DATA CONVERSION/INTEGRATION PROCESS

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DATA CONVERSION/INTEGRATION PROCESS

- **Data Inventory**
  - Existing hard-copy maps / digital data
- **Data Collection** (additional)
  - Satellite Imagery, Aerial Photo, etc.
  - Field Collection (hand-held devices-GPS, etc.)
- **Data Input/Conversion**
  - Keyboard entry of coordinates
  - Digitizing/Scanning/Raster-to-Vector
  - Editing/Building Topology
- **Data Integration**
  - Georeferencing/Geocoding

About Geographic Data

- Conversion of hardcopy to digital maps is the most time-consuming task in GIS
- Up to 80% of project costs
- Labor intensive, tedious and error-prone

Data Inventory

- **National overview maps**
  - 1:250,000 and 1:5,000,000 (small scale)
  - show major civil divisions, urban areas, physical features such as roads, rivers, lakes, elevation, etc.
  - used for planning purposes

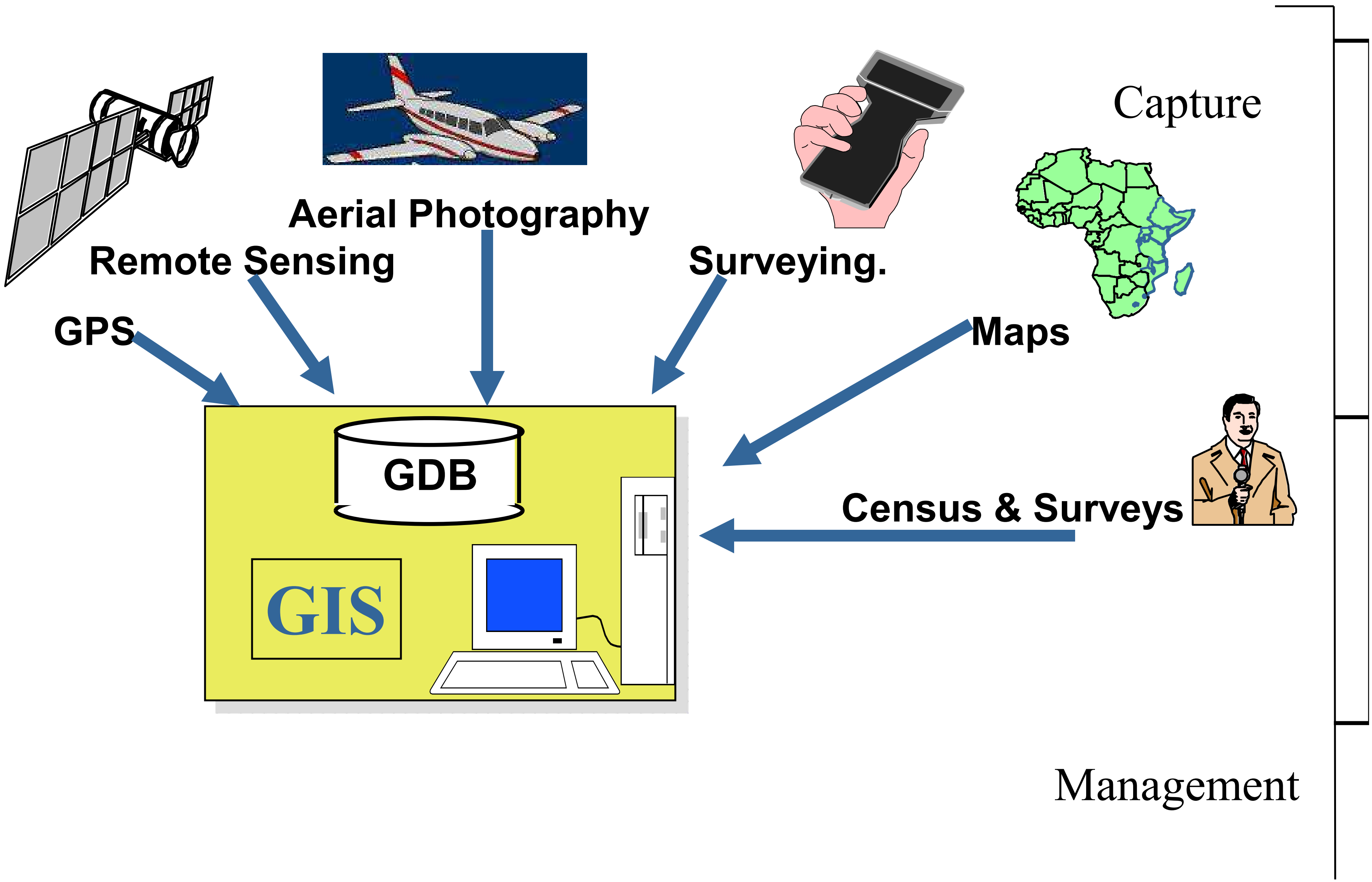
Data Inventory (cont.)

- Topographic maps- scales range from 1:25,000 to 250,000 (mid-scale)
- Town and city maps at large cartographic scales, showing roads, city blocks, parks, etc. (1:1,000 to 1:5,000)
- Maps of administrative units at all levels of civil division
- Thematic maps showing population distribution for previous census dates, or any features that may be useful for census mapping

Existing Digital Data

- Digital maps
- Satellite imagery
- GPS coordinates
- Etc.

Data Collection



Aerial photography

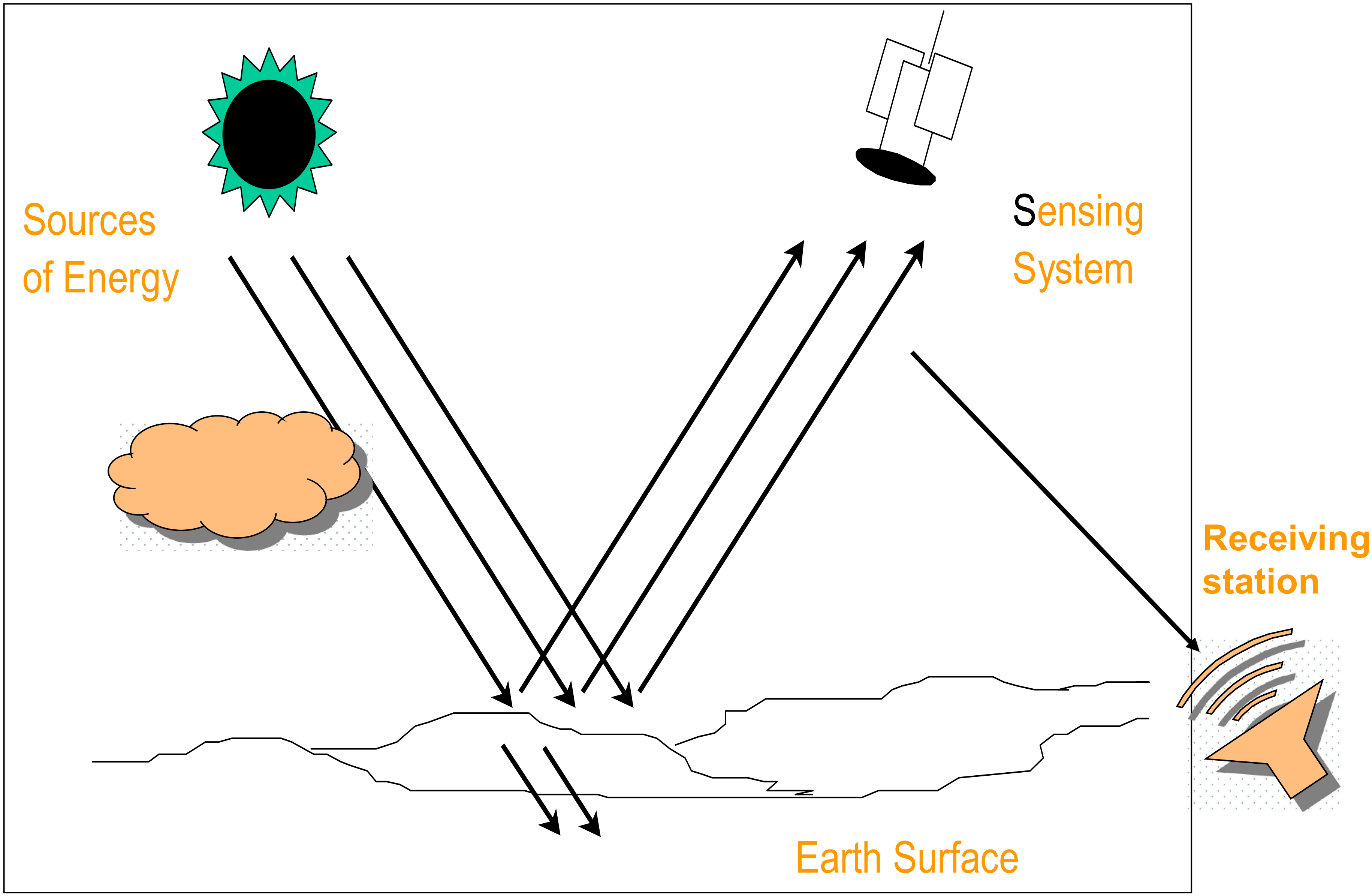
- Aerial photography is obtained using specialized cameras on-board low-flying planes. The camera captures the image digitally or on photographic film.
- Aerial photography is the method of choice for mapping applications that require high accuracy and a fast completion of the tasks.
- Photogrammetry—the science of obtaining measurements from photographic images.

Aerial photography (cont.)

- Traditional end product: printed photos
- Today: digital image (scanned from photo) in standard graphics format (TIFF, JPEG) that can be integrated in a GIS or desktop mapping package
- Trend: fully digital process
- digital orthophotos
  - corrected for camera angle, atmospheric distortions and terrain elevation
  - georeferenced in a standard projection (e.g. UTM)
  - geometric accuracy of a map
  - large detail of a photograph


ArcView GIS Version 3.0a
File
Edit
View
Theme
Analysis
Graphics
Window
Help
Scale 1:
230,377.07
903,859.38
View1
CB map
233d.tif
233c.tif
233b.tif
233a.tif

Remote sensing process



GPS

- Collection of point data, Stored as “waypoints” and Accuracy dependent on device and environmental variables

Surveying

- Paper Based, Manual recording of information, Electronic Based and Handheld device

Geographic data input/conversion

- Keyboard entry of coordinates
- Digitizing
- Scanning and raster to vector conversion
- Field work data collection using
- Global positioning systems
- Air photos and remote sensing

Keyboard entry

- keyboard entry of coordinate data
- e.g., point lat/long coordinates
  - from a gazetteer (a listing of place names and their coordinates)
  - from locations recorded on a map

Latitude/Longitude coordinate conversion

- Latitude is y-coo, Longitude is x-coo
- Common format is

  degrees, minutes, seconds

  113º 15’ 23” W 21º 56’ 07” N
- To represent lat/long in a GIS, we need to convert to decimal degrees

  -113.25639 21.93528
- DD = D + (M + S / 60) / 60

Data Conversion

- Conversion is often the easiest form to import digital spatial data into a GIS
- Data transfer often rely on the exchange of data in mostly **proprietary** file formats using the import/export functions of commercial GIS packages
- Open source data Conversion software becoming widely available

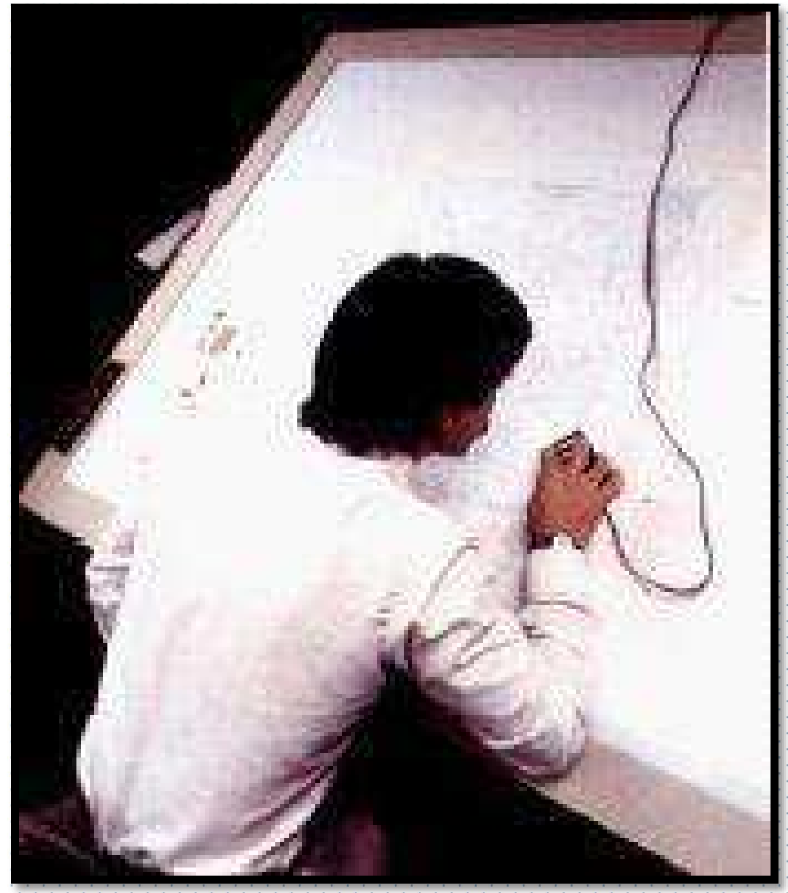
Conversion of hardcopy maps to digital data

- Turning features that are visible on a hardcopy map into digital point, line, polygon, and attribute information
- In many GIS projects this is the step that requires by far the largest time and resources
- Newer methods are arising to minimize this difficult step

Conversion of hardcopy maps to digital data (cont.)

- Digitizing: Manual digitizing and Heads-up digitizing
- Scanning
- Raster-to-Vector

Manual Digitizing



Most common form of coordinate data input

- Requires a digitizing table
- Ranging in size (25x25 cm to 150x200cm)
- Ideally the map should be flat and not torn or folded
- Cost: hundreds (300) to thousands (5000)

Digitizing steps (how points are recorded)

- trace features to be digitized with pointing device (cursor)
- point mode: click at positions where direction changes
- stream mode: digitizer automatically records position at regular intervals or when cursor moved a fixed distance

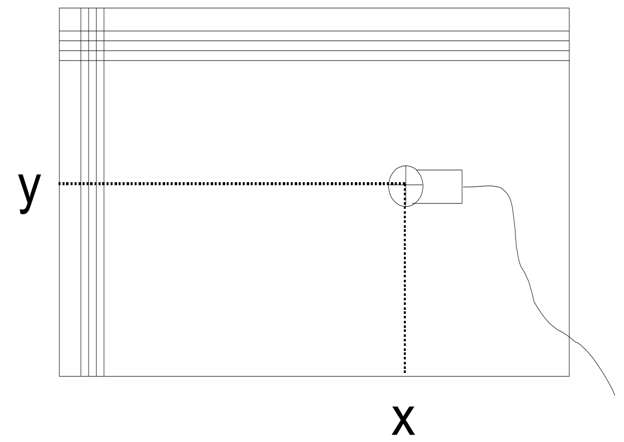
Control Points

- If a large map is digitized in several stages and the map has to be removed from the digitizing table occasionally, the control points allow the exact re-registration of the map on the digitizing board.

- Control points are chosen for which the real-world coordinates in the base map’s projection system are known.

Digitizing table

- Grid of wires in the table creates a magnetic field which is detected by the cursor



- X/Y coordinates in digitizing units are fed directly into GIS

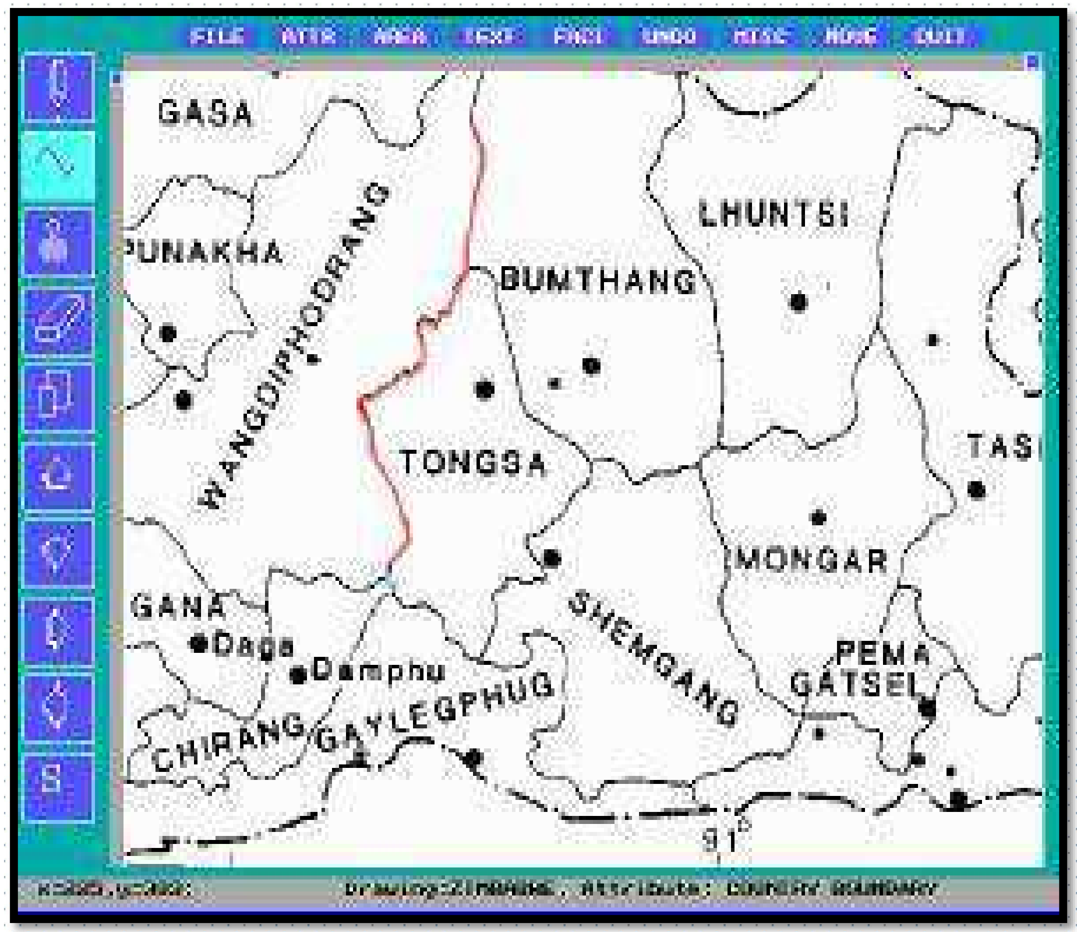
- High precision in coordinate recording

Heads-Up Digitizing

- Common today is heads-up digitizing, where the operator uses a scanned map, air photo or satellite image as a backdrop and traces features with a mouse
- This method yields more accurate results
- Quicker and easier to retrace and save steps

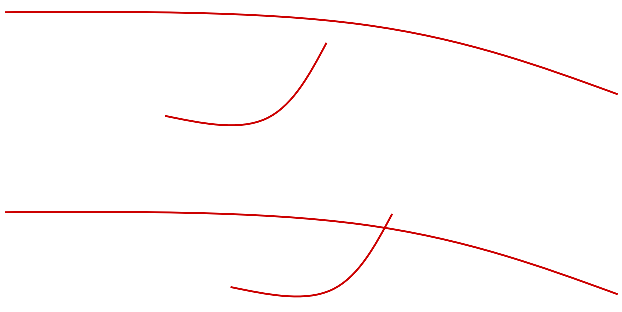
Heads-Up Digitizing

- Raster-scanned image on the computer screen
- Operator follows lines on-screen in vector mode



Digitizing Errors

- Undershoots
- Dangles
- False Polygons



Digitizing errors

- Any digitized map requires considerable post-processing
- Check for missing features
- Connect lines
- Remove false polygons
- Some of these steps can be automated

Fixing Errors

- Some of the common digitizing errors shown in the figure can be avoided by using the digitizing software's snap tolerances that are defined by the user
- For example, the user might specify that all endpoints of a line that are closer than 1 mm from another line will automatically be connected (snapped) to that line
- Small sliver polygons that are created when a line is digitized twice can also be automatically removed

Advantages and Disadvantages of Digitizing

Advantages

- It is easy to learn and thus does not require expensive skilled labor
- Attribute information can be added during digitizing process
- High accuracy can be achieved through manual digitizing; i.e., there is usually minimal loss of accuracy compared to the source map

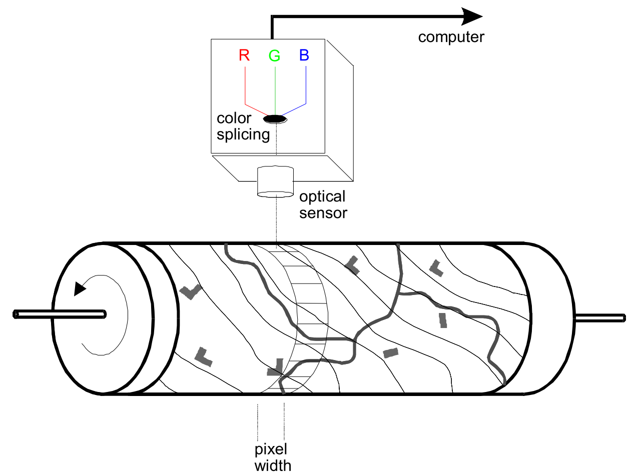
Disadvantages

- It is a tedious activity, possibly leading to operator fatigue and resulting quality problems which may require considerable post-processing
- It is slow. Large-scale data conversion projects may thus require a large number of operators and digitizing tables
- The accuracy of digitized maps is limited by the quality of the source material

Scanning: A viable alternative to digitizing

- The map is placed onto the scanning surface where light is directed at the map at an angle
- A photosensitive device records the intensity of light reflected for each cell or pixel in a very fine raster grid
- In gray scale mode, the light intensity is converted directly into a numeric value, for example into a number between 0 (black) and 255 (white)
- In binary mode, the light intensity is converted into white or black (0/1) cell values according to a threshold light intensity
  - Electronic detector moves across map and records light intensity for regularly shaped pixels
  - Flat-bed scanner
  - Drum-scanner (pictured)

Scanning (cont.)



Types of scanners

- Flat
  - small format, low cost, good for small tasks
- Drum
  - high precision but expensive and slow Feed
  - fast, good precision, lower cost than drum

  - direct use of scanned images
  - e.g., scanned air-photos
  - digital topographic maps in raster format

Scanning (cont.)

- Scanner output is a raster data set usually needs to be converted into a
- Vector representation

  - manually (on-screen digitizing)

  - automated (raster-vector conversion)

  line-tracing - e.g., MapScan
- Often requires considerable editing

Advantages and Disadvantages of Scanning

Advantages

- Scanned maps can be used as image backdrops for vector information
- Scanned topographic maps can be used in combination with digitized boundaries
- Clear base maps or original color separations can be vectorized relatively easily using raster-to-vector conversion software
- Small-format scanners are relatively inexpensive and provide quick data capture

Advantages and Disadvantages of Scanning

Disadvantages

- Converting large maps with a small format scanners requires tedious re-assembly of the individual parts
- Despite recent advances in vectorization software associated with scanning, considerable manual editing and attribute labeling may still be required

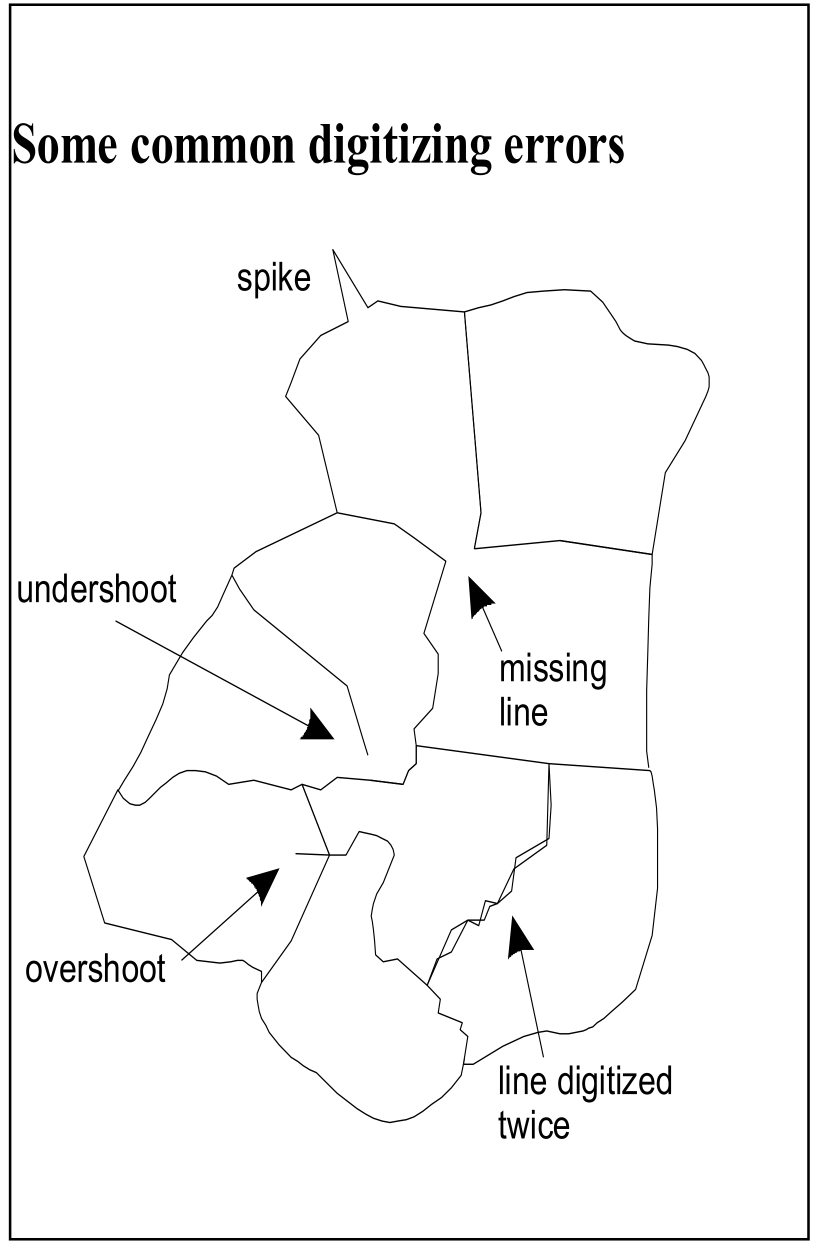
Raster to Vector Conversion

Gets scanned/image data into vector format

- **Automatic** mode: the system converts all lines on the raster image into sequences of coordinates automatically. automated raster to vector process starts with a line thinning algorithm
- **Semi-automatic** mode, the operator clicks on each line that needs to be converted; system then traces that line to the nearest intersections and converts it into a vector representation

Editing

- Manual digitizing is error prone
- Objective is to produce an accurate representation of the original map data
- This means that all lines that connect on the map must also connect in the digital database
- There should be no missing features and no duplicate lines
- The most common types of **errors;** Reconnect disconnected line segments, etc.



Building Topology

- GIS determines relationships between features in the database
- System will determine intersections between two or more roads and will create nodes
- For polygon data, the system will determine which lines define the border of each polygon
- After the completed digital database has been verified to be error-free
- The final step is adding additional attributes

- The building of relationships between objects
- Feature topology describes the spatial relationships between connecting or adjacent geographic features such as roads connecting at intersections
- The user typically does not have to worry about how the GIS stores topological information
- The user typically does not have to worry about how the GIS stores topological information

Converting Between Different Digital Formats

- All software systems provide links to other formats
- But the number and functionality of import routines varies between packages
- Problems often occur because software developers are reluctant to publish the exact file formats that their systems use -> instability of information (ex. file-geodatabase [.gdb])
- Option of using a third data format
  - Example: Autocad’s DXF format

Georeferencing/Geocoding

- Georeferencing
- Converting map coordinates to the **real world coordinates** corresponding to the source map’s cartographic projection.
- Attaching **codes** to the digitized features (geocoded feature)
- each line representing a road would obtain a code that refers to the road **status** (dirt road, one lane road, two lane highway, etc.)
- Or a unique code that can be linked to a list of street names.

For attribute data:

- **spreadsheets**
- **links to external database**
- **management systems (DBMS)**
- **tabulation programs**

Elements of Visual Interpretation

Recognizing targets is the key to interpretation and information extraction. Observing th differences between targets and their backgrounds involves comparing different targets based on any, or all, of the visual elements of **tone, shape, size, pattern, texture, shadow, and association**.

Tone refers to the relative brightness or colour of objects in an image. Generally, tone is the fundamental element for distinguishing between different targets or features. Variations in tone also allows the elements of shape, texture, and pattern of objects to be distinguished.

Shape refers to the general form, structure, or outline of individual objects. Shape can be a very distinctive clue for interpretation. Straight edge shapes typically represent urban or agricultural (field) targets, while natural features, such as forest edges, are generally more irregular in shape, except where man has created a road or clear cuts. Farm or crop land irrigated by rotating sprinkler systems would appear as circular shapes.

Size of objects in an image is a function of scale. It is important to assess the size of a target relative to other objects in a scene, as well as the absolute size, to aid in the interpretation of that target. A quick approximation of target size can direct interpretation to an appropriate result more quickly. For example, if an interpreter had to distinguish zones of land use, and had identified an area with a number of buildings in it, large buildings such as factories or warehouses would suggest commercial property, whereas small buildings would indicate residential use.

Pattern refers to the spatial arrangement of visibly discernible objects. Typically an orderly repetition of similar tones and textures will produce a distinctive and ultimately recognizable pattern. Orchards with evenly spaced trees, and urban streets with regularly spaced houses are good examples of pattern.

Texture refers to the arrangement and frequency of tonal variation in particular areas of an image. Rough textures would consist of a mottled tone where the grey levels change abruptly in a small area, whereas smooth textures would have very little tonal variation. Smooth textures are most often the result of uniform, even surfaces, such as fields, asphalt, or grasslands. A target with a rough surface and irregular structure, such as a forest canopy, results in a rough textured appearance. Texture is one of the most important elements for distinguishing features in radar imagery.

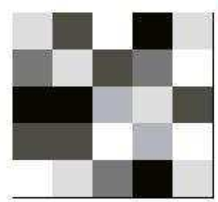
Shadow is also helpful in interpretation as it may provide an idea of the profile and relative height of a target or targets which may make identification easier. However, shadows can also reduce or eliminate interpretation in their area of influence, since targets within shadows are much less (or not at all) discernible from their surroundings. Shadow is also useful for enhancing or identifying topography and landforms, particularly in radar imagery.

Association takes into account the relationship between other recognizable objects or features in proximity to the target of interest. The identification of features that one would expect to associate with other features may provide information to facilitate identification. In the example given above, commercial properties may be associated with proximity to major transportation routes, whereas residential areas would be associated with schools, playgrounds, and sports fields. In our example, a lake is associated with boats, a marina, and adjacent recreational land.

DIGITAL IMAGE PROCESSING

Digital Image processing is a collection of techniques for manipulation of digital images by computers.

DIGITAL IMAGE: A digital remotely sensed image is typically composed of picture elements (pixels) located at the intersection of each row i and column j in each k bands of imagery. Associated with each pixel a number known as Digital Number (DN) or Brightness value (BV), that depicts the average radiance; of a relatively small area within a scene.



122	96	255	0	122
100	125	96	100	235
0	0	122	130	96
84	84	255	122	
200	122	100	0	122

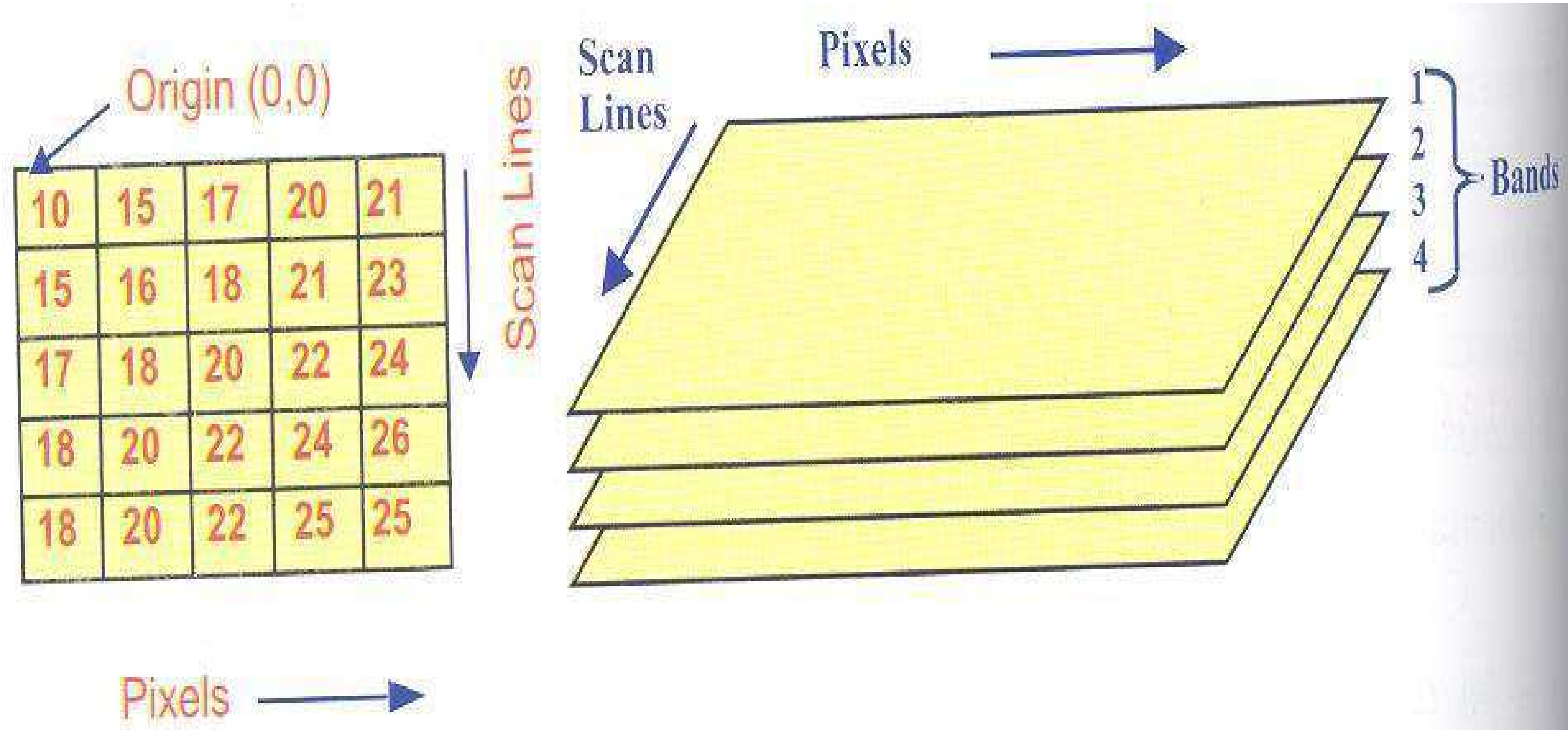


Figure 1 : Structure of a Digital Image and Multispectral Image

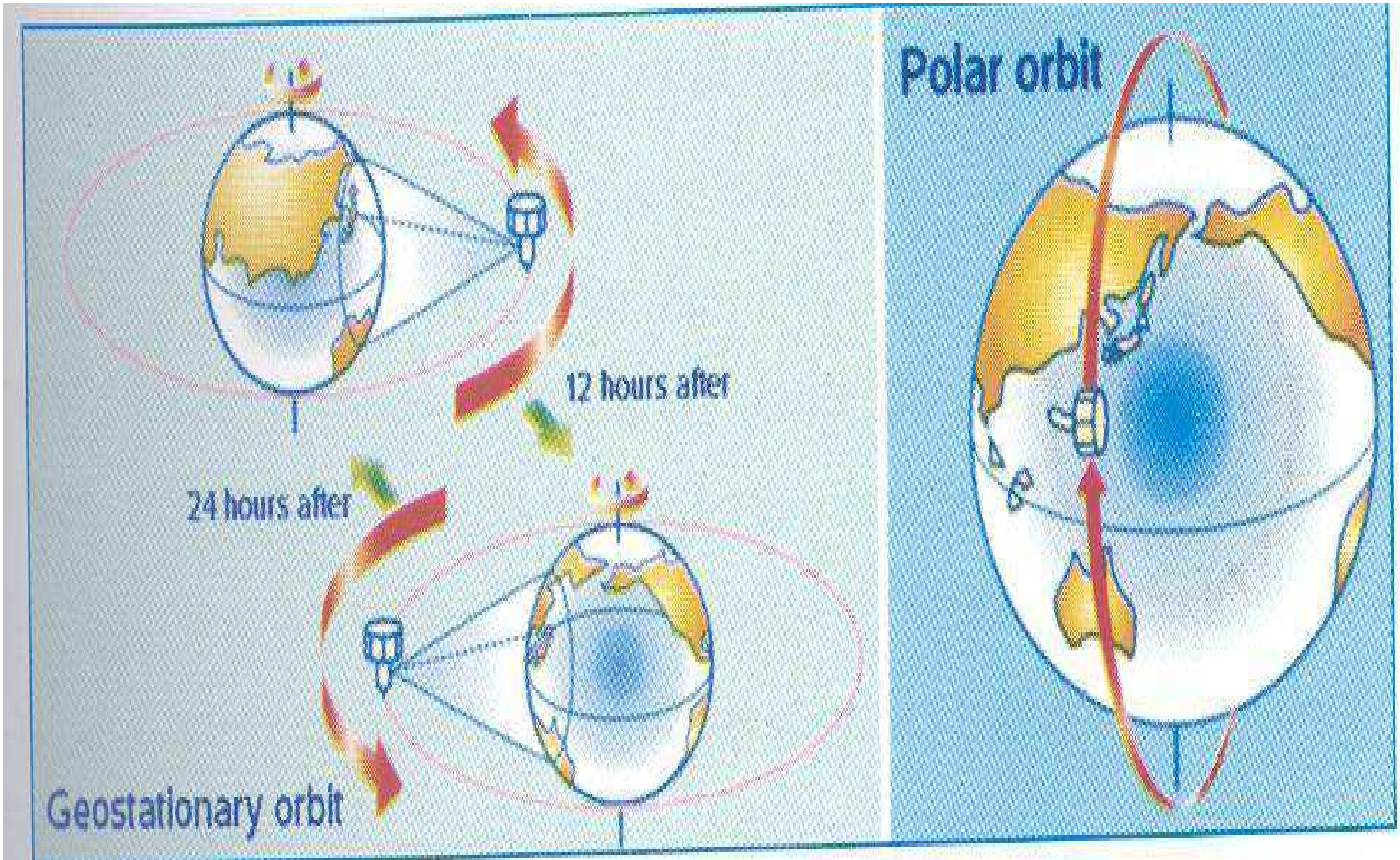


Figure 1 : Geostationary and Polar orbits

$$c = \nu\lambda.$$

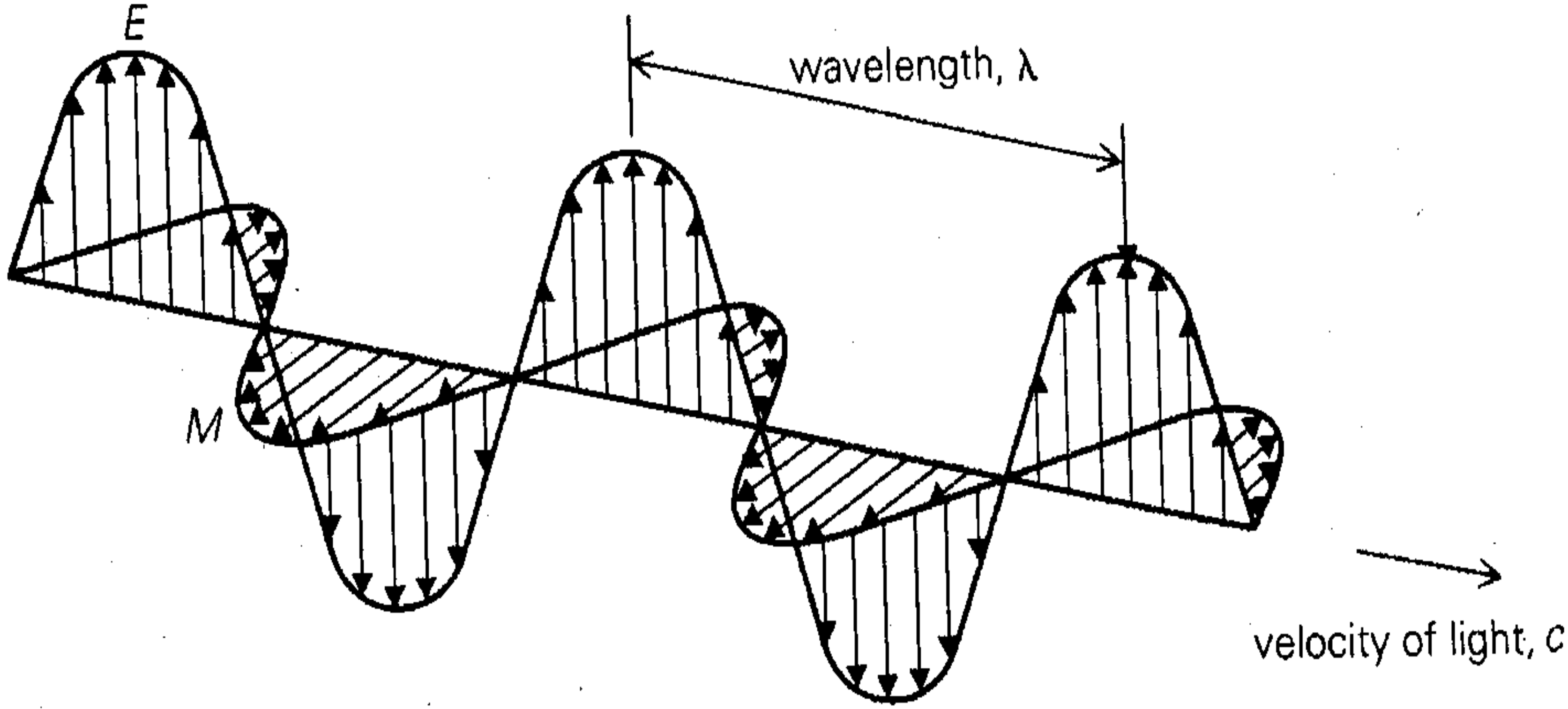


Figure 2: Electromagnetic wave. It has two components, Electric field E and Magnetic field M, both perpendicular to the direction of propagation

Table 2: Principal Divisions of the Electromagnetic Spectrum

Wavelength	Description
Gamma rays	Gamma rays
X-rays	X-rays
Ultraviolet (UV) region 0.30 µm - 0.38 µm (1µm = 10^{-6}m)	This region is beyond the violet portion of the visible wavelength, and hence its name. Some earth's surface material primarily rocks and minerals emit visible UV radiation. However UV radiation is largely scattered by earth's atmosphere and hence not used in field of remote sensing.
Visible Spectrum 0.4 µm - 0.7 µm Violet 0.4 µm -0.446 µm Blue 0.446 µm -0.5 µm Green 0.5 µm - 0.578 µm Yellow 0.578 µm - 0.592 µm Orange 0.592 µm - 0.62 µm Red 0.62 µm -0.7 µm	This is the light, which our eyes can detect. This is the only portion of the spectrum that can be associated with the concept of color. Blue Green and Red are the three primary colors of the visible spectrum. They are defined as such because no single primary color can be created from the other two, but all other colors can be formed by combining the three in various proportions. The color of an object is defined by the color of the light it reflects.
Infrared (IR) Spectrum 0.7 µm – 100 µm	Wavelengths longer than the red portion of the visible spectrum are designated as the infrared spectrum. British Astronomer William Herschel discovered this in 1800. The infrared region can be divided into two categories based on their radiation properties. Reflected IR (.7 µm - 3.0 µm) is used for remote sensing. Thermal IR (3 µm - 35 µm) is the radiation emitted from earth's surface in the form of heat and used for remote sensing.
Microwave Region 1 mm - 1 m	This is the longest wavelength used in remote sensing. The shortest wavelengths in this range have properties similar to thermal infrared region. The main advantage of this spectrum is its ability to penetrate through clouds.
Radio Waves (>1 m)	This is the longest portion of the spectrum mostly used for commercial broadcast and meteorology.

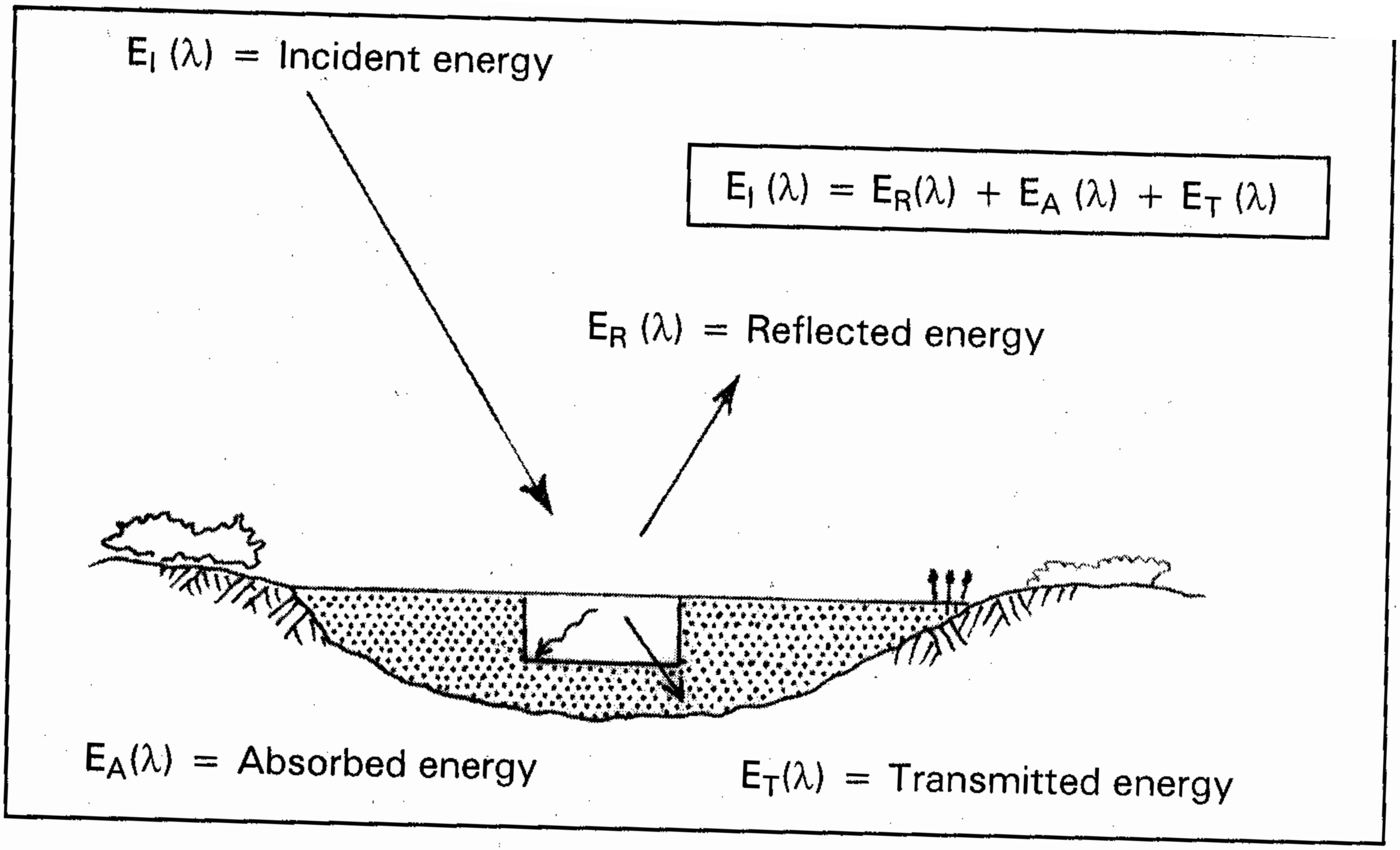


Figure 3: Interaction of Energy with the earth's surface. (source: Liliesand & Kiefer, 1993)

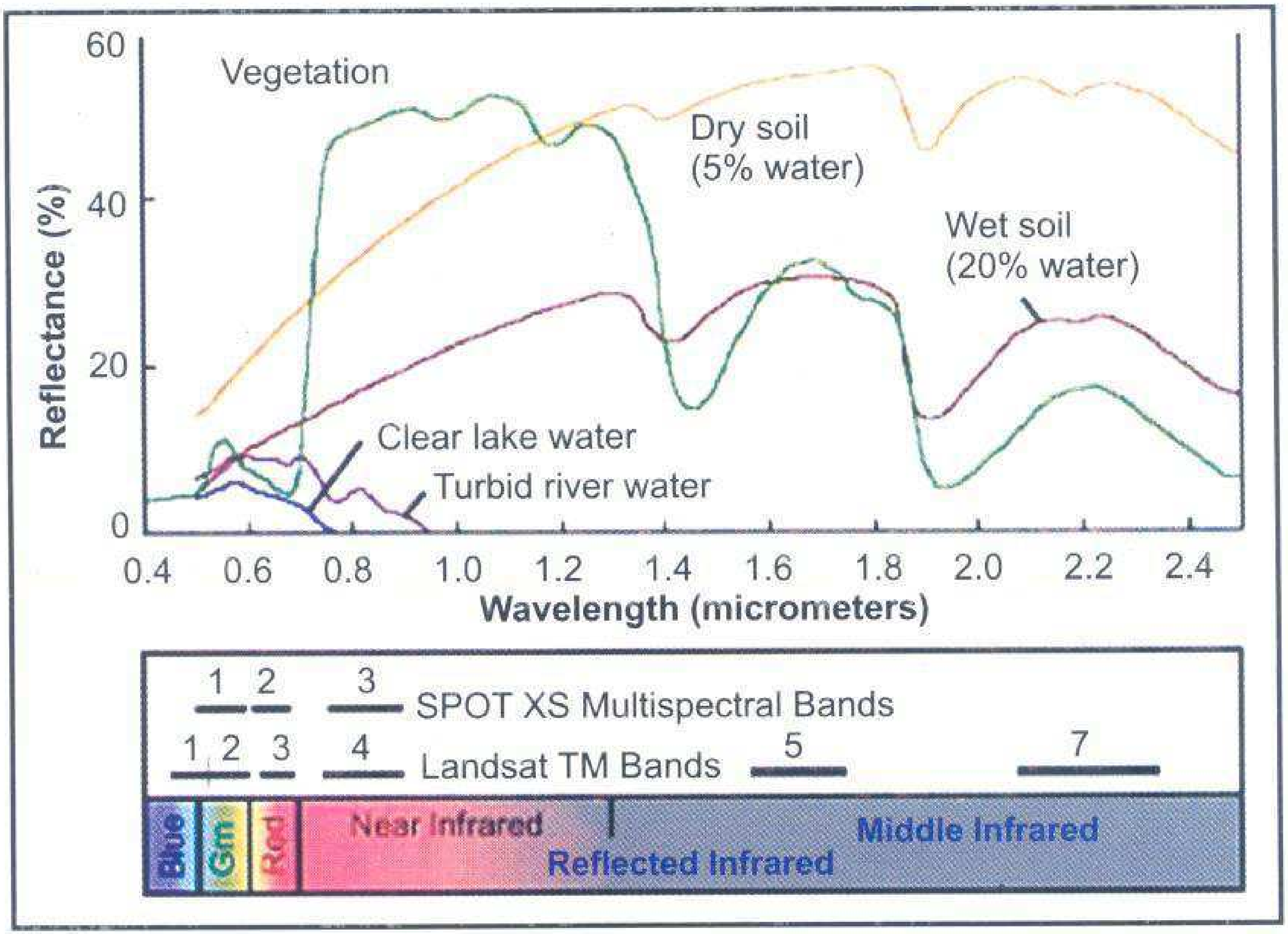


Figure 5. Typical Spectral Reflectance curves for vegetation, soil and water

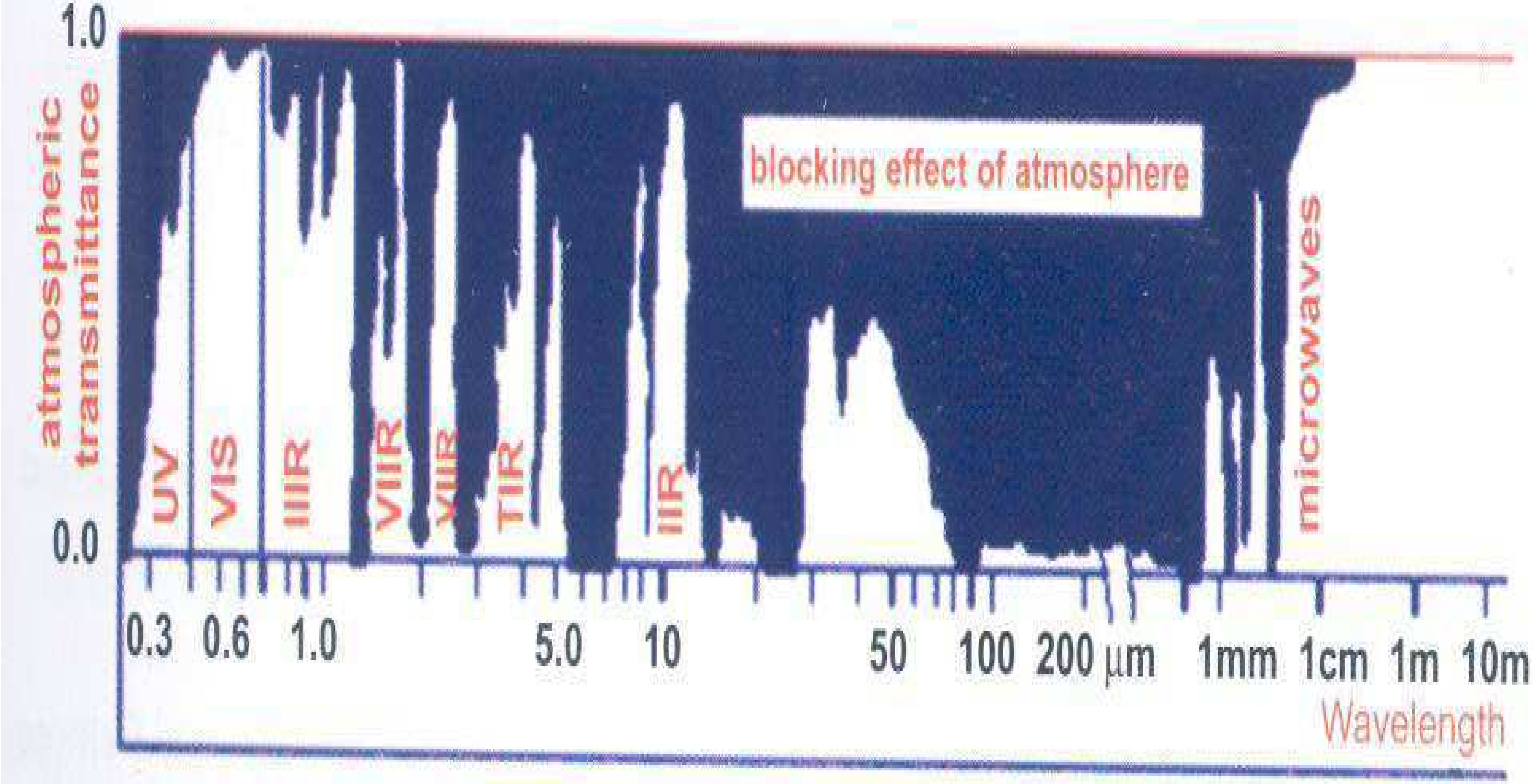


Figure 6 : Atmospheric windows

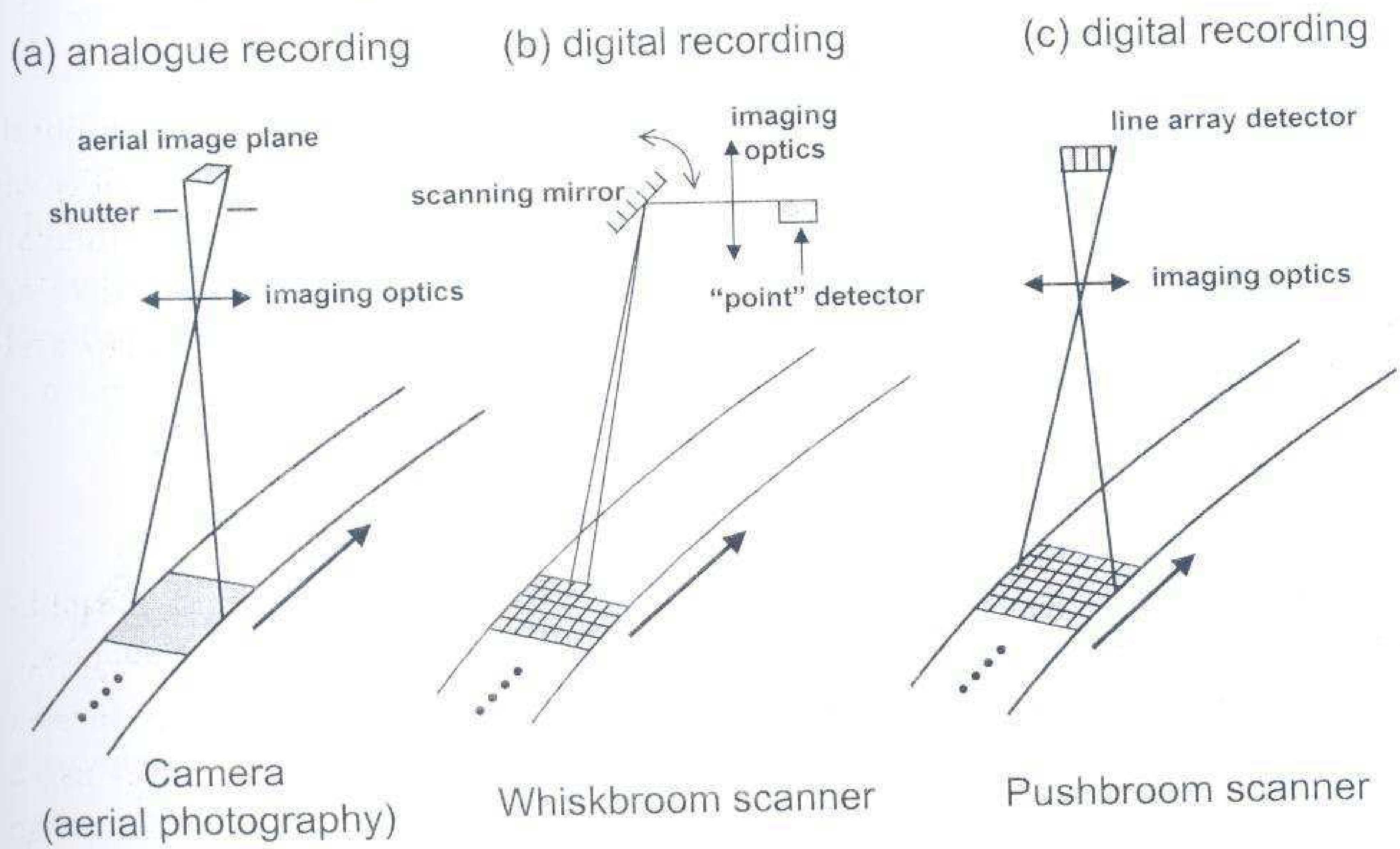


Figure 5. Principle of imaging sensor systems; (a) framing system, (b) whiskbroom scanner, (c) pushbroom scanner. (source :http://cgi.girs.wageningen-ur.nl/igi-new)

Table 1. Thermal Sensors

	HCMM	TM
Operational period	1978-1980	1982 to present
Orbital altitude	620 mm	705 km
Image coverage	700 by 700 km	185 by 170 km
Acquisition time, day	1:30 p.m.	10:30 a.m.
Acquisition time, night	2:30 a.m.	9:30 p.m.
Visible and reflected IR detectors		
Number of bands	1	6
Spectral range	0.5 0 - 1.1 µm	0.4 - 2.35 µm
Ground resolution cell	500 by 500 m	30 by 30 m
Thermal IR detector		
Spectral range	10.5 - 12.5 µm	10.5 - 12.5 µm
Ground resolution cell	600 by 600 m	120 by 120m 60 m by 60 m in Landsat 7

Table 2. Microwave Sensors

	Seasat SAR	SIR-C/X-SAR	ESA SAR	RADARSAT SAR	ENVISAT ASAR	JERS-1
Frequency	1.275 GHz	5.3 GHz 1.275 GHz	5.3 GHz	5.33 GHz	5.33 GHz	1.275 GHz
Wave length	L band 23 cm	X band 3 cm C band 6 cm L band 23 cm	C band	C band	C band	L Band (23 cm)
Swath Width	100 km, centered 20° off nadir	15 to 90 km Depend on orientation is antenna	100 km	45-510 km Varies	5 km – 100 km Varies	75 km
Ground Resolution	25 x 25 m	10 to 200 m	30 m	100x100 m to 9x9 m Varies	Varies	30 m

Table 3. Operational Earth Observation Satellites

EUROPE		MIDDLE EAST	NORTH AMERICA			ASIA	
France	ESA	Israel	USA		Canada	India	Japan
SPOT1-1986 10m			LANDSAT5 -85, 30m				
SPOT2-90 10m	ERS1-92/00 Radar		LANDSAT6-93				
SPOT3-93/96	ERS2-95 Radar		EARLYBIRD -98	IKONOS1-99, 1m	RADARSAT-95	IRS1C-95 6m	
SPOT4-98 10m	ENVISAT-2001Radar		LANDSAT7-99, 15m	IKONOS2 -99, 1m		IRS1D-97 6m	
		EROS A/ 1-00 2m	QUICKBIRD-01, 0.6m	ORBVIEW-01, 1m			
SPOT5-02 3m+ HRS10		EROS B/ 1-02, 1m		ORBVIEW -02, 1m	RADARSAT -03	IRS-P6-03, 6MMSS	ALOS-03, 2.5m
Distribution							
SPOT IMAGING	Miscellaneous	Imagesat	SI-EOSAT, Earthwatch, Orbimage, USGS		RADARSAT	NRSA-EOSAT	JSI

Table 4. Characteristics of Landsat-1 to -7 Missions

Sensor-system	Spectral resolution (μm)	Spatial resolution (m)	Scan-width (km)	Time interval Equator	Orbital altitude	Operation period
MSS	Band 4: 0.5 - 0.6	79×79	185	18 days	918 km	Landsat 1 23/07/1972-06/01/1978 Landsat 2 22/01/1975 -25/02/1982 Landsat 3 05/03/1978 - 30/11/1982
	Band 5: 0.6 - 0.7	79×79				
	Band 6: 0.7 - 0.8	79×79				
	Band 7: 0.8 - 1.1	79×79				
MSS	As Landsat 3		185	16 days	710 km	Landsat 4 16/07/1982 - 02/1983 Landsat 5 01/03/1984 -
TM	Band 1:0.45- 0.52	30×30				
	Band 2: 0.52 - 0.60	30×30				
	Band 3:0.63 - 0.69	30×30				
	Band 4:0.76 - 0.90	30×30				
	Band 5:1.55 -1.75	30×30				
	Band 6:10.40-12.50	120×120				
	Band 7:2.08 - 2.35	30×30				
TM	As Landsat 4-5	30x30	185	16 days	705 km	Landsat 7 15/04/1999 -
	Band 6:10.40 - 12.50	60×60				
	Panchromatic: 0.50 - 0.90	15×15				

Table 8. Envisat's Instrument
(source: www.esa.int/export/esasa/ESADTOMBAMC_earth_O.html)

Instrument	Main purpose
Global ozone monitoring by occultation of stars (GOMOS)	To observe the concentration of ozone in the stratosphere.
Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY)	To measure trace gases and aerosol concentrations in the atmosphere.
Michelson interferometer for passive atmospheric sounding (MIPAS)	To collect information about chemical and physical processes in the stratosphere, such as those that will affect ozone concentration in future.
Medium resolution imaging Spectrometer (MERIS)	Measures radiation in 15 frequency bands that give information about ocean biology, marine water quality, and vegetation on land, cloud and water vapor.
Advanced synthetic aperture Radar (ASAR)	All weather, day or night radar imaging.
Advanced along track scanning radiometer (AATSR)	To measure sea-surface temperature, a key parameter in determining the existence and/or extent of global warming.
Radar Altimeter (RA-2)	Measures distance from satellite to Earth. So can measure sea-surface height, an important measurement for monitoring El Nino, for example.
Microwave radiometer (MWR)	Allows corrections to be made to radar altimeter data.
Doppler Orbitography and Radio positioning integrated by satellite (DORIS)	Gives the position of Envisat in its orbit to within a few centimeters. This is crucial to understanding the measurements all the instruments make.
Laser retro-reflector (LRR)	Reflects pulsed laser to ground stations to help determine the satellite's exact position in its orbit.

Table 9. Characteristics of some more commercially available satellites

Satellite Name	Launch	Sensors	Types	No. of Bands	Spectral Range (microns)	Resolution (metres)	Swath Width (km)	Revisit Time
QuickBird-2	Oct. 18, 2001		Multi-spectral	4	blue (0.45-0.52)	2.5	17	
					green (0.52-0.6)			
					red (0.63-0.69)			
					NIR.(76-0.89)			
			Pan	1	0.45-0.9	0.61		
EROS 1	Dec. 5, 2000		Pan	1	0.5-0.9	1.8	12.5	1-4 days
EO 1	Nov. 21, 2000	ALI	Multi	9	0.433-0.453			
					0.45-0.515			
					0.525-0.605			
					0.63-0.69			
					0.775-0.805			
					0.845-0.89			
					1.2-1.3			
					1.55-1.75			
					2.08-2.35	30	37	16 days
			Pan	1	0.48-0.69	10		
		Hyperion	Hyper	220	0.4 to 2.5 (10nm sampling interval)	30	7.5 km x 100 km	

contd...

Satellite Name	Launch	Sensors	Types	No. of Bands	Spectral Range (microns)	Resolution (metres)	Swath Width (km)	Revisit Time
		LAC	Hyper	256	0.9-1.6 (2-6nm sampling interval)	250	185 km	
Terra (EOS AM-1)	Dec. 18, 1999	ASTER	Multi	3	VNIR - stereo (0.5-0.9)	15	60	16 days
				6	SWIR (1.6-2.5)	30		
				5	TIR (8-12)	90		
		CERES	Multi	3	SWIR, TIR, Total	20 km		
		MISR	Multi	4		250-275	360	
		MODIS	Multi	2	0.4-14.4	250	2330	
				5		500		
				29		1000		
		MOPITT	Multi	3	2.3 (CH4)	22 km	640	
					2.4 (CO)			
					4.7 (CO)			
CBERS	October 14, 1999	WFI	Multi	2	0.66 (green)	260	890	5 days
					0.83 (NIR)			
		CCD (stereo)	Multi	5	0.51-0.73 (pan)	20	113	26 days
					0.45-0.52 (blue)			
					0.52-0.59 (green)			
					0.63-0.69 (red)			
					0.7-0.89 (NIR)			

contd...

Satellite Name	Launch	Sensors	Types	No. of Bands	Spectral Range (microns)	Resolution (metres)	Swath Width (km)	Revisit Time
		IR-MSS	Multi	4	0.5-1.1 (pan)	80	120	
					1.55-1.75 (IR)			
					2.08-2.35 (IR)			
					10.4-12.5 (TIR)	160		
KITSAT-3	May 26, 1999	CCD	Multi	3	red, green, NIR	15		
			Pan	1		15		
NOAA-K	May - 1998	AVHRR	Multi	5		1100		
OrbView-2	August, 1997	SeaWiFS	Multi	8	0.402-0.422	1130	2,800	1 day
					0.433-0.453			
					0.48-0.5			
					0.50-0.52			
					0.545-0.565			
					0.66-0.68			
					0.745-0.785			
					0.845-0.885			
RADARSAT	November, 1995	SAR	Radar	1	C-band (HH polarization)	8-120		24 days
ERS-2	1995	AMI	Radar	1	5.3 GHz(C-band)	26	99	35 days
		ATSR	Multi	4		1000		

Satellite Name	Launch	Sensors	Types	No. of Bands	Spectral Range (microns)	Resolution (metres)	Swath Width (km)	Revisit Time
NOAA-14	1994	AVHRR	Multi	5		1100		
RESURS-O1-3	1994	MSU-SK	Multi	4	0.5-0.6 (green)	170	600	21 days
					0.6-0.7 (red)			
					0.7-0.8 (NIR)			
					0.8-1.1 (NIR)			
				1	10.4-12.6 (Thermal IR)	600		
JERS-1	February, 1992	SAR	Radar	1	1275 MHz (L-band, HH polarization)	18	75	44 days
		OPS	Multi	3	Visible NIR	18 x 24	75	
				4	SWIR			
ERS-1	1991	AMI	Radar	1	C band (VV polarization)	26		35 days
		ATSR	Multi	4		1000		
NOAA-12	1991	AVHRR	Multi	5		1100		

Table 1: Spectral characteristics and applications of AVHRR.

Channel	Spectral Interval (μm)	Resolution (km)	Application
1	0.58-0.88	1.1	Cloud Mapping
2	0.73-1.0	1.1	Surface water boundaries
3	3.55-3.93	1.1	Thermal mapping, cloud distribution, fire detection
4	10.3-11.3	1.1	Cloud Distribution, SST, WV correction
5	11.5-12.5	1.1	——do——

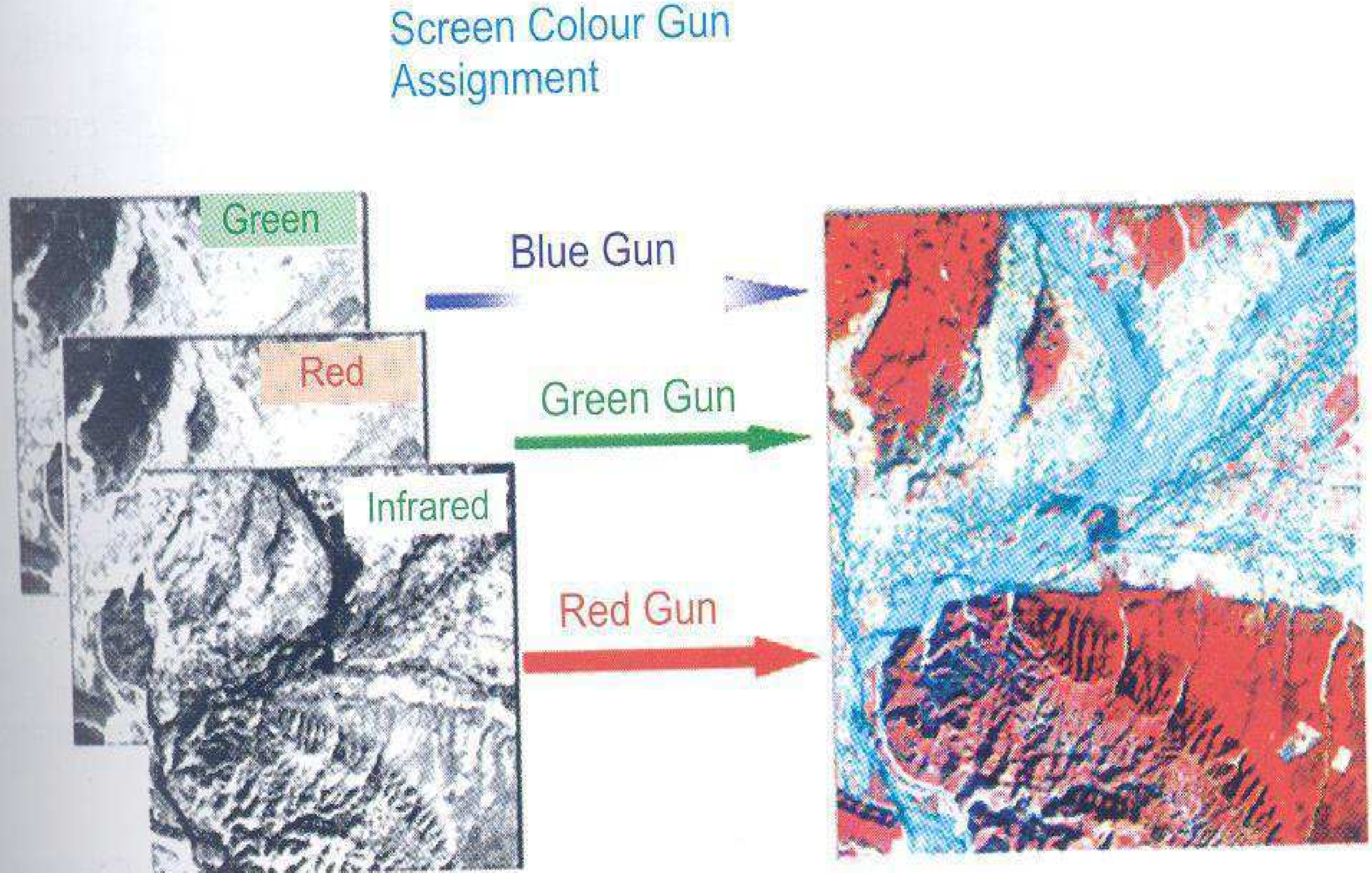


Figure 2: False Color Composite (FCC) of IRS : LISS II Poanta area

The procedure for digital image processing may be categorized into the following types of computer-assisted operations.

- **Image Rectification:** These operations aim to correct distorted or degraded image data to create a faithful representation of the original scene. This typically involves the initial processing of raw image data to correct for geometric distortion, to calibrate the data

- **Image Enhancement:** It involves techniques for increasing the visual distinction between features in a scene. It includes the following:

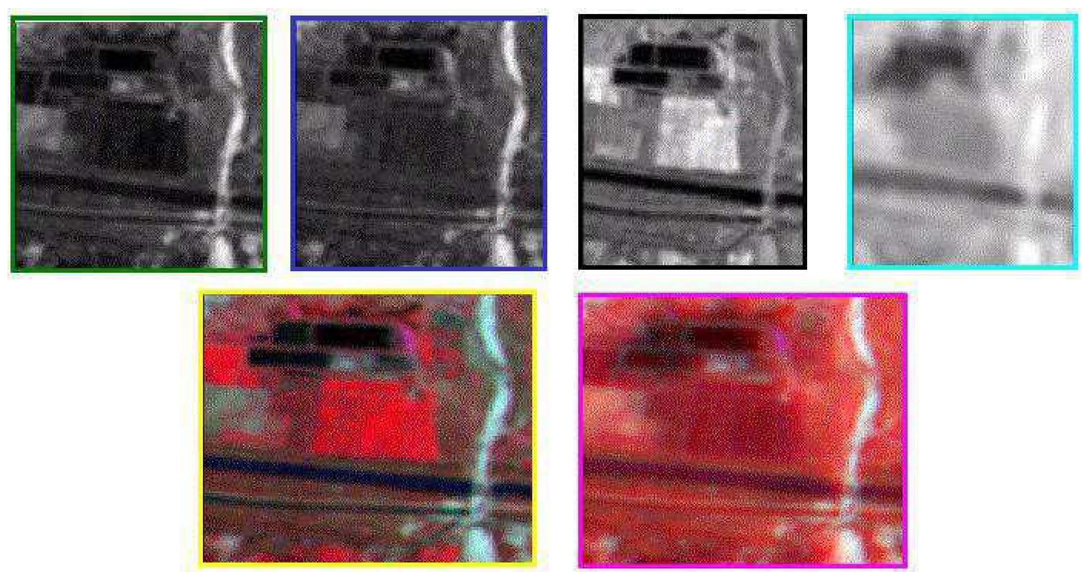
- Level slicing
- Contrast stretching
- Spatial filtering edge enhancement
- Spectral ratioing
- Principal components and intensity-hue- saturation
- Colour space transformations.

Assignment: write down about the types of resolutions

❑ Image Classification: It is a quantitative technique of analysing multi-spectral data for automating the identification of features in a scene. The intent of classification process is to categorize all pixels in a digital image into one of several land cover classes or themes.

❑ Colour Composites

- True colour composite
- A colour infrared composite
- Standard false colour composite (Fig.).



STANDARD FCC ORDINARY FCC

DIGITAL IMAGE PROCESSING

A. PREPROCESSING

1. Radiometric corrections

a) <u>Correction for Missing Scan Lines (Scan line drop out):</u>

Correction based on any of the following three methods

i) Replacement by either the preceding or the succeeding line

V_{ij}= Vij-1 or Vij= Vij+1

where Vij is a missing pixel value of pixel i and scan line j
Vij-1 represents pixel value of preceding scan line and
Vij+1 indicates pixel value of succeeding scan line

ii) Averaging of the neighbouring pixel values

Vij= Vij-1 += Vij+1/2

iii) Replacing the line with other highly correlated band.

b) <u>Correction for line striping (De-stripping):</u>

i) Linear Method

Due to detector imbalance, the mean and standard deviation of all (viz., 6 in case MSS, 24 in case of TM etc.) histograms are equalised

The overall standard deviation is given by:

$$\frac{\sqrt{\sum ni(xi^2+vi)-\underline{x}^2}}{\sum ni}$$

where $\underline{x}$ =overall mean, vi=variance of detector i, xi= mean of detector i , ni= no. of pixels processed by det I

ii)Histogram Matching (Non Linear)

The shape of the individual cummulative histogram is matched with the target histogram

iii) <u>Random Noise Correction</u>

Random noise means pixels having offset values from the normal. It can be easily corrected by means of a smoothing filter on the data.

2. Atmospheric corrections

i) Histogram minimum method (Dark pixel subtraction)

I°(I,j)=I(i,j) = I(i,j)-Bias
Where, I(i,j)=input pixel value at line I and samp-le j
I°(I,j)=Enhanced pixel value at the same location
The bias is the amount of offset for each spectral band

ii) Regression method

Pixel values of low reflectance under short wave IR region
are plotted against other spectral bands and a best fit (least squares)
straight line is computed using standard regression methods.
The offset on the X-axis in different bands is the atmospheric path
radiance and hence has to be subtracted from the respective image

3. Geometric Errors and corrections

a) Systematic Geometric Errors

These errors are caused due to the following:

- **Scan- Time Skew**
- **Sensor Mirror Sweep**
- **Panoramic Distortions**

a) Non-Systematic Geometric Errors

Such errors are caused due to the following:

- **Perspective projection**
- **Platform altitude**
- **Platform attitude**
- **Earth Rotation**
- **Spacecraft Velocity**

The above errors can be divided into the following two classes:

a) Those that can be corrected using data from platform and knowledge of internal sensor distortion and

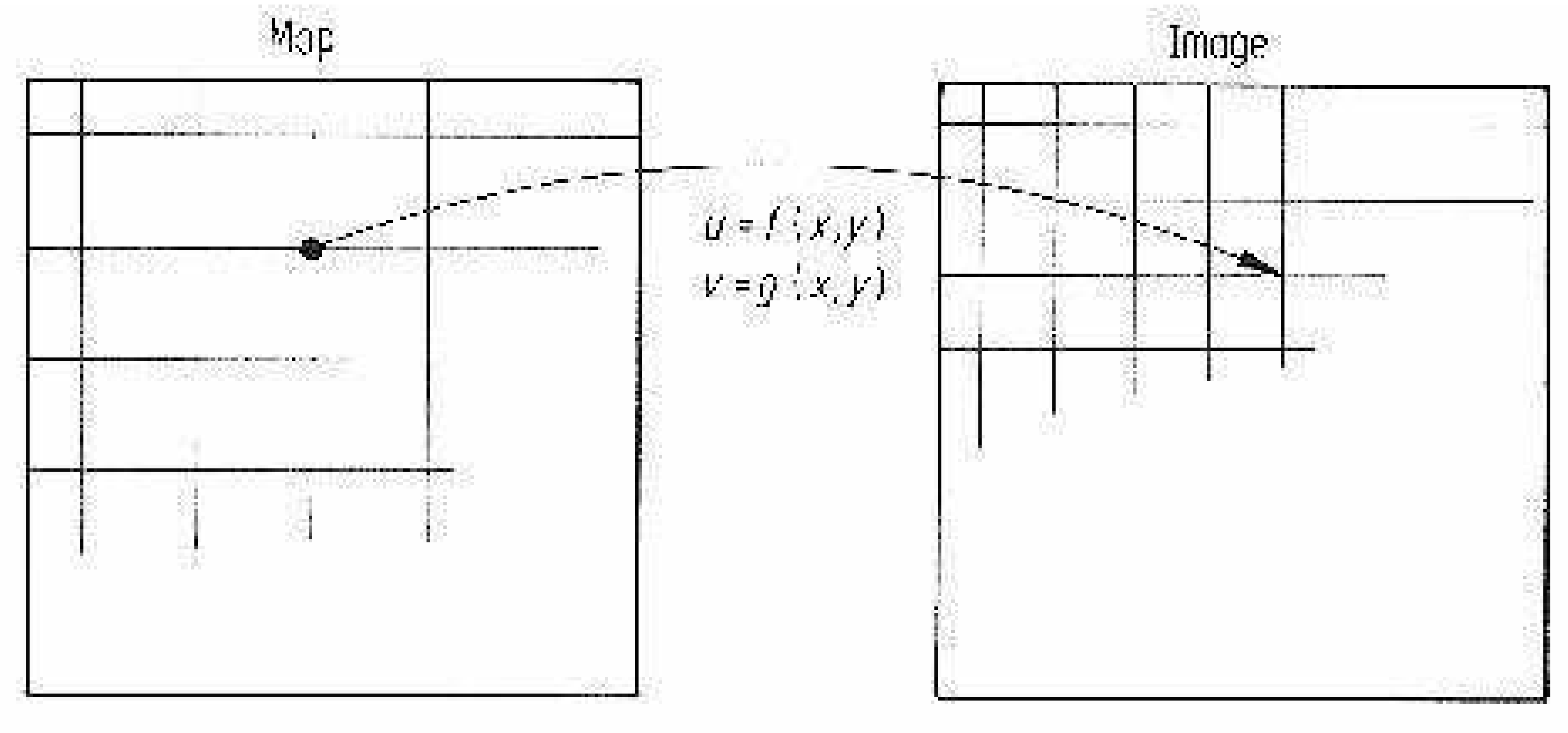
b) those that can not be corrected with acceptable limit of accuracy without a sufficient number of ground control points (GCP)

The errors caused by altitude and attitude are removed by interlinking the GCP'S of topographical map with the known reference points identified on digital image by using a computer software package.

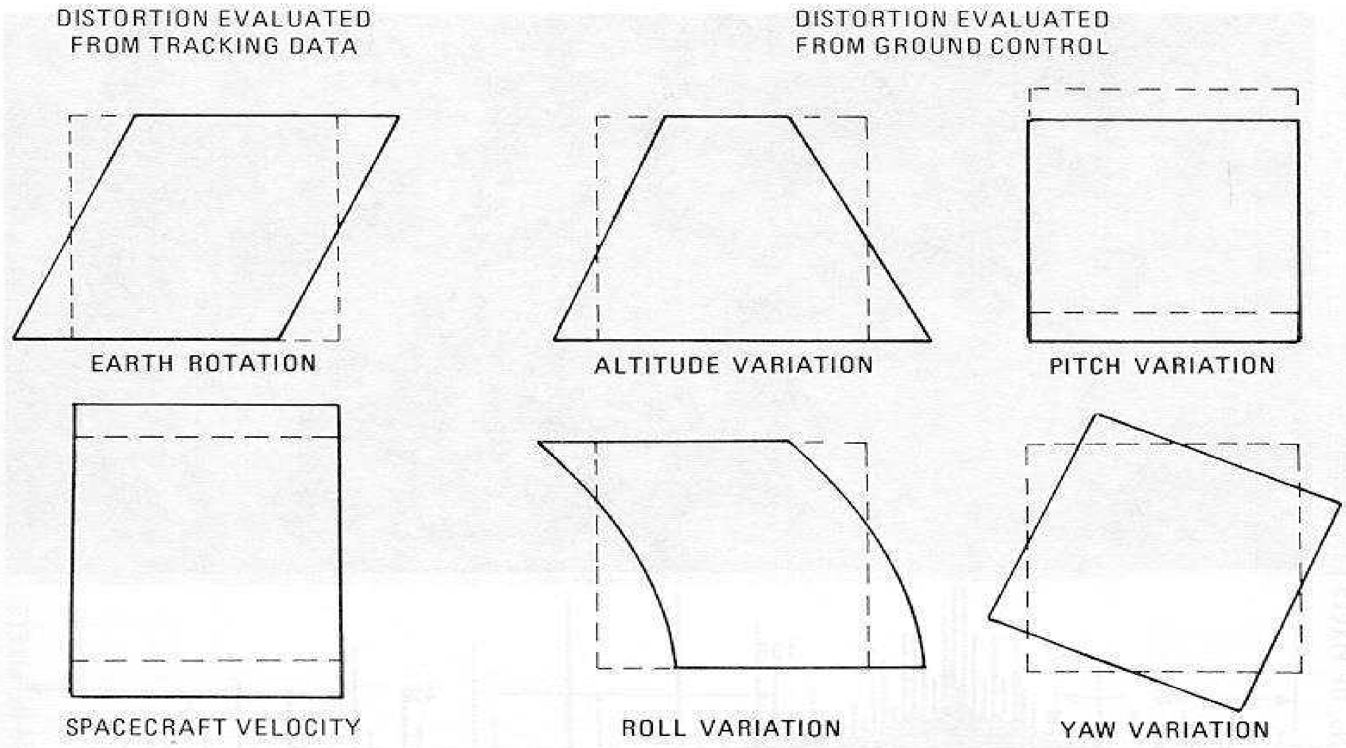
- **The above process is called image to map and image to image rectification.**
- **In order to determine the exact plannimetric positions of image objects as in case of map, the process of resampling is carried out**

CORRECTIONS/RECTIFICATIONS

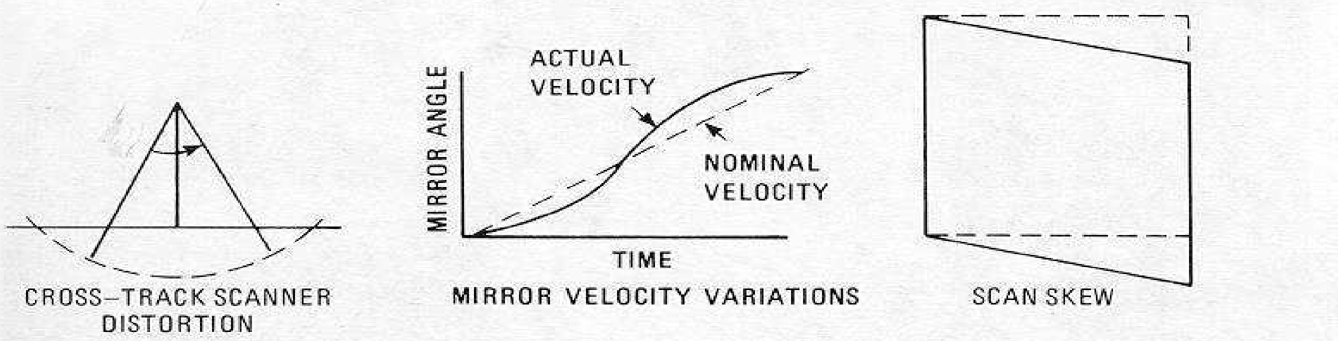
- **Image to map rectification**



- **Image to Image Registration**
- **Resampling**



A. NONSYSTEMATIC DISTORTIONS. DASHED LINES INDICATE SHAPE OF DISTORTED IMAGE; SOLID LINES INDICATE SHAPE OF RESTORED IMAGE.



B. SYSTEMATIC DISTORTIONS.

IMAGE DATA FORMATS

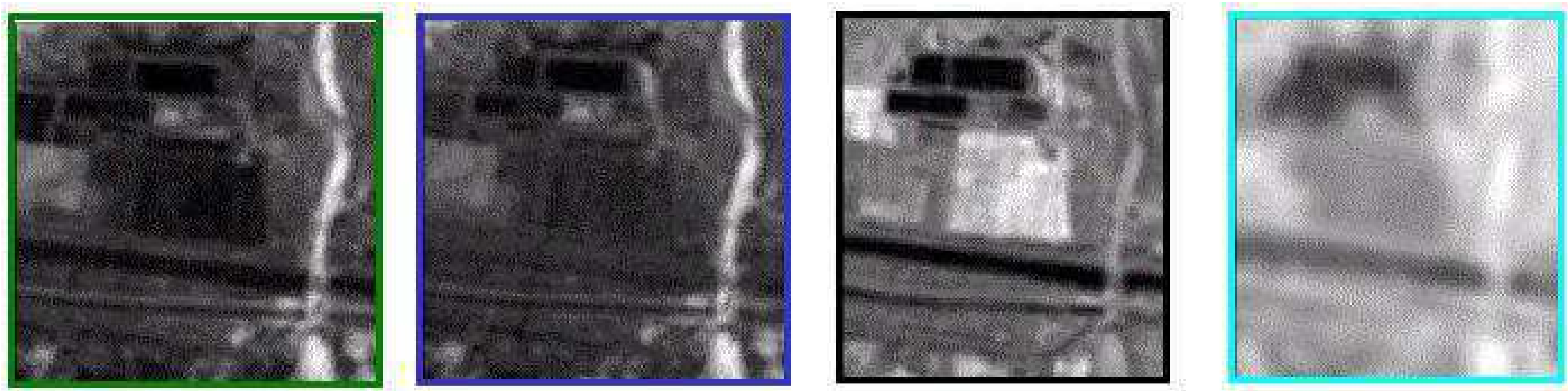
- ❖ Band sequential (BSQ)
- ❖ Band interleaved by line (BIL)
- ❖ Band interleaved by pixel (BIP).

IMAGE PROCESSING SYSTEMS

Digital Image processing is a collection of techniques for manipulation of digital images by computers. A digital image processing system consists of computer hardware and image processing software necessary to analyse digital image data. The procedure for digital image processing may be categorized into the following types of computer-assisted operations.

- ❖ Image Rectification
- ❖ Image Enhancement
- ❖ Image Classification
- ❖ Colour Composites

COLOUR COMPOSITES



STANDARD FCC

ORDINARY FCC

IMAGE ENHANCEMENT TECHNIQUES

- **Contrast**

- **Contrast Enhancement**
  - **Linear Contrast Stretch**
  - **Non-Linear Contrast Enhancement**
  - **Histogram Equalization**
  - **Gaussian Stretch**
  - **Density Slicing**
  - **Spatial Filtering**
  - **Spatial Convolution Filtering**
  - **High Frequency Filtering in Spatial Domain**
  - **Edge Enhancement**
  - **Linear Edge Enhancement**
  - **Non-linear Edge Enhancement**
  - **Band ratioing**
  - **Colour Ratio Composite Images**
  - **Tasseled Cap Transformation**
  - **Decorrelation Techniques**
  - **Principal Component Analysis (PCA)**
  - **HSI Technique**

Assignment: Write down one para for each enhancement techniques

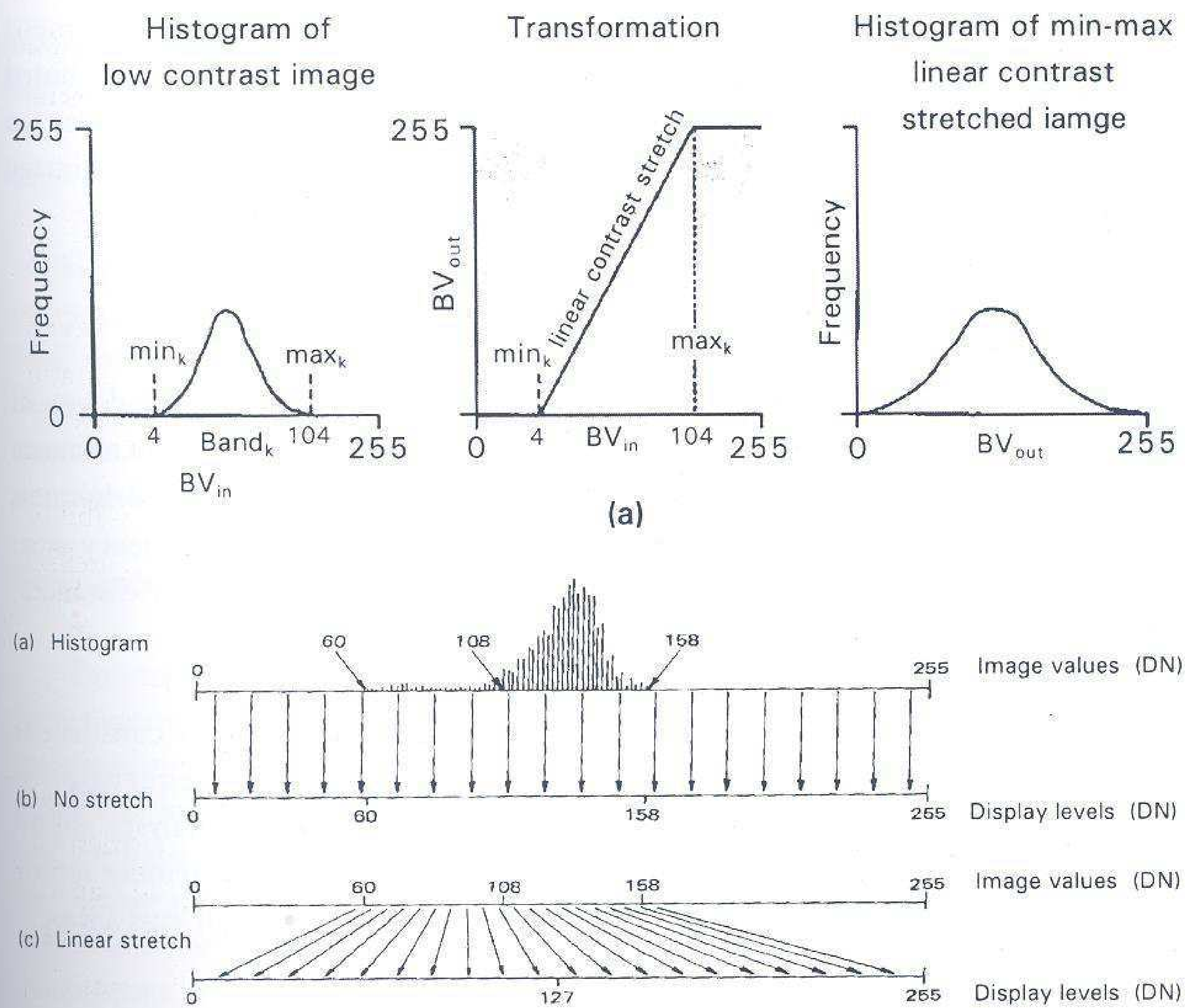
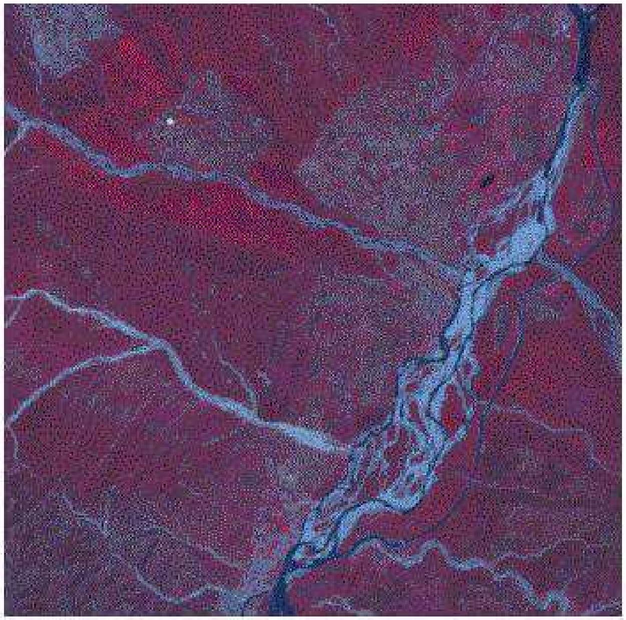
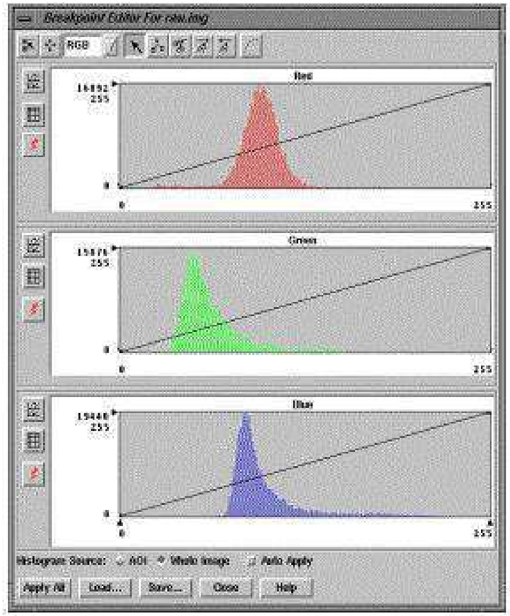


Figure 4: Linear Contrast Stretch (source Lillesand and Kiefer, 1993)

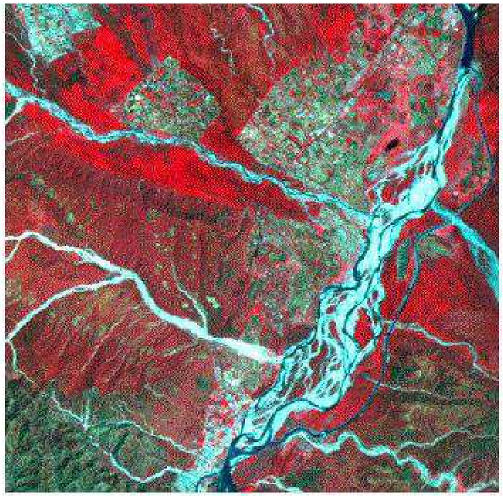
IRS-1C LISS III 19 April 1998 Raw Data set

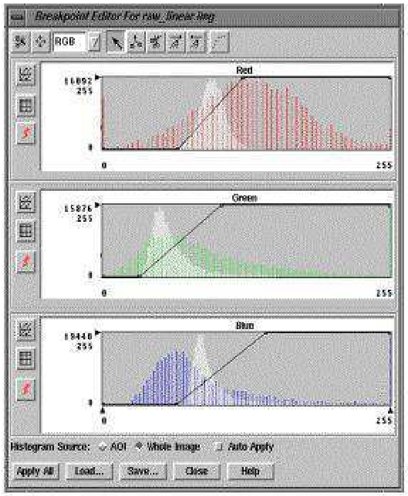


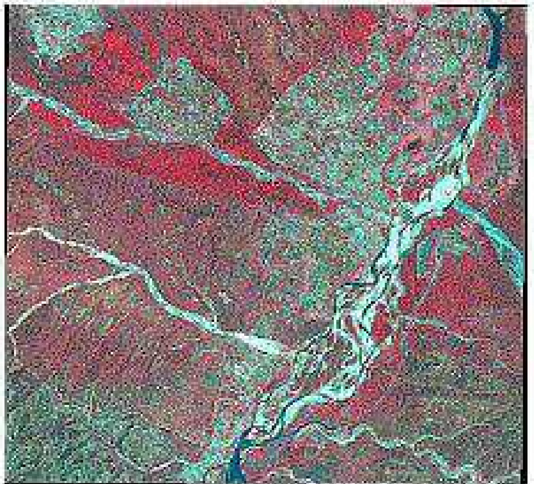


Linear Stretching

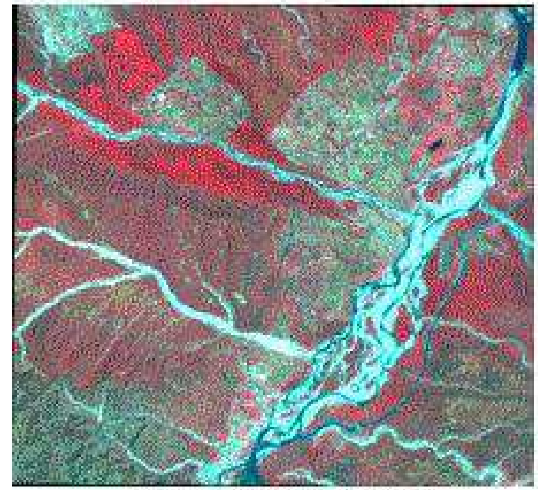
Figure 5. Linear enhancement



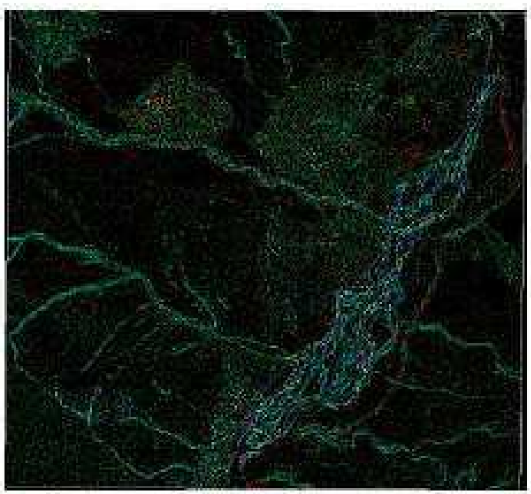




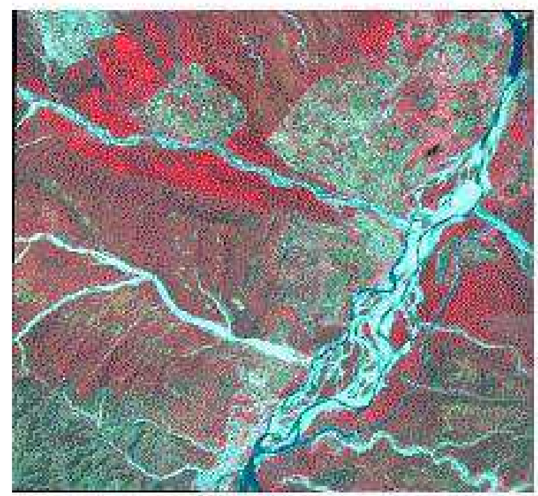
HIGH PASS FILTER



LOW PASS FILTER



EDGE DETECTION

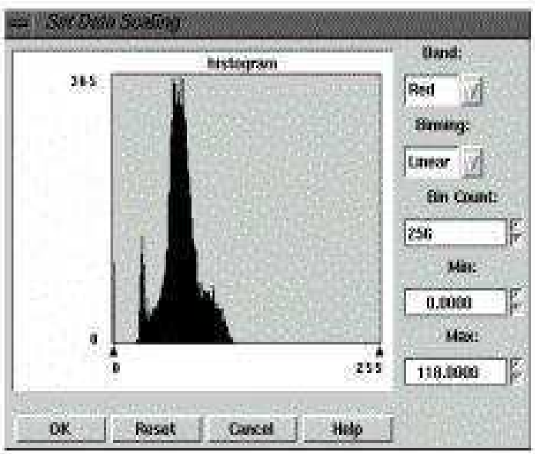


EDGE ENHANCEMENT

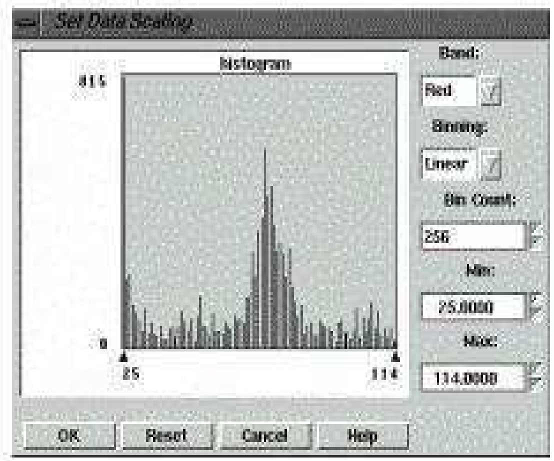
Filtering of images

RAW IMAGE

STRETCHED IMAGE



HISTOGRAM FOR RAW IMAGE



HISTOGRAM FOR STRETCHED IMAGE

Figure 4. Contrast enhancement

Gaussian Stretch

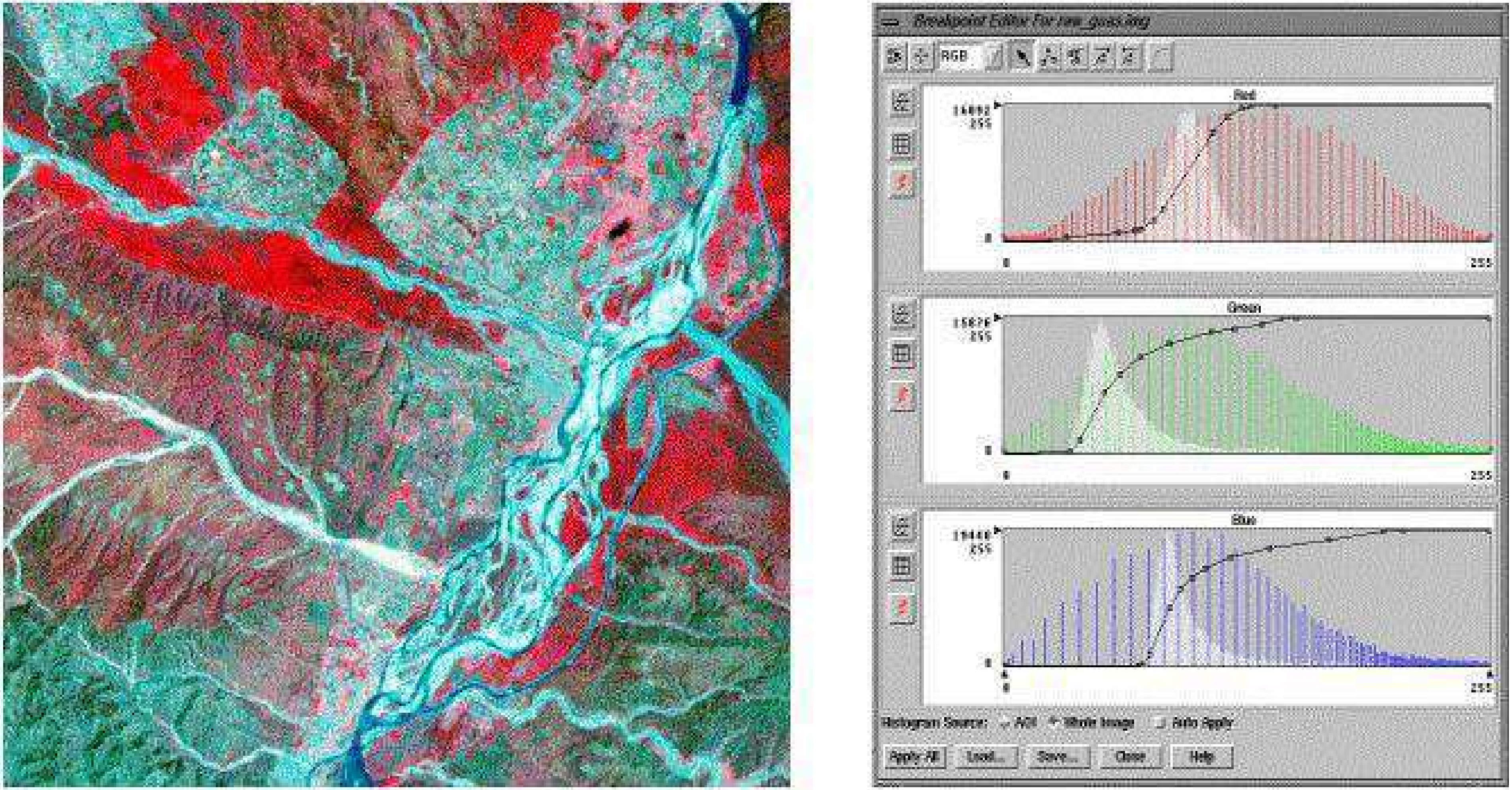


Figure 7. Gaussian stretch

Histogram Equalization

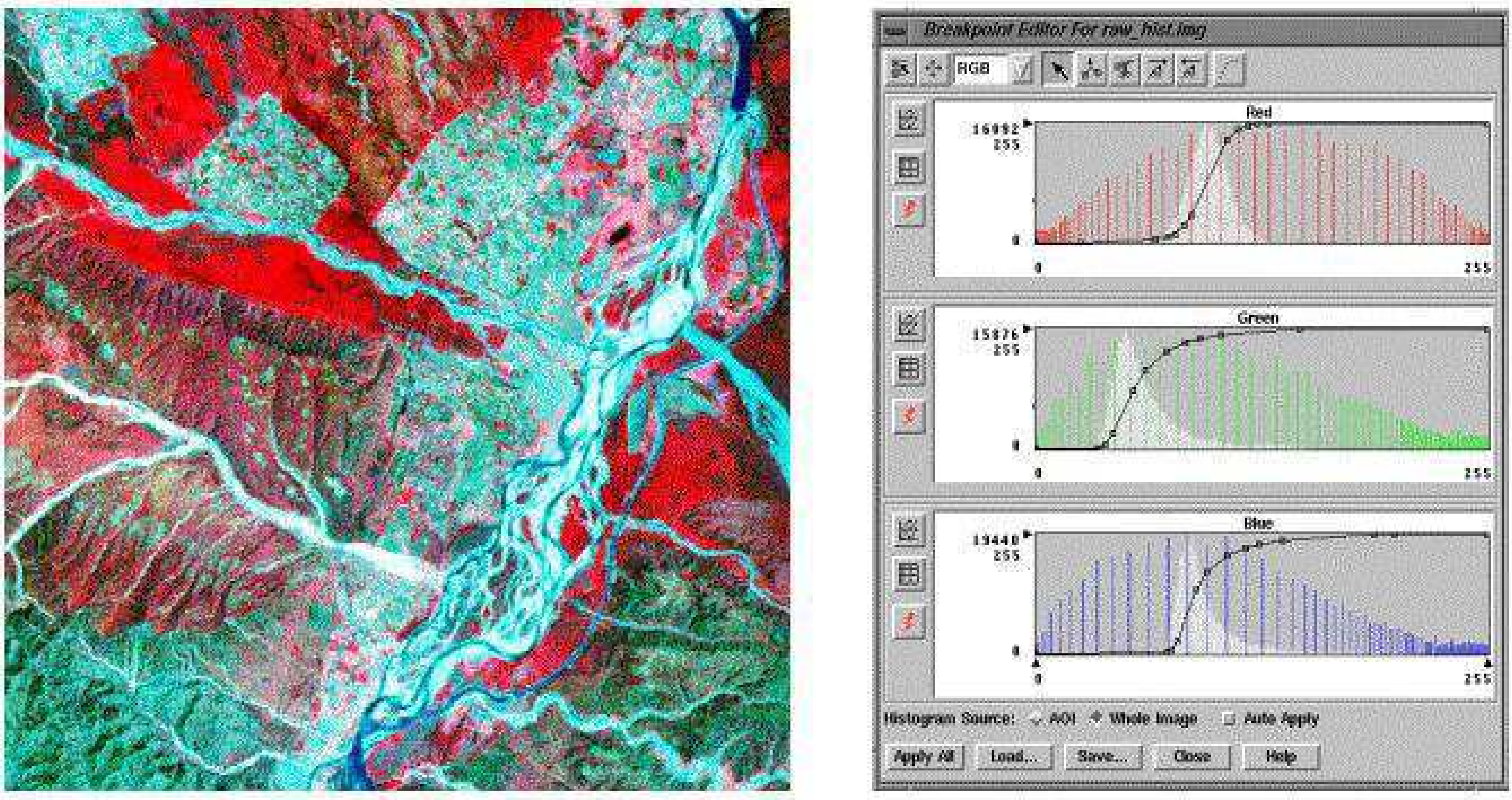


Figure 6. Histogram equalisation

Digital Classification

The main Points to be considered:

- Remote sensing data of Multispectral in nature

- Measurement space-256k possible pixel vectors for an image with 8 bits / pixel / band

- The set of discrete spectral radiance measurements define the spectral signature of each class as modified by the atmosphere between the sensor and the ground.

- The spectral signature is a multi dimensional vector whose coordinates are the measured radiance in each spectral band.

Training set assignment for classification

- The first step of any classification procedure is the training of the computer program to recognize the class signatures of interest.

Sl. No.	Enhancement techniques	Function Achieved
1.	Density slicing	Colour representation of land cover features in individual band data or in any other output data mathematical treatment.
2.	Addition	Reduction of number of images and judicious combination in the form of false colour composite (FCC) allowing vegetation to appear differently (like different intensity or red in Landsat MSS FCC bands 1, 2 & 4) Standard FCC combinations for vegetation studies 1. Landsat MSS – bands 1, 2, &4 Landsat TM - bands 2, 3, & 4 or 4, 3 & 5 IRS –1A LISS-I & LISS-II – bands 2, 3 & 4
3.	Subtraction	Detects change (spatial or phonological) in vegetation at two particular time periods
4.	Ratio	Enhances the subtle contrast between different vegetation types. Provides 'idea' about green foliage density and quantity of vegetation. Removes atmospheric effects and impact of partial hill shadows. Commonly used ratios in vegetation studies. IR/R, IR-R, IR+R & IR-MIR/IR+MIR
5.	Contrast stretching	Increases the separation between two vegetation types boundaries allowing higher delineation accuracy
6.	Texture analysis	Forest density and heterogeneity measure
7.	Temporal analysis	Allows to incorporate phonological features for interpretation. Change detection of vegetation at two time periods.
8.	Principal component transformation	Data compression and judicious combinaproduction capabilities

Table Image enhancement techniques and Its applications in forest type mapping

- To train the computer program, we must supply a sample of pixels from each class which is likely to be separated based on its ground evidences and spectral curve separability

- Mean vectors and covariance matrices are developed based on the assignment of above pixels containing the set of spectral signatures .

There are basically two ways to develop signatures:

1.Supervised training/classification

- It requires a Prior knowledge from field survey, photo-interpretation and other sources about the cover types or the area of interest for their classification on the digital data.

- Training samples of above classes, showing a set pixels, are assigned .

- Multi- variate statistical parameters (means, standard deviation, covariance matrices, etc) are calculated for each training site.

- **Every pixel both within and out side these training sites is evaluated and assigned to the class of which it has the likelihood of being a member**

Important aspects of supervised classification

- **Appropriate classification scheme**
- **Representative training sites**
- **Appreciation for signature extension factor**
- **Extraction of statistics from training sites**
- **Appropriate classification algorithm**
- **Statistical evaluation of clssification accuracy**

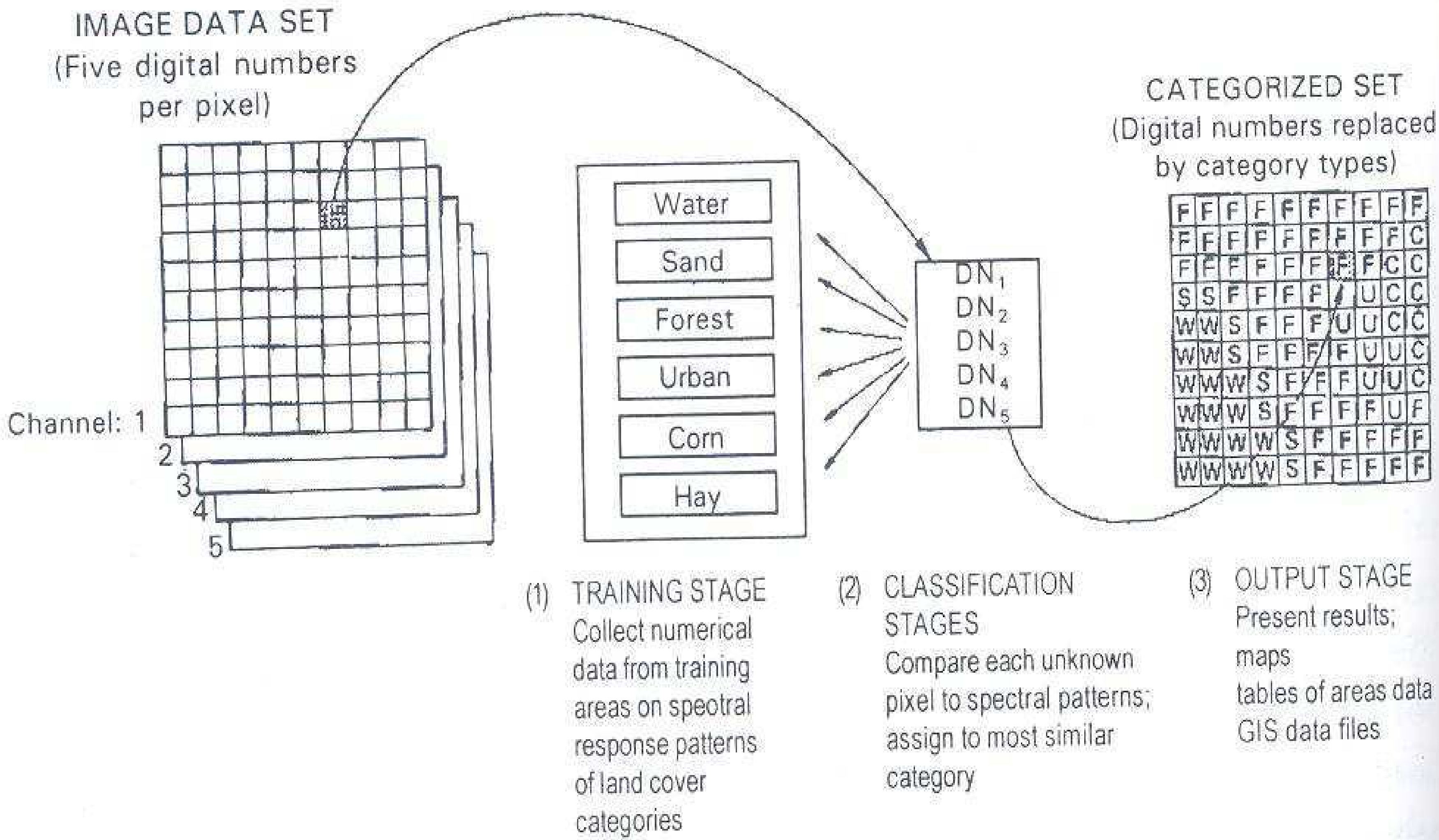


Figure 6: Basic Steps in Supervised Classification

Algorithm for supervised classification

1. **Maximum likelihood Classification**

2. **Minimum Distance Classification**

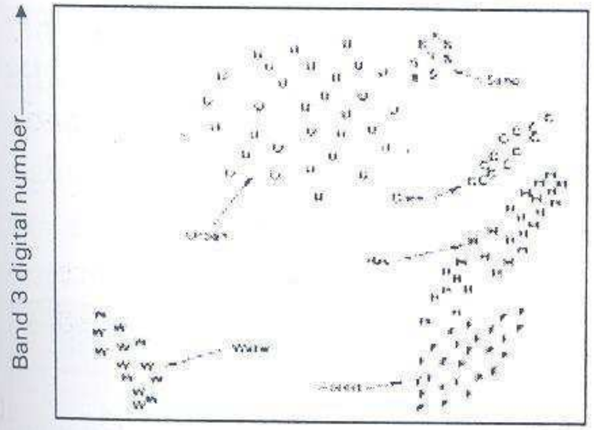


Figure 7a: Pixel observations from selected training sites plotted on scatter diagram

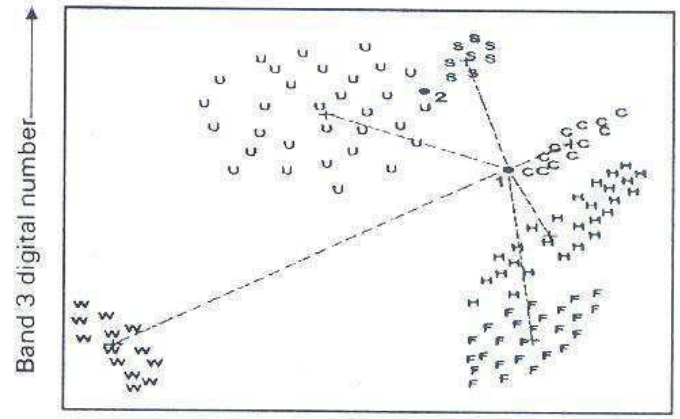


Figure 7b: Minimum Distance to Means Classification strategy

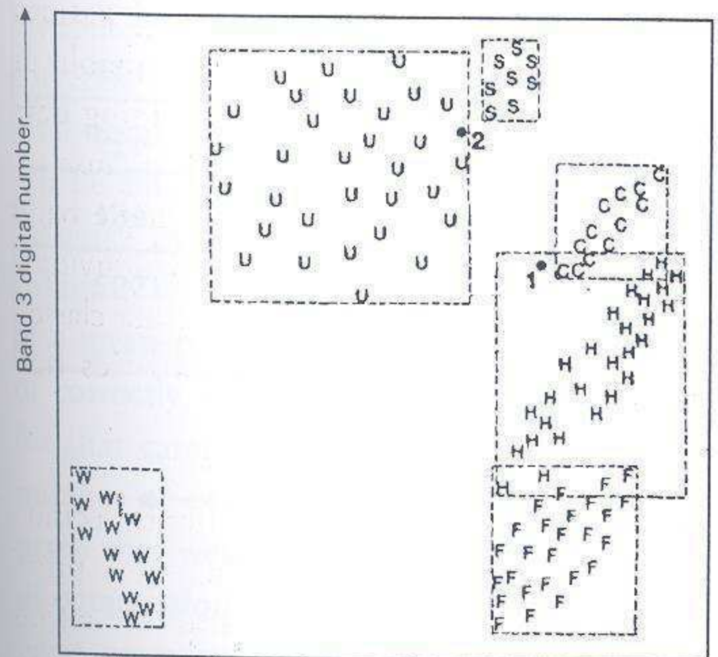


Figure 7c: Parallelepiped classification strategy

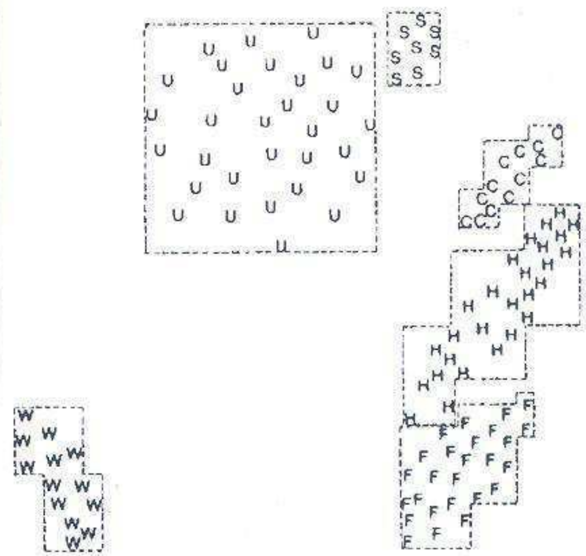


Figure 7d: Stepped parallelepipeds to avoid overlap (source Lillesand and Kiefer, 1993)

Table 1. Error Matrix resulting from classifying training Set pixels

	W	S	F	U	C	H	Row Total
W	480	0	5	0	0	0	485
S	0	52	0	20	0	0	72
F	0	0	313	40	0	0	353
U	0	16	0	126	0	0	142
C	0	0	0	38	342	79	459
H	0	0	38	24	60	359	481
Column Total	480	68	356	248	402	438	1992

Classification data Training set data (Known cover types) ⟶

Producer's Accuracy

W = 480/480 = 100%

S = 052/068 = 16%

F = 313/356 = 88%

U = 126/2411 = 51%

C = 342/402 = 85%

H = 359/438 = 82%

Users Accuracy

W = 480/485 = 99%

S = 052/072 = 72%

F = 313/352 = 87%

U = 126/147 = 99%

C = 342/459 = 74%

H = 359/481 = 75%

Overall accuracy = (480 + 52 + 313+ 126+ 342 +359)/1992= 84%

W, water; S, sand; F, forest; U, urban; C, corn; H, hay (source Lillesand and Kiefer, 1993).

...al characteristics about classification

THANKS

Preprocessing of Satellite Images

Radiometric and geometric corrections

Outline

- Remote sensing data suffers from variety of radiometric and geometric errors.
- These errors diminish the accuracy of information extracted and thereby reduce the utility of data.
- Image Registration/Preprocessing involves removal of distortions, degradation and noise.
- Types of error: internal and external.
- Geometric and Radiometric corrections.

Introduction:

A digital remotely sensed image typically composed of picture elements (pixel) having Digital Number (DN) or Brightness Value (BV) located at the intersection of each row i and column j in band k in imagery. A smaller number indicates low radiance from the area and high number is an indicator of high radiant properties of the area.

Raw digital images usually contains distortion or various types of error so they cannot be used directly as a map without proper processing. Sources of these distortions range from variation in the altitude and velocity of sensor to Earth rotation and curvature etc. Correction is needed for satellite images. These rectification operations aim to correct distorted or degraded image data to create a faithful representation of the original scene. Image rectification involves the initial processing of raw image data to correct for geometric distortion, to calibrate the data radiometrically and to eliminate noise present in the data. Image rectification and restoration procedures are often termed preprocessing operations because they normally precede manipulation and processing of image data.The former deals with initial processing of raw image data to correct geometric and radiometric distortions. Enhancement procedures are applied to image data in order to effectively display the data for subsequent visual interpretation. The intent of classification process is to categorize all pixels in a digital image into one of several land cover classes or themes. This classified data may be used to produce thematic maps of the land cover present in an image.

Types of Error

- **Internal errors/Systematic errors:**

  Internal errors are introduced by remote sensing system. They are generally systematic (predictable) and may be identified and then corrected based on pre-launch or in flight calibration measurements (Figure 1). For example n-line stripping in the imagery may be caused by single detector that has become uncelebrated. In many instances, radiometric correction can adjust for detector miscaliberation.

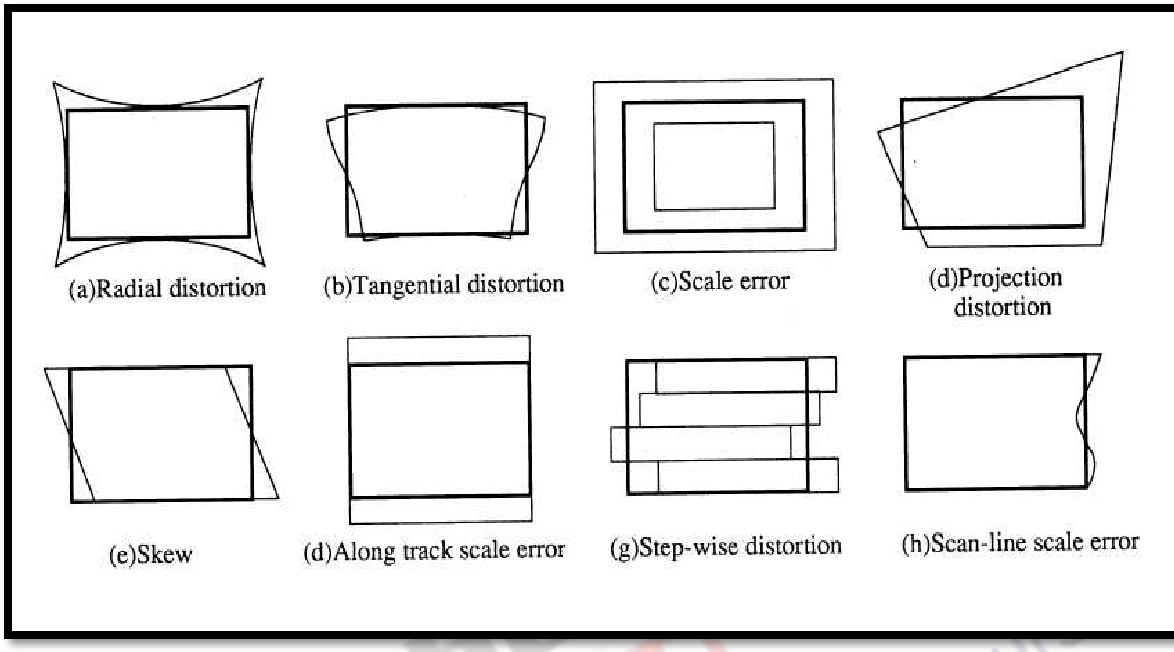


Figure.1 Internal distortion

Source: www.jars1974.net/pdf/10_Chapter09.pdf

- **External error/Non-Systematic errors:**

  External errors are introduced by phenomena that vary in nature through space and time. External variable that can cause remote sensor data to exhibit radiometric and geometric error include the atmosphere, terrain elevation, slope and aspect. Some external error may be corrected by relating empirical ground observations (i.e. radiometric and geometric ground control points) to sensor measurements (Figure 2).

Some high point behavior of external errors is listed below:

- Caused due to platform perturbations and changes of atmospheric and seismic characteristics.
- They are unpredictable.
- They are variable.

- Can be determine by relating points of the ground to sensor system measurement.
- Eg: Spacecraft velocity, attitude, altitude, atmospheric effects.

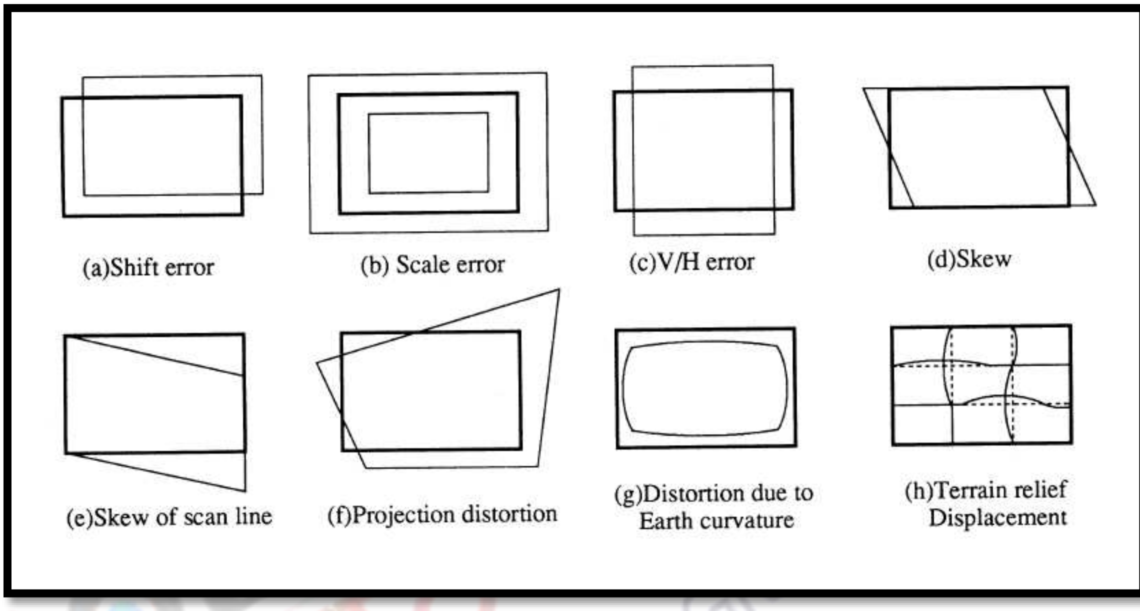


Figure.2 External distortion

Source: www.jars1974.net/pdf/10_Chapter09.pdf

Several most common remote sensing system–induced radiometric errors are

- **Line start or stop problems:**

Occasionally, scanning systems fail to collect data at the beginning or end of a scan line, or they place the pixel data at inappropriate locations along the scan line. For example, all the pixels in a scan line might be systematically shifted just one pixel to the right. This is called a line-start problem (Figure 3).

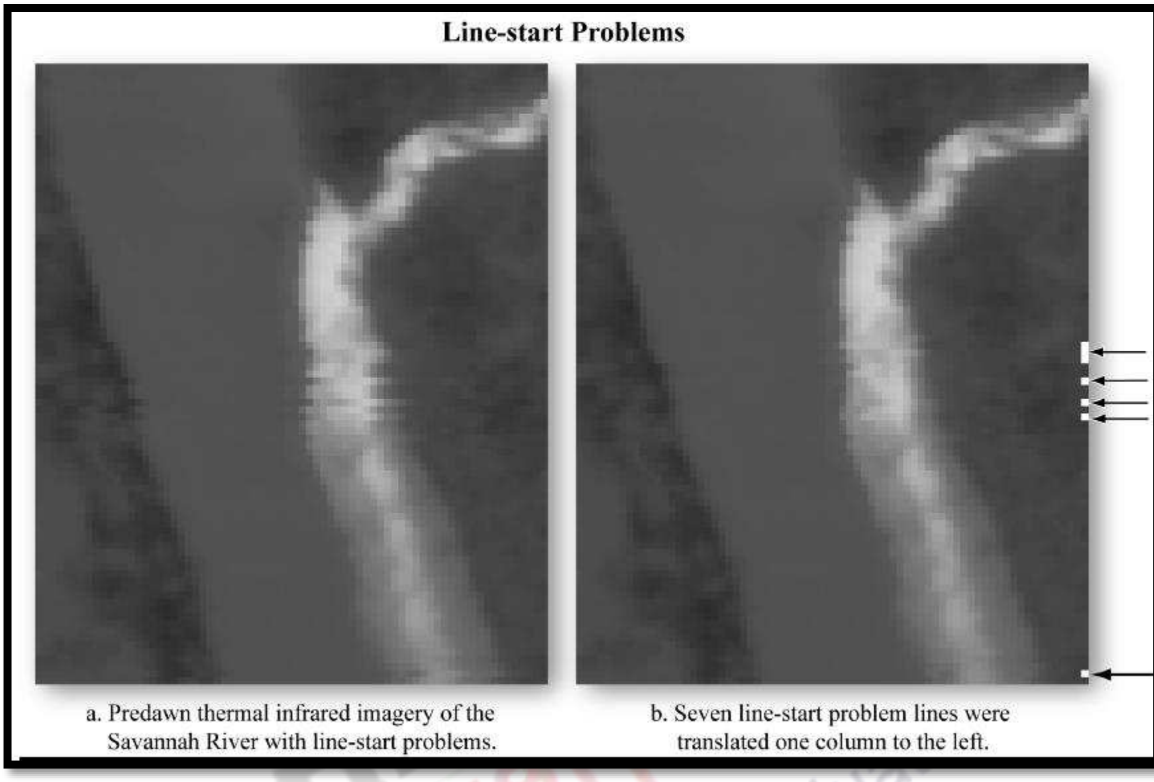


Figure3: Line start error

Source: http://www.csre.iitb.ac.in/~avikb/GNR401/DIP/DIP_401_lecture_1.pdf

- **Line or column dropout**

If one of the six detectors of Landsat MSS fails to function during a scan. This results in zero brightness value for every pixel j in a particular line i. This line drop out appears as a completely black line in band k. This is no way to restore data since it is never acquired, but it is possible to improve visual interpretability of data by introducing estimated brightness value for each bad line. If a detector in a linear array (e.g., SPOT XS, IRS-1C, QuickBird) fails to function, this can result in an entire column of data with no spectral information. The bad line or column is commonly called a line or column drop-out and contains brightness values equal to zero. For example, if one of the 16 detectors in the Landsat Thematic Mapper sensor system fails to function during scanning, this can result in a brightness value of zero for every pixel, j, in a particular line, i. This line drop-out would appear as a completely black line in the band, k, of imagery. This is a serious condition because there is no way to restore data that were never acquired.

Correction of Line drop out

a) **Replacement by preceding line**

Here the brightness value of the pixels along the dropped scan line is replaced by the value of corresponding pixel on immediately preceding or succeeding line

Bvi, j = Bvi, j-1 or Bvi, j+1

Where,

Bvi, j = missing pixel value of pixel i and scan line j

b) **Replacement by Averaging**

A thresholding algorithm can flag any scan line having mean brightness value at or near zero. Correction for line dropout can be done by calculating the output pixel value by averaging preceding line ($BV_{i-1,j,k}$) and succeeding line ($Bv_{i+1,j,k}$) pixel value and assign the output pixel ($BV_{i.j,k}$) in drop out line.

$$BV_{I,j,k} = BVi\text{-}1,j,k+Bvi+1,j,k / 2$$

❖ **Stripping:**

Sometimes a detector does not fail completely, but simply goes out of radiometric adjustment. For example, a detector might record spectral measurements over a dark, deep body of water that are almost uniformly 20 brightness values greater than the other detectors for the same band. The result would be an image with systematic, noticeable lines that are brighter than adjacent lines (Figure 4). This is referred to as n-line striping. The maladjusted line contains valuable information, but should be corrected to have approximately the same radiometric scale at the data collected by the properly calibrated detectors associated with the same band. Data although valid should be averaged so that it get same contrast as other detectors per scan. Identification of bad line is done by computing the histograms of the values of each of n detector over a homogeneous area such as water body. Now if one of the detectors's Response is significantly different from others than may be it is out of adjustment.

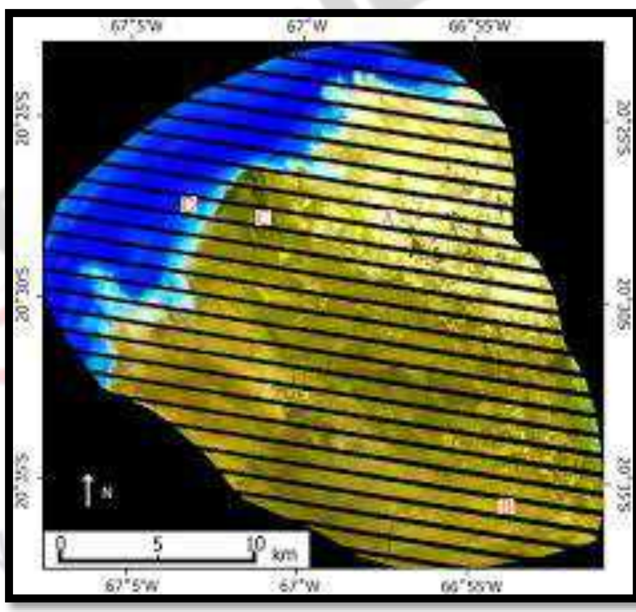


Figure 4. Stripping Error

Source: http://www.mdpi.com/2072-4292/6/10/10131/html

Correction of Stripping

$$Y_k(i, j) = (\sigma/\sigma_k) \times [X_k(i, j) - M_k] + M$$

Where,

$Y_k(i, j)$ = output pixel gray value.

$X_k(i, j)$ = input pixel gray value.

M = Mean of full image.

M_k= Mean of k_{th} detector.

σ = Standard deviation of full image.

σ_k= Standard deviation of k_{th} detector.

❖ **Random bad pixels (shot noise)**

This occurs randomly, it is called a bad pixel. When there are numerous random bad pixels found within the scene, it is called shot noise because it appears that the image was shot by a shotgun. Normally these bad pixels contain values of 0 or 255 (in 8-bit data) in one or more of the bands. Shot noise is identified and repaired using the following methodology (Figure 5). It is first necessary to locate each bad pixel in the band k dataset. A simple thresholding algorithm makes a pass through the dataset and flags any pixel (BVi,j,k) having a brightness value of zero (assuming values of 0 represent shot noise and not a real land cover such as water). Once identified, it is then possible to evaluate the eight pixels surrounding the flagged pixel, as shown below:

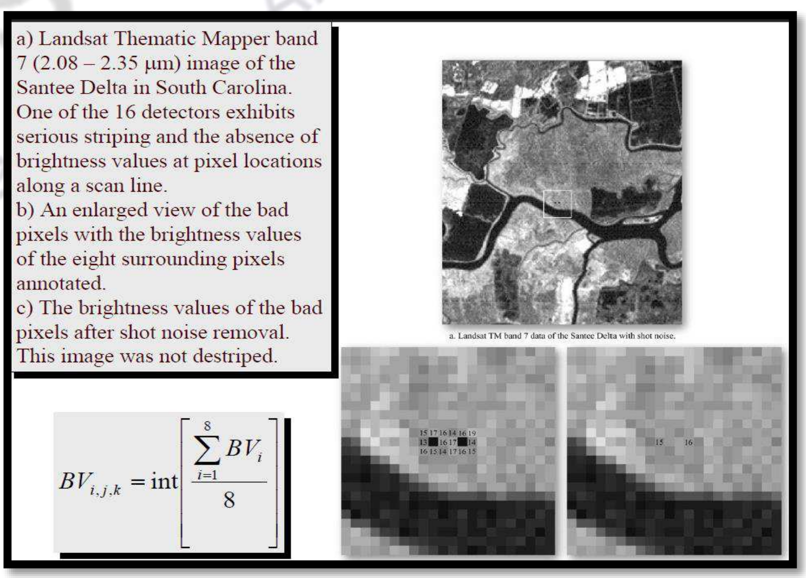


Figure.5 Random bad pixel error

Source: http://www.csre.iitb.ac.in/~avikb/GNR401/DIP/DIP_401_lecture_1.pdf

Radiometric preprocessing:

Radiometric correction applied to any given digital set varies widely among sensors. The radiance measured by any given system over a given subject is influence by such factors as change in scene illumination, atmospheric condition, viewing geometry, and instrument response characteristics. Some of these effects, such as viewing geometry variation, are greater in the case of airborne data collection than in satellite image acquisition.

Radiometric corrections can be further divided in two parts:

•Absolute Radiometric Correction

•Relative Radiometric Correction

Absolute Radiometric Correction:

This method uses model atmosphere along with in-situ atmospheric measurements acquired at the time of data acquisition. Atmospheric model can be more accurately refined along with local condition. However it cannot be applied in most applications, therefore the relative correction is applied because the atmospheric model is so complicated and the exact measurement of atmospheric condition is difficult. The atmosphere affects the radiance measured at any point in scene in two ways:

a) It attenuates the energy illuminating the ground object

b) It acts as a reflector itself, adding scattered, and extraneous "Path radiance" to the signal detected by sensor (Figure 6)

$$L_s = RE_g T_\Theta / \pi + Lp$$

Where,

Ls = Total spectral radiance measured by sensor.

R = Reflectance of object.

Eg =Irradiance on object.

Tθ=Transmittance of atmosphere.

Lp = Path radiance.

First term in the above equation contains valid information about ground reflectance. Second term represents the scattered path radiance, which introduces haze in the imagery and reduces image contrast.

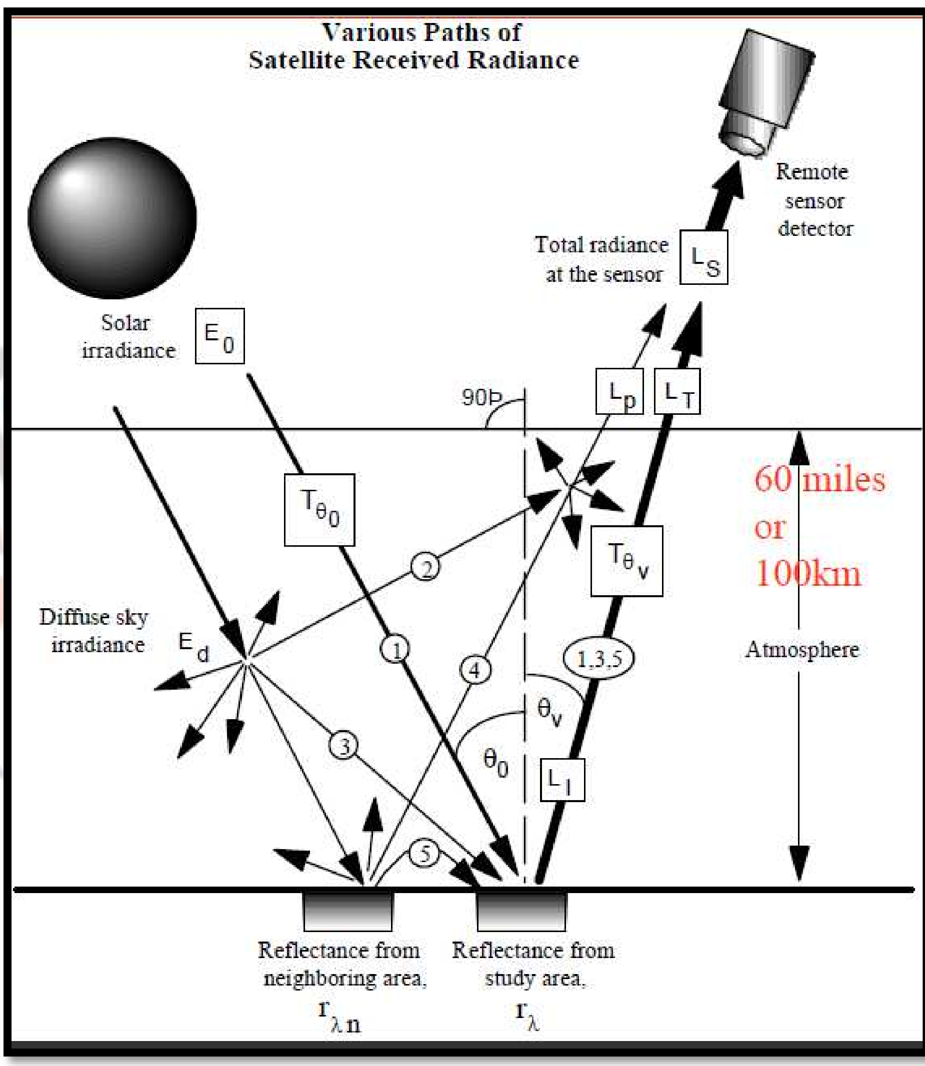


Figure.6 Radiance received by RS System

Source: http://www.utsa.edu/LRSG/Teaching/EES5083/L4-Radiom.pdf

Another absolute radiometric correction method is conversion of DNs to absolute radiance values. Such conversions are necessary when changes in absolute reflectance of objects are to be measured over time using different sensors.

Such conversions are important in the development of mathematical models that physically relate image data to quantitative ground measurements (e g. Water quality data). Each spectral band of sensor has its own response function, and its characteristics are monitored using on-board calibration lamps. The absolute spectral radiance output of calibration sources is known from prelaunch calibration and is assumed to be stable over life of sensor. Onboard calibration sources relate known radiance values incident to n^{th} detectors to the resulting DNs.

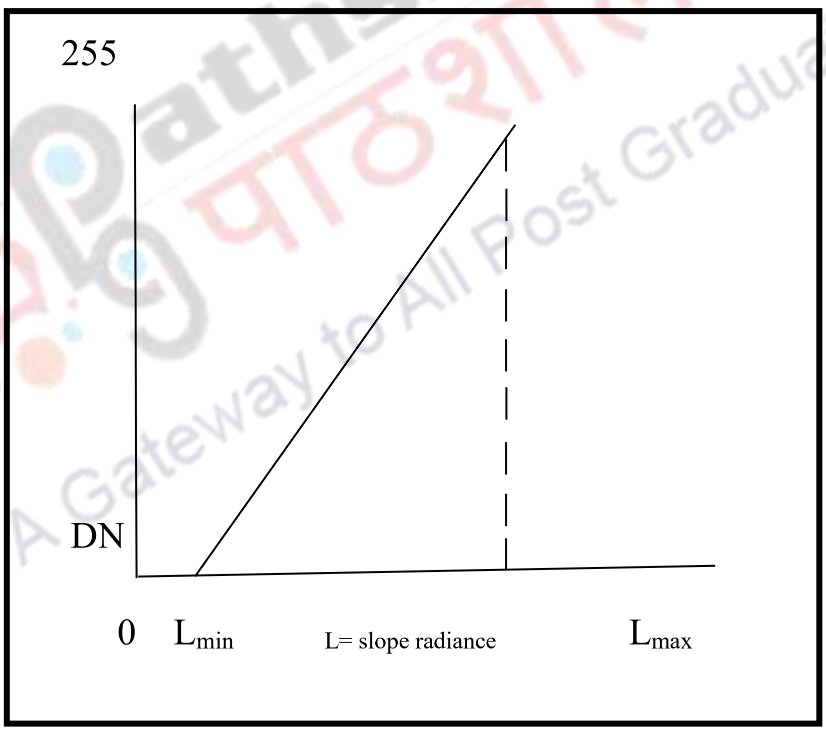


Figure. 7 Graph of Slope distance against DN value

Source: Self

$$DN = GL + B$$

Where,

DN = digital number value recorded.

G = slope of response function (gain).

L = Spectral radiance measured.

B = intercept of response function (offset).

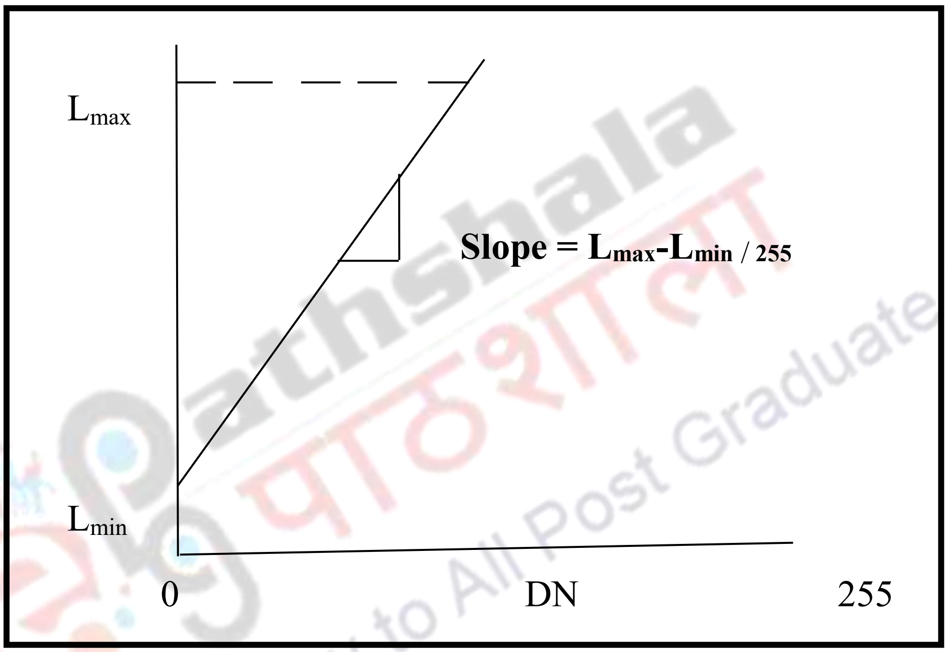


Figure.8 Graphical plot of DN against spectral radiance

Source: Self

$$L = \frac{(L_{MAX} - L_{MIN})\, DN}{255} + L_{MIN}$$

This equation is used to convert any DN in a particular band to absolute units of spectral radiance in that band if L_{MAX} and L_{MIN} are known from sensor calibration (Figure 8).

Relative Radiometric Correction

Relative radiometric correction is use to normalize multi-temporal data taken on different dates to a selected reference data at specific time. Atmospheric attenuation is minimized by using multiple looks at the same object or view the same object in multiple bands. The multiple look method suffers with drawbacks that the atmospheric path changes with the different look.

Relative radiometric correction may be used for:

•Single-image normalization using histogram adjustment

•Multiple-data image normalization using regression

Single-image normalization using histogram adjustment: This method is based on examination of spectral characteristics of objects of known or assumed brightness recorded by multispectral imagery. This approach is often known as "image-based atmospheric correction" because it adjusts for atmospheric effect mainly, from evidence available within the image itself. This strategy can be implemented by identifying dark object or feature within the scene which may be large water body or possibly shadows cast by clouds or by large topographic features. In the infrared portion of the spectrum, both water bodies and shadows should have brightness stay over near zero, because clear water absorbs strongly in the near infrared spectrum and every little infrared energy is scattered to the sense or from shadowed pixels. But it is observed from the histograms of the DN values for a scene that the lowest values (for dark areas, such as clear water bodies) are not zero but have some larger value. These values, assumed to represent the value contributed by atmospheric scattering for each band, are then subtracted from all DN values for that scene and band. Thus the lowest value in each band is set to zero, the dark black color assumed to be the correct tone for a dark object in the absence of atmospheric scattering. This method is simplest method and is known as the histogram minimum method (HMM) or the dark object subtraction (DOS) technique.

DOS/HMM Correction: This procedure has the advantages of simplicity, directness, and almost universal applicability, as it exploits information present within the image itself. But the atmosphere can cause dark pixels to become brighter and bright pixels to become darker, so application of a single correction to all pixels will provide only a rough adjustment for atmospheric effects. DOS technique is capable of correction for additive effects of atmospheric scattering, but not for multiplicative effects of absorption.

Multi Date Image Normalization: Applications such as change detection involves the use of multi date historical images. So for the historical temporal images to be radiometrically corrected. Two methods can be applied:

•Multi-date Empirical Radiometric Normalization

•Multi-date Deterministic Radiometric Normalization

In Unknown atmospheric conditions pseudo invariant ground targets may be used to normalize multi-temporal datasets to a single reference scene. Non anniversary date imagery is a major problem in using temporal images. Image normalization can be achieved by applying regression equations to multi-date imageries which predict what will be the value of brightness of a pixel if it would have been acquired under same conditionals that of reference image.

Regression Method: The method generally involves calculation of regression lines for a number of surface materials of contrasting spectral properties. The regression line method (RLM) determines a 'best fit line' for multi spectral plots of pixels within homogenous cover types. If no atmospheric scattering has taken place, the intersection of the line would be expected to pass through the origin. The slope of the plot is proportional to the ratio of the reflective material. Intersect on the x and y axis producing two offset values which represent the amount of bias caused by atmospheric scattering shown in Fig(9)

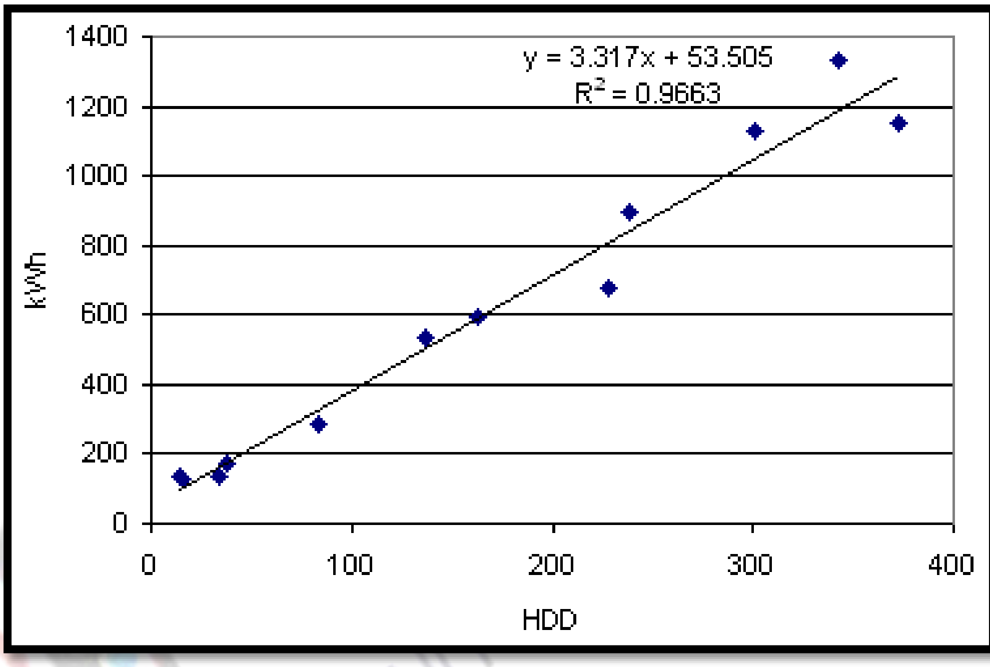


Figure.9 Regression Graph

Source: http://www.degreedays.net/regression-analysis

Target Properties: Target should be at approximately same elevation as other land within the scene. It should contain minimal amounts of vegetation. Target taken should be relatively flat. Patterns of the target should change over time.

Multi-date Deterministic Radiometric Normalization

$$Bv_{norm} = Bv_{ref} + C / M$$

Where,

BV_{norm} = Brightness value of scene to be normalized

BV = Brightness value of reference scene

C = Additive correction

M = Multiplicative Correction

$$M = \frac{(Cos\theta_{0ref})\left(\frac{1}{(ES^2_{ref})(A_{ref})}\right)}{(Cos\theta_{0norm})\left(\frac{1}{(ES^2_{norm})(A_{norm})}\right)}$$

$$C = D_{ref} - (D_{norm})\,(M)$$

Where,

D = dark normalization target brightness value.

1/A = radiance interval between successive BV (Obtained from header).

Θ_0 = solar zenith angle.

ES = Earth Sun Distance.

N_{orm} = scene to be normalized.

Ref = Reference Scene.

Solar Elevation Correction: The satellite scenes taken at different time of the year it is must to correct the sun elevation correction and earth sun distance correction. Sun elevation correction accounts for the seasonal position of the sun relative to the earth. Image data acquired can be normalized by assuming that sun was at zenith at each date of sensing. This correction is applied by dividing each pixel by the cosine of the sun's angle from the zenith. This correction ignores the topographic and atmospheric effect which is shown in Fig (10).

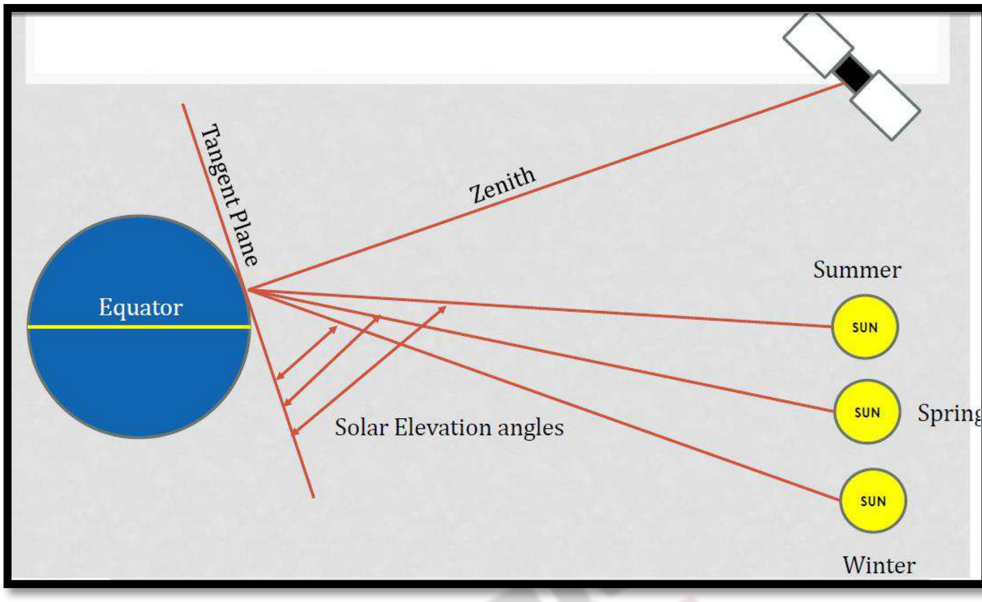


Figure.10 Solar elevation angle

Source: http://mikeyharris.weebly.com/energy-efficient-house.html

Earth Sun Distance Correction:

Earth sun distance correction is applied to normalize for the seasonal changes in the distance between earth and sun. The earth sun distance is usually expressed in astronomical units. This astronomical unit is equivalent to mean distance between the earth and sun, approximately 149.6x106 km. The irradiance of the sun decreases as the square of the earth sun distance increases.

$$E = \frac{E_0 \cos \theta_0}{d^2}$$

Where,

E = normalized solar irradiance.

E_0= solar irradiance at mean earth sun distance.

Θ_0= sun's angle from zenith.

d = earth-sun distance, in astronomical units.

Topographic Normalization: The variations of the topographic parameters (slope, aspect and altitude) affect the variation in the brightness of the satellite images in rugged mountainous terrain due to which object lying in shadow gets less solar irradiance than one on a sunny side (Figure 11). A surface perpendicular to the sun at a low sun elevation will receive less radiation than a surface perpendicular to the sun at a high solar elevation (Ekstrand, 1996). South aspect (Sun facing illuminated slopes) shows more reflectance whereas the effect is opposite in north aspect (Warren et al. 1998; Riano et al. 2003). These differential illumination effects in satellite imagery will restrain the maximum information on the north facing slopes, thus negatively affecting the results of various quantitative methods of snow cover mapping specifically classification, change analysis and other peril information (Mishra et al. 2010). Therefore effective removal or minimization of topographic effects is necessary in satellite image data of the mountainous regions.

Variations in illumination affect land cover discrimination as the same land cover will have different spectral responses among had owed and non-shadowed areas. The correction of illumination variations is referred to as Topographic Normalization or Topographic correction. Techniques are grouped into two major categories:

(a) Band ratios

(b) Modeling of illumination conditions

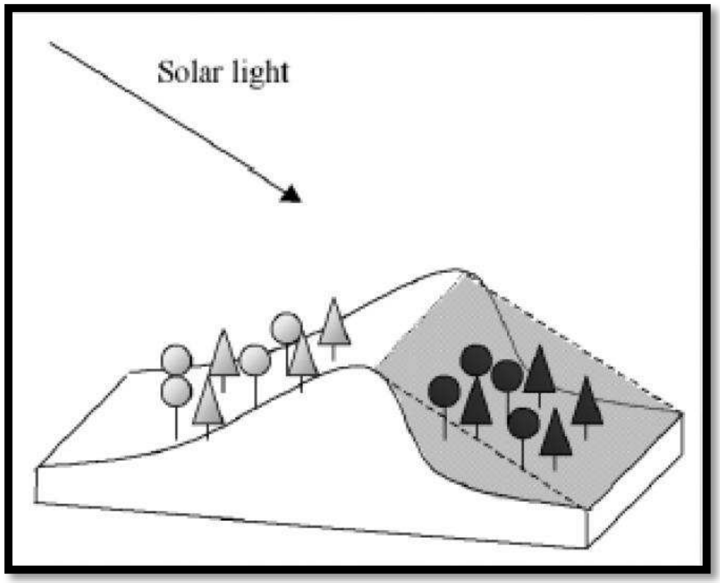


Figure.11 Topographic Normalization

Source: Remote Sensing of the Environment, John R. Jensen

Techniques under group b) model illumination to compute the flat-normalized radiance of each pixel. They are grouped into two additional sub categories, Lambertian and non-Lambertian, depending on whether they assume a Lambertian or non-Lambertian surface behavior:

Correction for Slope and Aspect Effects

Slope aspect corrections are given by Teilletetal (1982)

1. Cosine Correction
2. Modified Cosine Correction
3. Semi empirical Method
    - Minnaert correction
    - C-Correction
4. Statistic empirical Methods

Each of these corrections is based on illumination (defined by cosine of incident solar angle). Illumination is dependent on the orientation of the pixel towards sun's actual position. Digital elevation model of the study area is required for these corrections. DEM and Satellite sensor data must be geometrically registered and resampled to same spatial resolution.

Lambertian Technique: This techniques are the easiest to implement, but are based on somewhat unrealistic assumptions, such as:

- The surface reflects energy equally in all directions,
- The correction is wavelength independent,
- Constant distance between the Earth and the Sun, and
- Constant amount of solar energy illuminating the Earth.

Cosine Correction (Lambertian): Amount of irradiance reaching a pixel on slope is directly proportional to the cosine of incidence angle "i". Incidence angle "i" is defined as the angle between normal on the pixel and zenith direction. This method has a limitation that it accounts for only the direct part of irradiance that illuminates a pixel on ground. It doesn't take into account the diffused sky light and light reflected from surrounding mountain sides which may illuminated the pixel. So weakly illuminated areas in terrain receive a disproportionate brightening effect when cosine correction is applied (Figure 12). Smaller the value of cosine greater will be the slope correction.

$$L_H = LT \frac{\cos \theta_Z}{\cos i}$$

Where,

LH = radiance observed for a horizontal surface

LT = radiance observed for a sloped surface

Θz = sun's angle from zenith

I = sun's incidence angle in relation to normal on pixel.

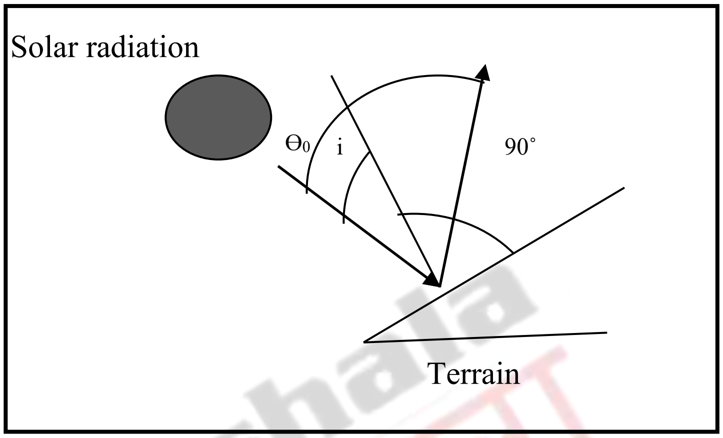


Figure.12 Cosine Correction

Source: Self

MODIFIED COSINE CORRECTION (Lambertian)

$$L_H = L_T + \left[\frac{(IL_m - IL)}{IL_m}\right]$$

IL_m = average IL value for the study area

Non Lambertian Technique: These techniques try to model the roughness of the surface, or the degree to which it is Lambertian. Usually, they require the calculation of correction coefficients which are wavelength dependent. Therefore, each band is processed separately. The computation of the correction factors will be done using a subset of pixels from the same land cover class. First, we will extract the pixel values from the image bands and illumination layers, and then we will compute the correction factors.

MINNAERT CORRECTION: Minnaert method is non-Lambertian and implemented for topographic corrections which depends on the type of surface and spectral wavelength bands. It varies from 0 (ideally non-Lambertian surface) to 1 (perfect Lambertian surface). This method is an improved of cosine correction and is given by

$$L_H = LT \frac{\cos \theta_z}{\cos i}$$

Where,

LH = radiance observed for a horizontal surface.

LT=radiance observed for a sloped surface.

Θz=sun's angle from zenith.

I= sun's incidence angle in relation to normal on pixel.

K= the Minnaert constant.

The value of constant varies between 0 and 1

K is measure of the extent to which a surface is Lambertian. A perfectly Lambertian surface has k =1and thus represents the traditional cosine correction.

$$\ln(L_T) = \ln(L_H) + K_k \ln\left(\frac{IL}{\cos \theta z}\right)$$

where: $\ln(L_H)$ = intercept of the regression

K_k = slope of the regression for band k

C-Correction

In this method an additional adjustment to the cosine correction is added which modifies the correction to C-correction given below:

$$L_H = L_T \frac{\cos\theta_0 + c}{\cos i + c}$$

Where,

L_H = radiance observed for a horizontal surface.

L_T = radiance observed for a sloped surface.

Θ_0 = sun's angle from zenith.

I = sun's incidence angle in relation to normal on pixel.

C = b/m.

C increases the cosine I and thus weakens the correction of faintly illuminated pixel.

$$L_T = b_k + m_k IL$$

Statistical Empirical Correction: A DEM based topographic correction model is proposed to decrease the divergence caused by solar illumination on the same land cover but located on different (north and south) aspect of mountain so that the land cover class with the same reflectance in a different solar azimuth shows the same spectral response in optical remote sensing image. For this an atmospheric transmittance from ground surface to sensor as well as atmospheric transmittance along the path from sun to ground is calculated using (Pandya et al. 2002) and an improved dark object subtraction (DOS) technique was implemented. This is further implemented in topographic correction method based on empirical statistical analysis of the radiance values of remotely sensed data acquired for rugged terrain and the cosine of the solar illumination angle .It possible to correlate the predicted illumination from the DEM & actual remote sensing data and also to generate regression line for that. Slope of the regression line suggests that a same kind of class can occurred, differently on different terrain slope.

$$L_H = L_T - \cos(i)m - b + \overline{L_T}$$

Where,

L_H = radiance observed for a horizontal surface.
L_T = radiance observed for a sloped surface.
$\overline{L_T}$ = average of LT.
i = sun's incidence angle in relation to normal on pixel.
m = slope of regression line.
b = y intercept of regression line.

Another absolute radiometric correction method is conversion of DNs to absolute radiance values, such conversion are necessary when changes in absolute reflectance of objects are to be measured over time using different sensors. Such conversions are important in the development of mathematical models that physically relate image data to quantitative ground measurements (e g. Water quality data). Each spectral band of sensor has its own response function, and its characteristics are monitored using on board calibration lamps. The absolute spectral radiance output of calibration sources is known from prelaunch calibration and is assumed to be stable over life of sensor. Onboard calibration sources relate known radiance values incident to n^{th} detectors to the resulting DNs.

Radiometric correction is further classified into the following three types

1) Radiometric correction due to sensor sensitivity: In this case image corner will be darker as compared with the central area. This is called vignetting. Vignetting can be expressed by $\cos^n\Theta$, where Θ is the angle of ray with respect to the optical axis. n is dependent on the lens characteristic. In this case of electro-optical sensor, calibration is measured between irradiance and the sensor output signal which can be used for radiometric correction.

2) Radiometric correction for Sun angle and topography

a. Sun spot: The solar radiance will be reflected diffusely onto the ground surface, which results in lighter area in an image. It is called a Sun spot. The Sun spot together with vignetting effects can be corrected by estimating a shading curve which is determined by Fourier analysis to extract a low frequency component.

b. Shading: The shading effect due to topographic relief can be corrected using the angle between the solar radiation direction and the normal vector to the ground surface.

3) Atmospheric correction: Atmospheric effects cause absorption and scattering of the solar radiation. Reflected or emitted radiation from an object and path radiance should be corrected.

- **Geometric Correction**

It is a process of transforming imagery to remove undesirable or misleading geometric distortion (due to sensor pitch, roll, height etc). Simple applications such as Land use / Land Cover don't required atmospheric correction since the various features such as soil, water, vegetation and urban signals are strong and much different from others that atmospheric attenuation can be neglected in that case But when we are extracting the biophysical properties within a specific class then the differences in reflectance of various constituents may be so small that the atmospheric attenuation might make them inseparable. When the atmospheric attenuation is small as compared to signal from terrain being sensed the model atmosphere can be used. Model Atmosphere is an assumed atmosphere which is calculated using time of year, altitude, latitude and longitude of the study area. There are three steps of Geometric Correction; the first one is to collecting GCPs, pre-registration checking and then, registration. The raw digital images that have the nonsystematic distortion need to be rectifying by using whether the image to map These distortions may be due to several factors such as:

(i) Scan Skew Distortion

(ii) Space Craft Velocity Distortion

(iii) Panoramic Effect

(iv) Earth Rotation Correction

(v) Altitude and Attitude

Scan Skew Distortion:

During the time the scan mirror completes one active scan, the satellite moves along the ground track. Therefore, scanning is not at right angles to the satellite velocity vector (ground track) but is slightly skewed, which produce along track geometric distortion, if not corrected (Figure 13).

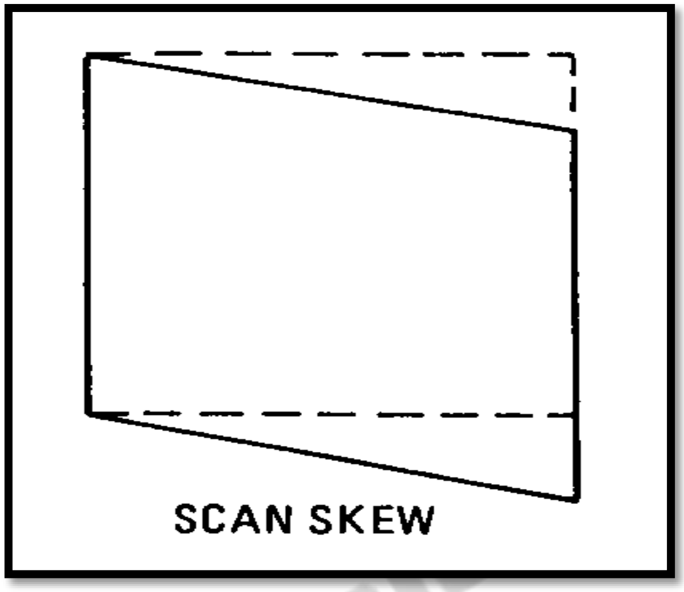


Figure. 13 Scan skew effect

Earth Rotation Correction

Amount of earth rotation during the time required to scan one frame results in distortion in scan direction. The process is along track distortion. This is a function of space craft latitude and orbit (Figure 14).

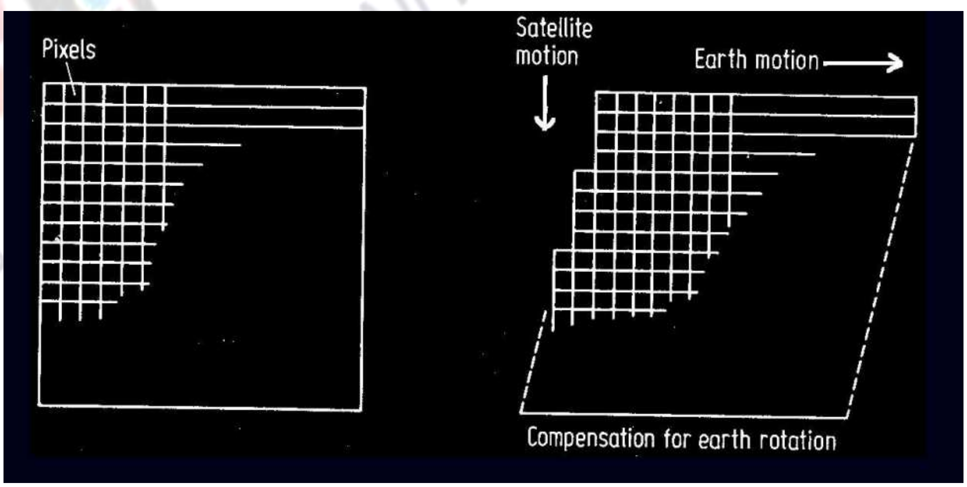


Figure 14 Earth rotation error

Source: http://www.geos.ed.ac.uk/~rharwood/teaching/msc/adv_ip/corr.pdf

Altitude and Attitude

Deviation of the space craft from nominal altitude causes scale distortion in remote sensing data with decrease in height of the space craft the pixel size decrease sand vice-versa. For Landsat system the distortion is primarily along scan line. For IRS systems distortion will be in both direction since the scanning mechanism is different from landsat Satellite position is stable in space and its axis system is perpendicular to each other. Rotation along the Y-axis (Longitudinal axis) of the sensing platform is called “Roll” (Fig 15). Rotation along the X-axis (along track direction) of the sensing platform is called “Pitch”(Fig17). Rotation on axis orthogonal to previous two axis i .e along line passing through vertically through the sensing platform to center of the earth is called “Yaw”(Fig 16). If space craft departs from this normal position, geometric distortions inherit the RS Data. This distortion Is unpredictable and uncertain.

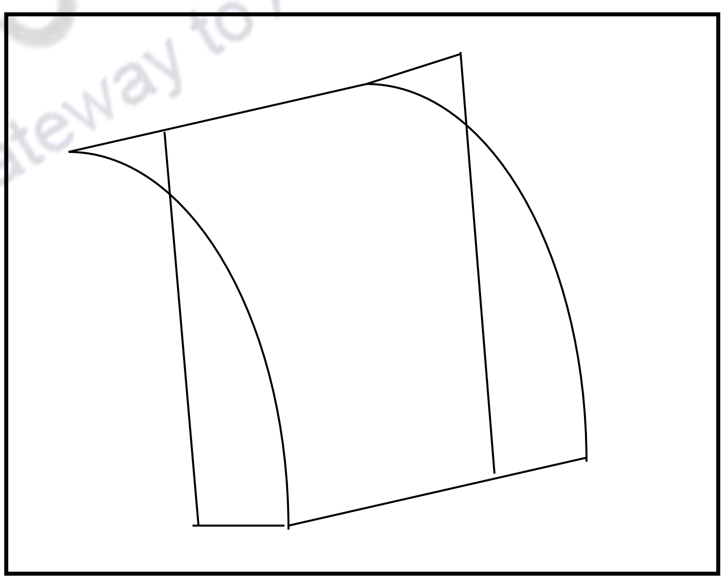


Figure 15 Roll

Source: Self

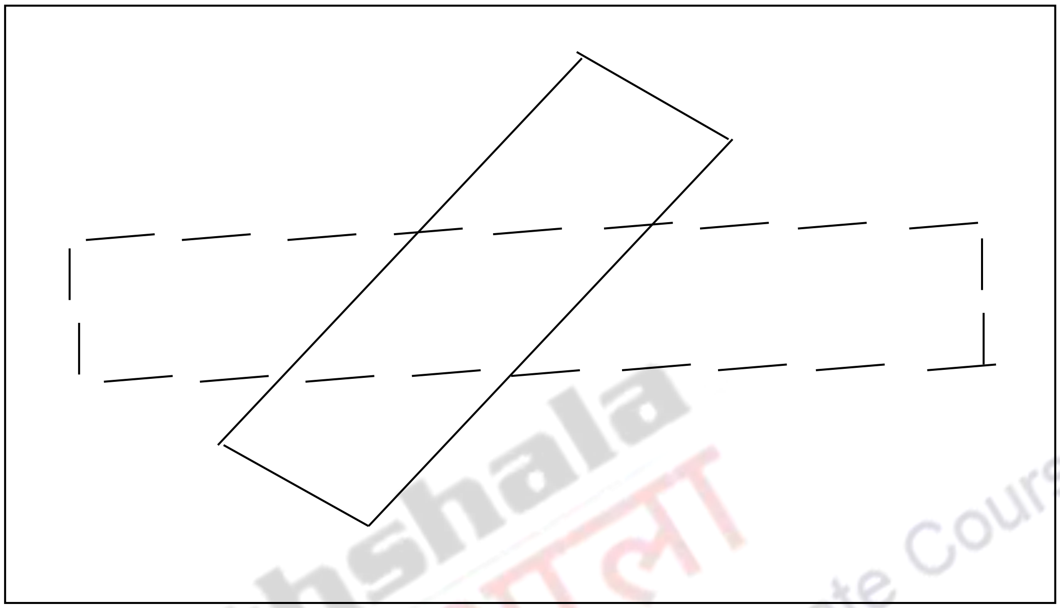


Figure 16 Yaw

Source: Self

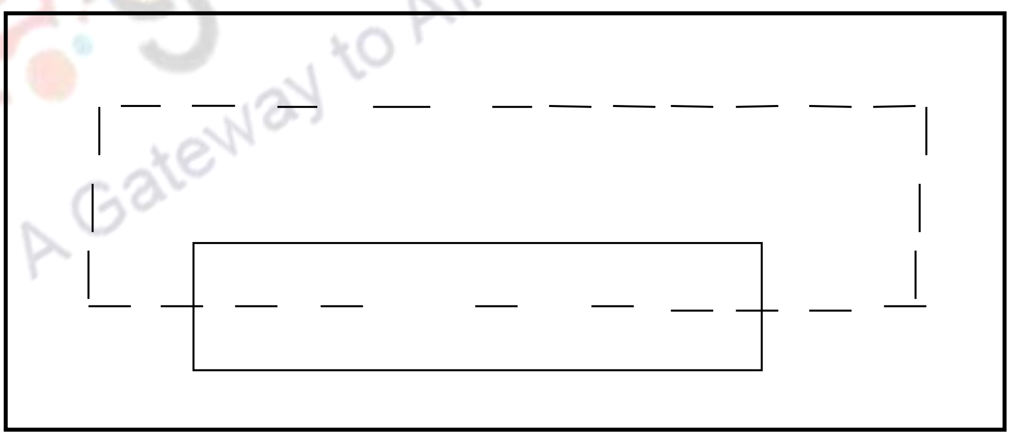


Figure 17 Pitch

Source: Self

Geometric Correction for Unsystematic Error

Random/Non-Symmetrical distortions are corrected by analyzing well distributed ground control points (GCP"s).GCP's are features of known ground location that can be accurately located on digital imagery. E.g. Highway Intersection, building corners, distinct shorelines. In correction process numerous GCP's are located in both terms of the image coordinate system (Column and row numbers) on distorted image and in terms of their ground coordinates (measured from map, GPS readings, or from already projected in projected or geographic coordinate system). Number of GCP required based on order of transformation model is given by:

$$[(N+1)*(N+2)]/2$$

Values are then submitted to least square regression least square regression equation to determine coefficients for two coordinate transformation equation. These are used to relate geometrically correct map coordinates to distorted image coordinates.

$\mathbf{x = f_1(X,Y)\ y = f_2 =(X,Y)}$

Where,

(x, y) = distorted image coordinate

(X,Y) = correct map coordinates

(f_1, f_2) =Transformation functions

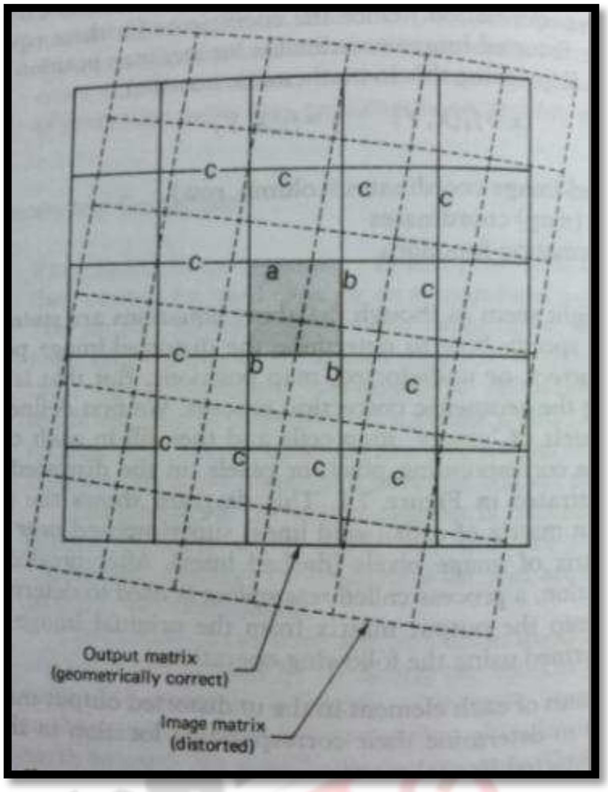


Fig (18): Transformation Matrix

Source: Remote Sensing and Image Interpretation, Lillsand and Kiefer

An undistorted output matrix of empty map cells is defined. Coordinates of each element in undistorted output matrix are transformed to determine their corresponding location in original input (distorted) matrix. Cell in output matrix will not overlay exactly over the pixel in input matrix. So the intensity values or digital number assigned to cell in output matrix is determined on basis of its surrounding pixel in transformed image.

Resampling: Resampling is a technique of extraction of gray values from a location in original input image and its relocation to appropriate coordinates rectified output image.

- Coordinates of each element in undistorted output matrix are transformed to determine their corresponding location in original input (distorted) matrix .
- Cell in output matrix will not overlay exactly over the pixel in input matrix. So the intensity values or digital number assigned to cell in output matrix is

determined on basis of its surrounding pixel in transformed image.Three resampling techniques can be identified based on degree of precision and cost effectiveness:

A) Nearest neighborhood

B) Bilinear interpolation

C) Cubic Convolution

(A) Nearest Neighborhood

The DN for this pixel could be assigned simply on the basis of the DN of the closest pixel in the input matrix. In mentioned example Fig. 19 the DN of the input pixel labeled would be transferred to the shaded output pixel. This approach is called Nearest Neighbor resampling. It offers the advantage of computational simplicity and avoids having to alter the original input pixel values. This method preserves the original array values of the pixel and thus doesn't alter the thematic in formation, but it introduces a spatial shift of √2 times of pixel size Geometry of features such as road, canals, railways, etc may appear disjointed in rectified output.

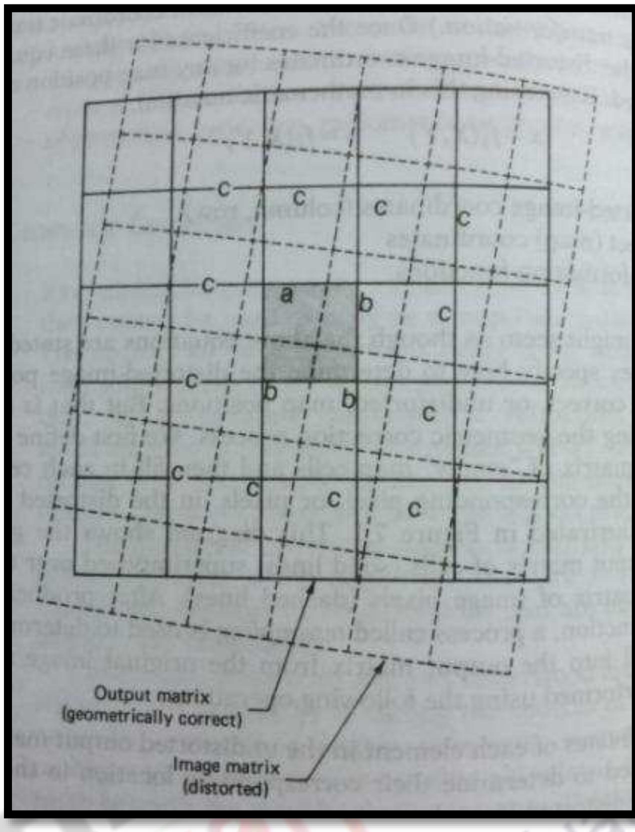


Fig (19): Matrix of geometrically correct output pixels superimposed on matrix of original, distorted input pixels

Source: Remote Sensing and Image Interpretation, Lillsand and Kiefer

(B) Bilinear Interpolation

The bilinear interpolation technique takes a distance weighted average of the DNs of the four nearest pixel (labeled a and b in the distorted image matrix) Figure 19. This process is simply the two dimensional equivalent to linear interpolation. This technique generates a smoother appearing resampled image.

New pixel gets a value from the weighted average of 4 (2 x 2) nearest pixels; smoother but 'synthetic. This technique takes a distance weighted average of DN of the four nearest pixels. The resultant image is much smoother than that of NNB interpolation. Linear features such as road, canal etc is continue. It has $1/4^{th}$ of mean square resampling error of NNB (Fig 19). It requires more computational time because of four multiplications. It also alters the DN values so it may created confusion in classification process.

$$Bv_m = \frac{\sum_{k=1}^{4} Z\,k/\mathrm{D2k}}{\sum_{k=1}^{4} 1/D2k}$$

Z_k is DN value of nearest four pixels $D^2{}_k$ is the distance between data point and nearest pixels.

(C) Cubic Convolution

An improved restoration of image is provided by the cubic convolution method of resampling. In this approach, the transferred “synthetic” pixel values are determined by evaluating the block of 16 pixels in the input matrix that surrounds each output pixel (labeled a,b and c in Fig 19). Cubic convolution resampling avoids the disjointed appearance of the nearest neighbor method and provides a slightly sharper image than the bilinear interpolation method. This technique takes a distance weighted average of DN of the 16 nearest pixels. The resultant image is much smoother than that of bilinear interpolation. It requires more computational time because of 16 multiplications. It also alters the DN values so it may create confusion in classification process.

$$Bv_m = \frac{\sum_{k=1}^{16} Z\,k/D2k}{\sum_{k=1}^{16} 1/D2k}$$