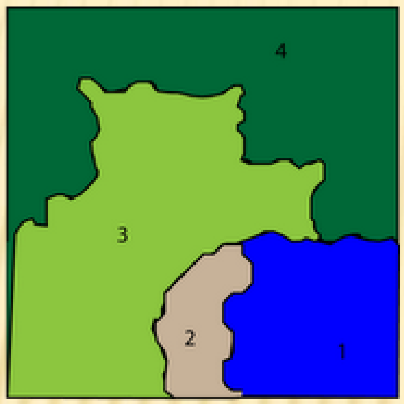
- Data in remote sensing can be stored in two formats

Raster Format:

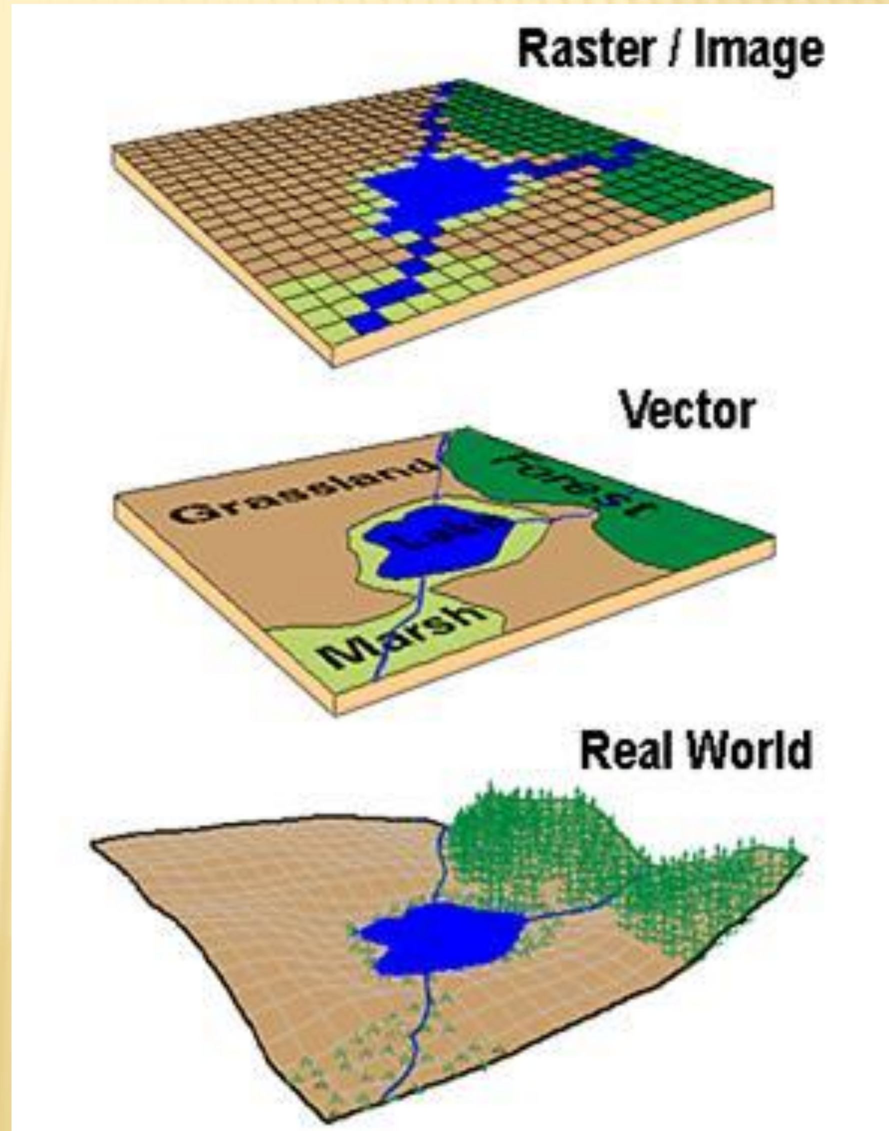
- The image is treated as an array of values
- Each pixel is treated as a separate unit, and is designated using row and column index *starting from upper left corner*
- Each pixel has same dimension (defines resolution of image) and generally aligned in N-S direction
- Raster is faster – Manipulation of pixel values by image processing algorithms is easy *(since, pixels can be easily located)*
- In general, representation of actual ground objects (buildings; roads, vegetation; …..) are not so accurate in raster data system
- ***Vector Format*** uses polygonal patches and boundaries for representation and analysis



Values	Name	Count
1	Forest	10
2	Grass	9
3	Beach	2
4	Water	4



FID#	Name	value	Public?	Owner
1	Water	4	Yes	State
2	Beach	3	Yes	State
3	Grass	2	Yes	State
4	Forest	1	No	Warner



DATA STORAGE IN RASTER FORMAT

- Consider an image in FOUR spectral channels (bands), which together can be visualized as FOUR superimposed images
- The pixel representing a feature will lie exactly on top of the same pixel (representing in all other bands) in superimposition mode
- There are THREE methods of storing such images

1) Band Interleaved by Pixel (BIP)

✓ Data are arranged in sequence values for

Row 1; Column 1; Band 1

Row 1; Column 1; Band 2

Row 1; Column 1; Band 3;

Row 1; Column 1; Band 4

✓ Next is for Row 1; Column 2; for all bands, and so on

DATA STORAGE IN RASTER FORMAT

- ❑ For a given pixel location, all the band values are stored sequentially
- ❑ Used for analyses of small area (limited pixels)
- ❑ Used for analyses in which, brightness value (DN) is queried or used to calculate another quantity

2) Band Interleaved by Line (BIL)

- ✓ Treats each line (row) data as a separate unit
- ✓ In sequence, the data is stored as:

  Line (Row) 1 for Band 1;

  Line (Row) 1 for Band 2;

  Line (Row) 1 for Band 3;

  Line (Row) 1 for Band 4;

- ✓ Next if for Line/Row 2 for all Bands, and so on

DATA STORAGE IN RASTER FORMAT

3) Band Sequential Format (BSQ)

- ✓ All data (pixels) specific to Band 1 are written first, followed by all data specific to Band 2, and so on
- ✓ For many (general) applications, BSQ format is convenient
- ✓ If areas smaller than the entire scene are to be examined, the analysis must read all four images before the sub area being identified
- ✓ The best data format depends on

  a) application (use)

  b) software / equipment available

MULTI SPECTRAL IMAGERY

- ✓ Band Combination → Assignment of colours to represent brightness in different regions (bands) of spectrum
- ✓ Multi spectral images capture the image data at specific frequencies (more than 1 spectral band)
- ✓ Multi spectral images are usually represented with RED, GREEN, and BLUE channels
- ✓ TRUE COLOURS → Uses red, green, and blue channels mapped to their respective colours (plain colour photograph)
- ✓ GREEN-Red-Infrared → Blue is used to represent Infra red (more reflectance for vegetation). Used for detection of vegetation
- ✓ Blu-NIR-MIR → Green is used for NIR (Vegetation); Red is used for MIR (water depth, soil moisture)

MULTI SPECTRAL IMAGERY

- ✓ Landsat → Largest enterprise in world for acquiring satellite images
- ✓ Landsat 7 has 8 spectral bands; with spatial resolution 15 to 60 m and temporal resolution 16 days
- ✓ Spectral Bands → Panchromatic, Blue, Green, Red, NIR, MIR, TIR
- ✓ Land sat Thematic Mapper → Earth observing sensor induced in Landsat Program
- ✓ Useful in the study of albedo and its relation to climate change

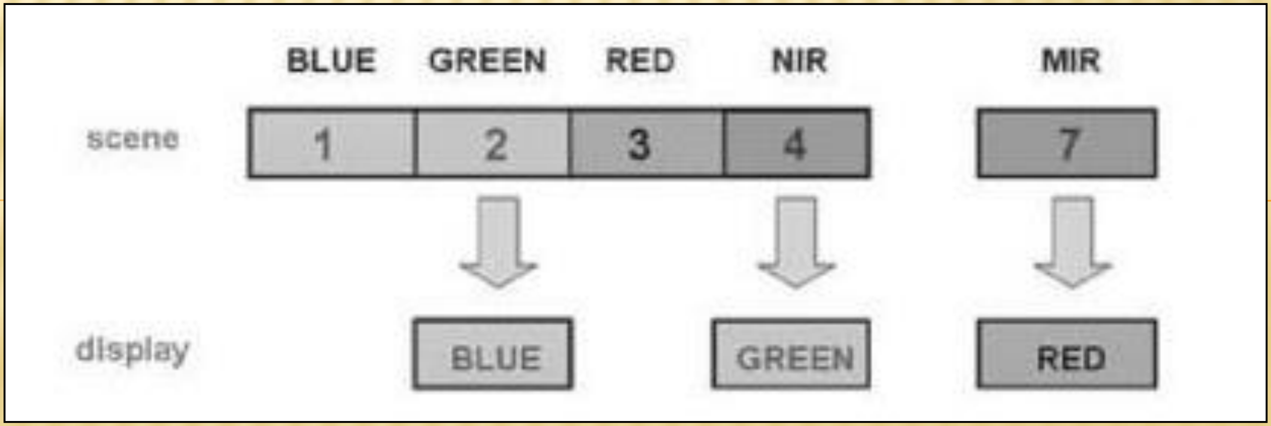
LANDSAT – SPECTRAL BANDS

Landsat 7			Landsat 8		
Band Name	Bandwidth (µm)	Resolution (m)	Band Name	Bandwidth (µm)	Resolution (m)
			Band 1 Coastal	0.43 – 0.45	30
Band 1 Blue	0.45 – 0.52	30	Band 2 Blue	0.45 – 0.51	30
Band 2 Green	0.52 – 0.60	30	Band 3 Green	0.53 – 0.59	30
Band 3 Red	0.63 – 0.69	30	Band 4 Red	0.64 – 0.67	30
Band 4 NIR	0.77 – 0.90	30	Band 5 NIR	0.85 – 0.88	30
Band 5 SWIR 1	1.55 – 1.75	30	Band 6 SWIR 1	1.57 – 1.65	30
Band 7 SWIR 2	2.09 – 2.35	30	Band 7 SWIR 2	2.11 – 2.29	30
Band 8 Pan	0.52 – 0.90	15	Band 8 Pan	0.50 – 0.68	15
			Band 9 Cirrus	1.36 – 1.38	30
Band 6 TIR	10.40 – 12.50	30/60	Band 10 TIRS 1	10.6 – 11.19	100
			Band 11 TIRS 2	11.5 – 12.51	100

LANDSAT – BAND COMBINATIONS

742 Band Combination

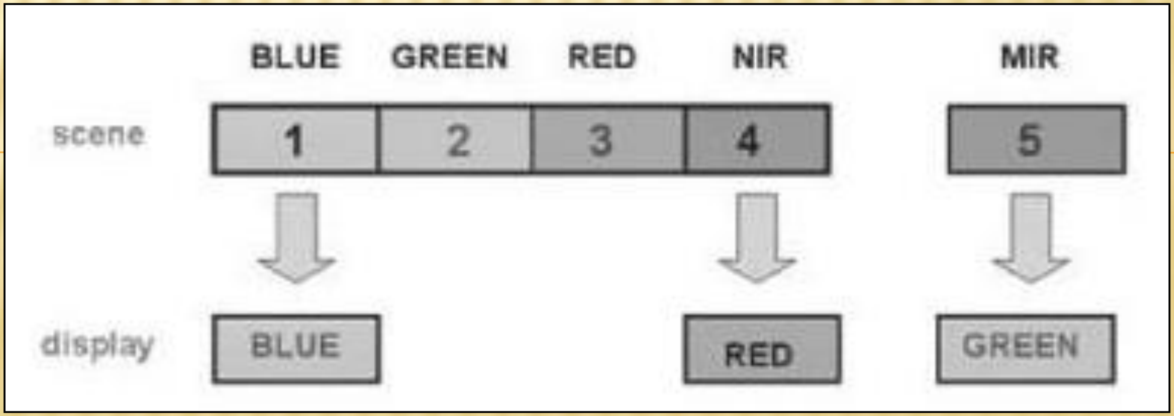
- ✓ Uses one region from visible, one from NIR and one from MIR bands
- ✓ Uses False colours, such that they resembles natural appearance in respective bands
- ✓ Vegetation – Green; Barren land – Pink; Dry / sparse vegetation – orange and brown; Open water – Blue
- ✓ Employed for geologic and agricultural analysis



LANDSAT – BAND COMBINATIONS

451 Band Combination

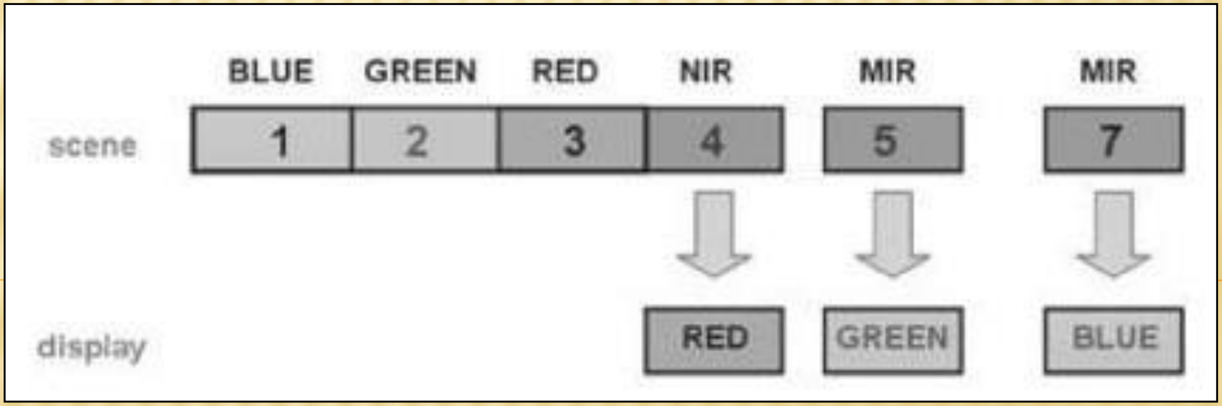
- ✓ Uses Blue, NIR and MIR bands
- ✓ Deep and clear water bodies appear very dark
- ✓ Shallow and turbid water appears as shades of lighter blue
- ✓ Healthy vegetation is represented in red, brown, orange
- ✓ Urban features are represented in white, cyan, and grey
- ✓ Bare soil appear as green and brown



LANDSAT – BAND COMBINATIONS

754 Band Combination

- ✓ Uses three bands from outside of visible region
- ✓ Used for geological analysis
- ✓ It is free from effects of atmospheric scattering (long wave)
- ✓ Coastlines are clearly and sharply defined



LANDSAT – BAND COMBINATIONS

543 Band Combination

- ✓ Uses NIR, MIR, and RED regions of spectrum
- ✓ Edges of water bodies are sharply defined
- ✓ Variation in vegetation type and status is clearly represented in brown, green, and orange
- ✓ Sensitive to variation in soil moisture
- ✓ Useful for soil and vegetation analysis

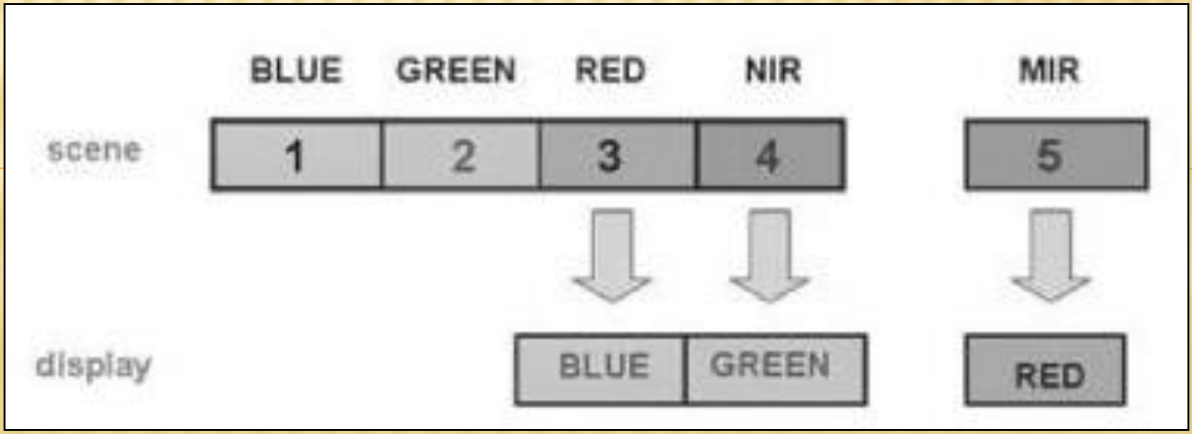


IMAGE ENHANCEMENT

- ✓ ***Image Enhancement*** is the process of improving the visual appearance of digital images
- ✓ Original brightness values will be altered in the process of improving their visual quality
- ✓ The changed brightness values may loose the relationship to the original brightness values (ground truths)
- ✓ Contrast refers to the range of brightness values present in an image (can even go beyond visible range values)
- ✓ ***Contrast Enhancement*** rescales the image brightness to ranges that can be accommodated by human vision, photographic films
- ✓ Contrast enhancement alters the pixel value in the old image to suit the given range of brightness (0 – 256 for 8 bit system)

IMAGE ENHANCEMENT

- ✓ ***Linear Stretch*** Converts the original data distribution into a new distribution such that:

  New Minimum = Mean – 2 (Standard Deviation)

  New Maximum = Mean + 2 (Standard Deviation)

- ✓ Algorithm then matches old minimum with new minimum; and old maximum with new maximum.
- ✓ All the old intermediate values are scaled proportionately between new minima and maxima

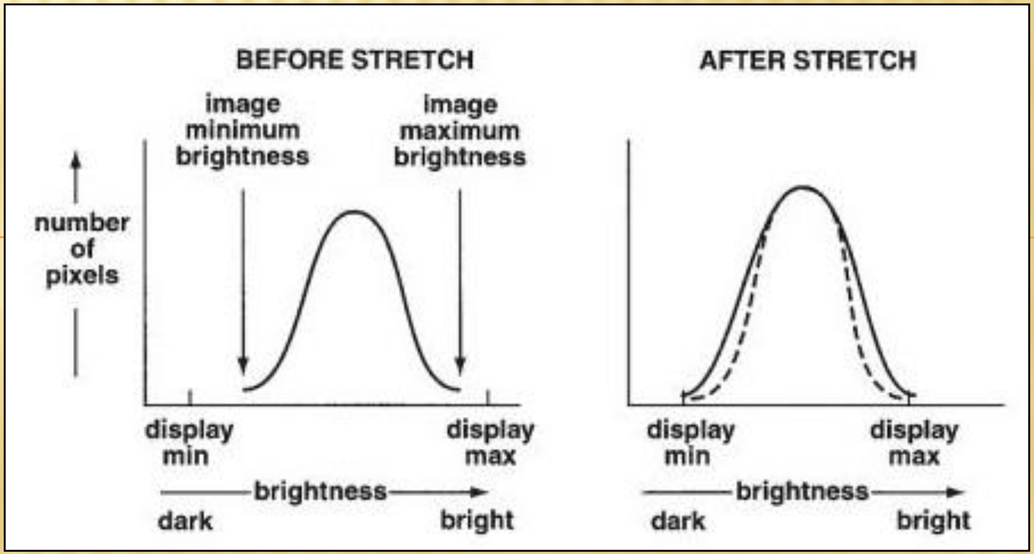


IMAGE ENHANCEMENT

- ✓ ***Histogram Equalization*** Reassigns digital values in the old image such that, brightness in the output image are equally distributed among the output range
- ✓ Histogram peaks are broadened and valleys are made shallower
- ✓ Used for image comparison process

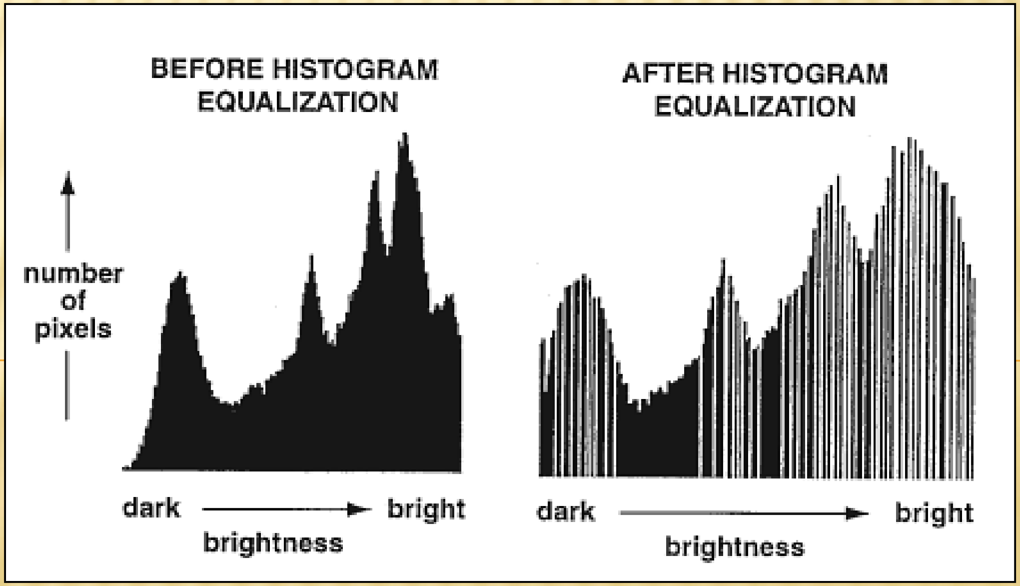
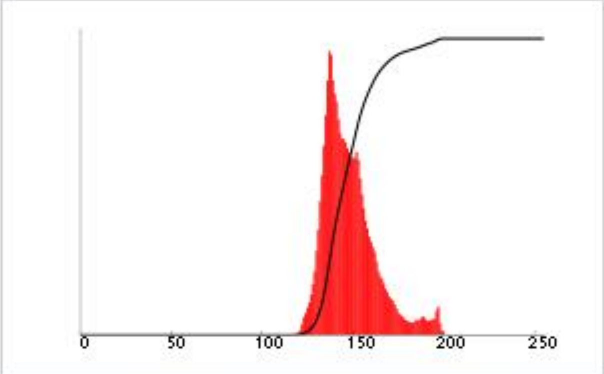


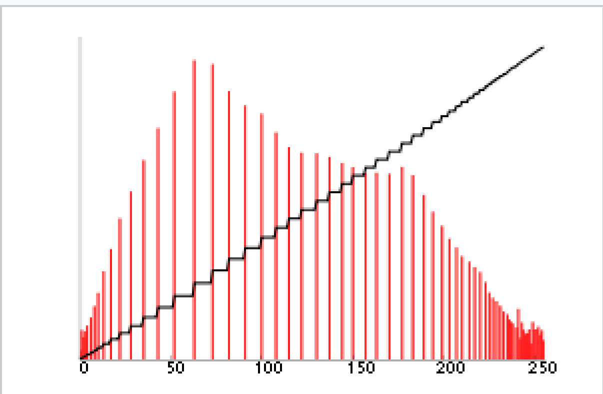
IMAGE ENHANCEMENT

Before Histogram Equalization



Corresponding histogram (red) and cumulative histogram (black)

After Histogram Equalization



Corresponding histogram (red) and cumulative histogram (black)

IMAGE ENHANCEMENT

- ***Density Slicing*** is accomplished by arbitrarily dividing the range of brightness in a single band into intervals and assign each interval a colour
- For example, in a black-and-white thermal image the temperature values in the image can be split into bands of 2°C, and each band represented by a colour of the spectrum

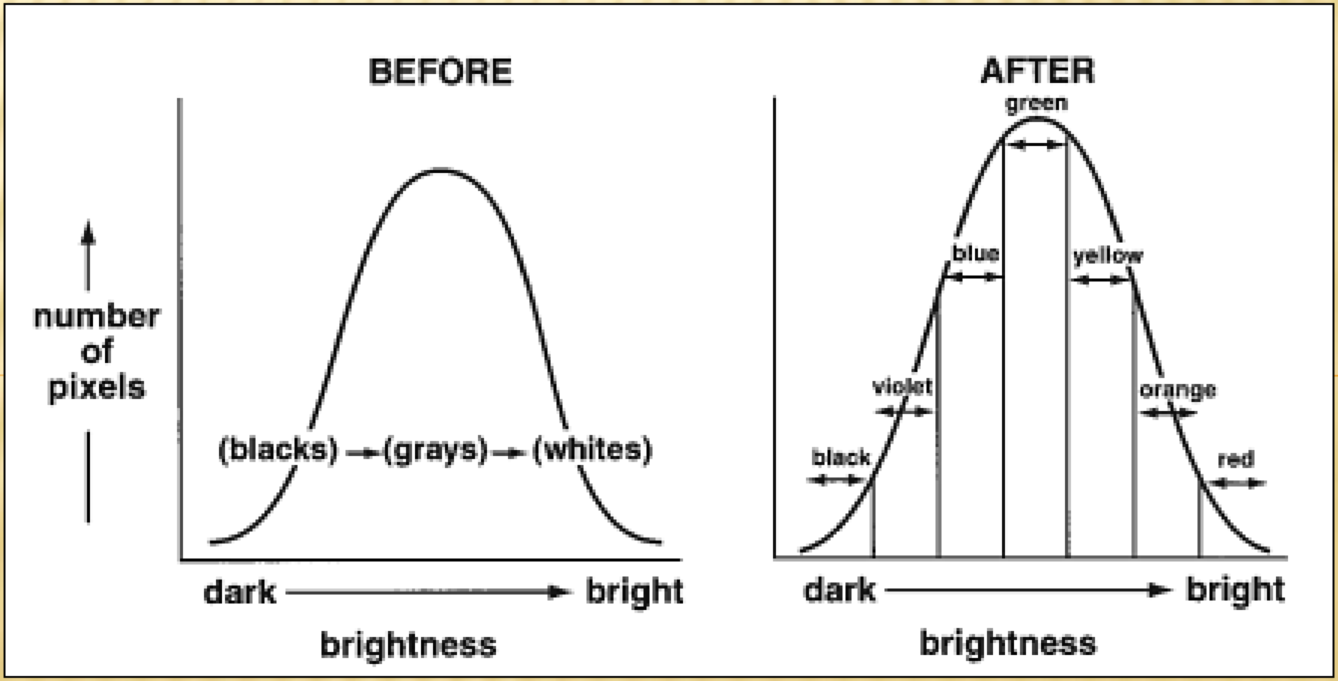


IMAGE ENHANCEMENT

- ✓ ***Edge Enhancement*** reinforces the visual transitions between regions of contrasting brightness
- ✓ The presence of noise, coarse resolution, and other factors may blurr or weaken the distinctiveness of the transitions
- ✓ Edge enhancement magnifies local contrast (enhancement of contrast) within a local region
- ✓ Uses a 3 x 3 roving window.

1) Brightness in window pixels (except central pixel) is multiplied by - 1

2) Central pixel is multiplied by 8

3) Central pixel in the output range is the sum of all nine values (used in step 1 and 2)

4) Move the roving window till the end of the old image

QUESTIONS ?