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Unit - 2

9
Visual image interpretation
Elements of image interpretation
Digital image formats
Raster data format
Image distortion and rectification
Atmospheric correction
Radiometric correction
Geometric correction
Image enhancement
Contrast enhancement
Image classification
Supervised classification
Unsupervised classification
Pattern recognition
Filtering techniques
Change detection
Image merging

Advantages

PYQ →

27. a.	Elaborate on elements of interpretation.	10
	(OR)	
b.	Describe the point and local operations in image enhancement.	10

Notes →

visual image interpretation →

Visual image interpretation is the process of analyzing and making sense of information contained within an image or series of images. This is a crucial skill in various fields, including remote sensing

Elements of image interpretation

- Image analysis requires explicit recognition of eight ***elements of image interpretation*** that form the framework and understanding of an image
  - Shape
  - Size
  - Tone
  - Texture
  - Shadow
  - Site
  - Association
  - pattern

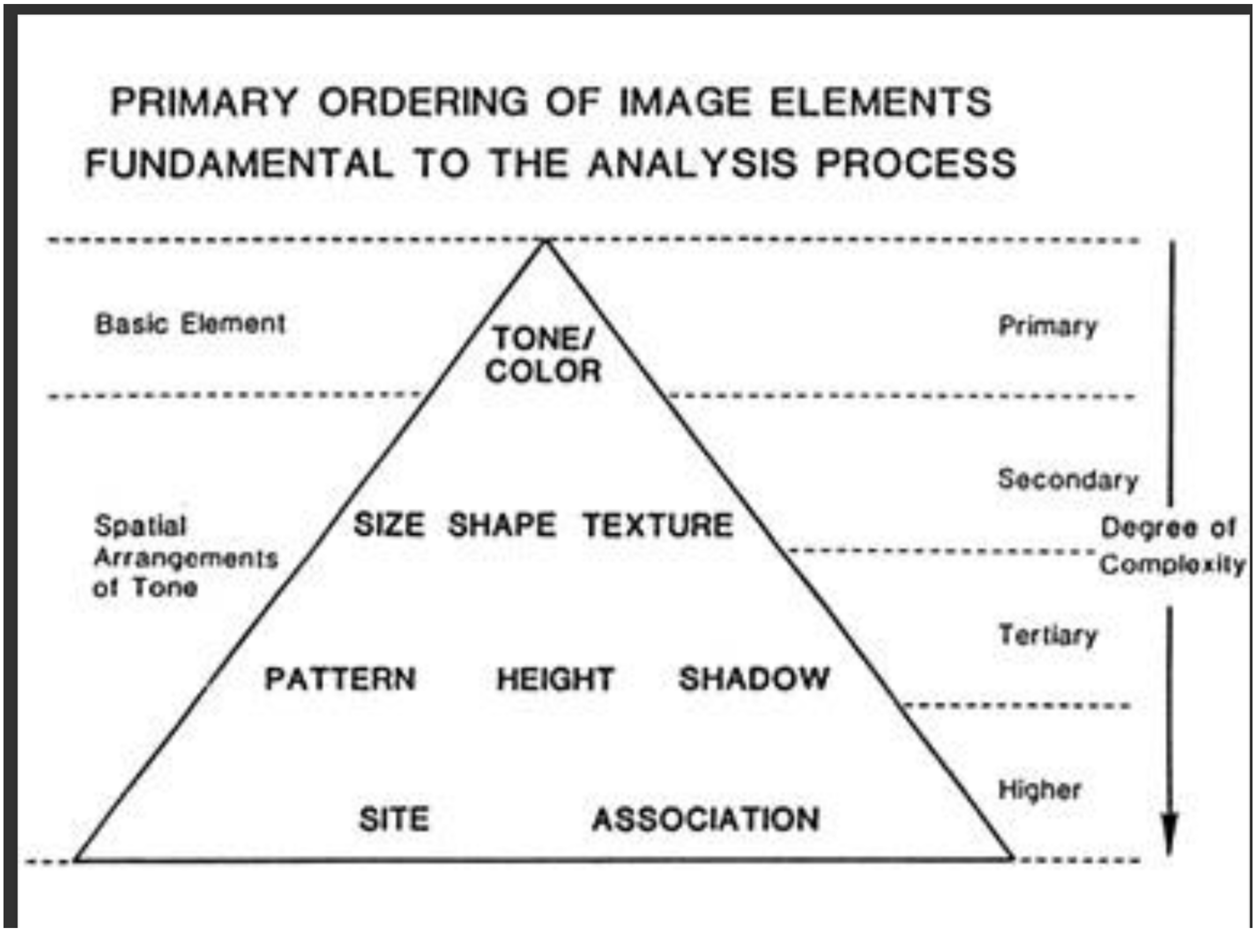
This process relies on identifying and understanding specific elements within the images. Here are some key elements of image interpretation:

1. color
2. shape
3. size
4. texture
5. tone and contrast
6. pattern
7. shadow
8. association and context
9. **Color:** The color of objects and features within an image can provide valuable information. Different colors can indicate variations in material, vegetation, land use, or other characteristics. For example, in remote sensing, healthy vegetation may appear green, while water bodies may appear blue.
10. **Shape:** The shapes of objects and features are important for interpretation. Shapes can help identify specific objects or terrain features. For example, circular shapes may indicate bodies of water, while rectangular shapes may suggest buildings or man-made structures.
11. **Size:** The size of objects within an image can be used to estimate their dimensions or relative importance. For instance, in a satellite image, large clusters of buildings may suggest urban areas, while smaller ones may indicate rural settlements.
12. **Texture:** Texture refers to the visual pattern or roughness of surfaces. It can be used to differentiate between materials or features. For example, a rough, jagged texture might indicate a mountainous area, while a smooth texture could represent a cultivated field.
13. **Tone and Contrast:** Tone refers to the brightness or darkness of areas within an image, while contrast is the difference in brightness between adjacent areas. Variation in tone and contrast can help identify features like roads, water bodies, or geological formations.
14. **Pattern:** Patterns are repetitive or regular arrangements of features. Recognizing patterns is crucial for interpretation. For example, the layout of streets in a city, the

alignment of crops in a field, or the arrangement of geological strata can all provide important information.

15. **Shadow:** Shadows in an image can reveal information about the elevation and orientation of objects and terrain. Analyzing shadows can help in estimating the height of buildings or the topography of an area.
16. **Association:** The relationships between objects and features in an image are important for interpretation. This includes understanding how objects are related spatially and functionally. For example, interpreting the proximity of roads to buildings or the association of vegetation with water bodies.
17. **Context:** The context of an image provides important information for interpretation. This includes knowledge of the area being imaged, the scale of the image, and any additional data, such as metadata or ancillary information.
18. **Time and Change:** Monitoring images taken at different times can reveal changes over time. For example, comparing satellite images taken over several years can show land-use changes or natural phenomena like erosion.
19. **Knowledge and Expertise:** Human expertise is a critical element in image interpretation. Experts in a specific field can apply their knowledge and experience to make more accurate and informed interpretations.
20. **Technology and Tools:** Various software and tools, such as Geographic Information Systems (GIS), image processing software, and machine learning algorithms, can aid in image interpretation. These tools can help automate the analysis and extract data from images.

Understanding and considering these elements within an image is essential for accurate and meaningful image interpretation in a wide range of fields, including remote sensing, geospatial analysis, archaeology, medical imaging, and computer vision.



raster data format →

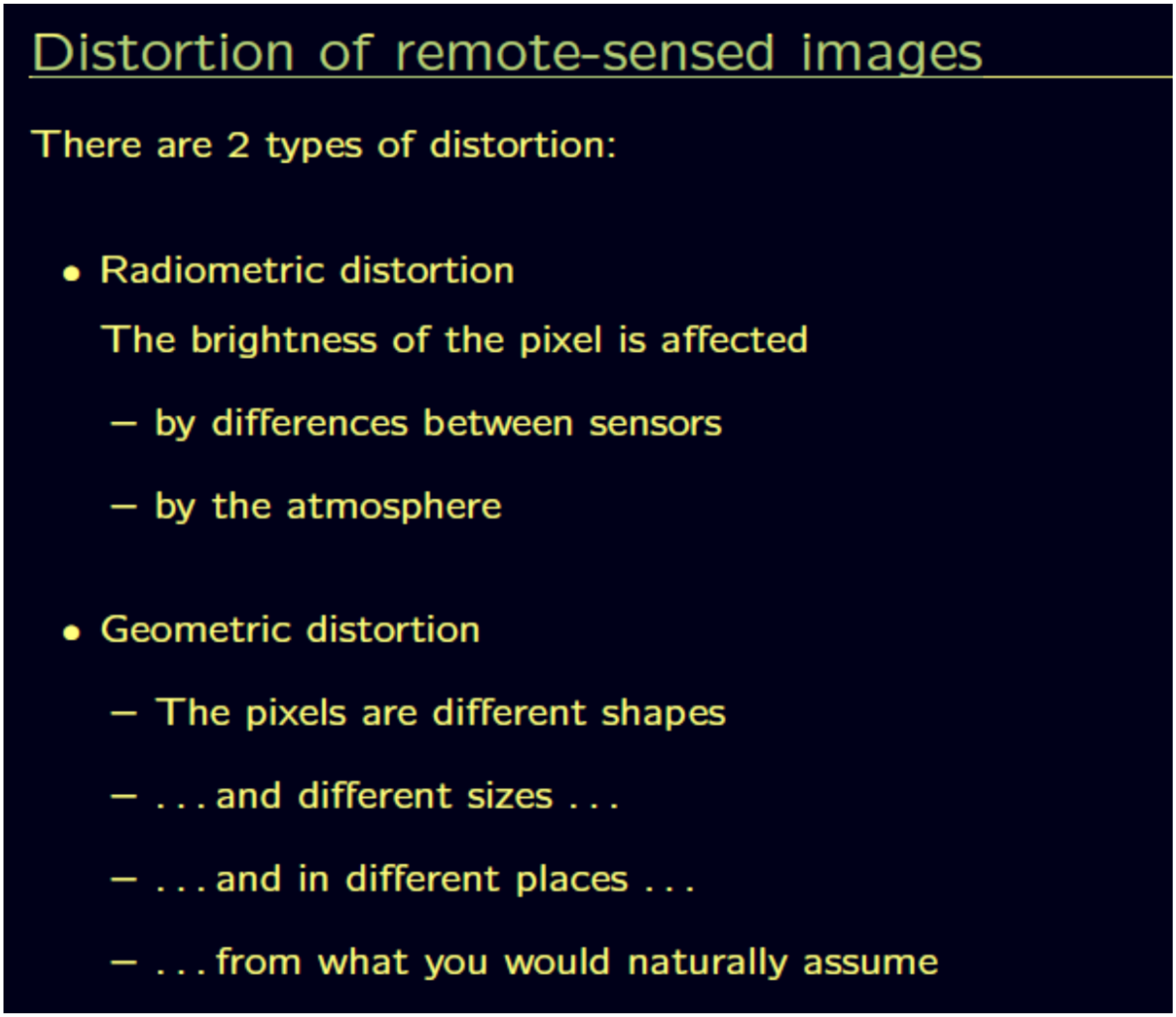
Raster data format is a way of representing and storing digital images, maps, and other spatial data in a grid of cells or pixels. Each pixel contains information that represents a specific location on the Earth's surface. Raster data is commonly used in Geographic Information Systems (GIS) for applications such as remote sensing, cartography, and environmental analysis. Here are some key characteristics and examples of raster data formats:

1. **Pixel Grid:** Raster data is organized as a regular grid of square or rectangular cells, each of which is referred to as a pixel. The pixels are arranged in rows and columns, and each pixel stores a value representing a specific attribute or measurement at that location.

2. **Resolution:** Raster data has a spatial resolution, which defines the size of the cells and the level of detail in the dataset. Higher resolution datasets have smaller cells and can represent more fine-grained information but result in larger file sizes.

Eg → jpeg , tiff format.

distortion of remote sensing images →



Geometric Distortion:

Geometric distortion is like the way objects may look stretched or squished when you view them from certain angles. It's similar to how things appear differently in a funhouse mirror. In remote sensing, this means that objects on the ground can look a bit funny or out of shape when you take pictures from a low-flying plane or a satellite. This can make it challenging to measure things accurately.

Radiometric Distortion:

Radiometric distortion is when colors and brightness in pictures don't look quite right.

Imagine taking a photo, but the colors seem off, or some parts are too bright while others are too dark. It's like a photo that doesn't capture the true colors and brightness of what you're looking at. In remote sensing, radiometric distortion can make it difficult to interpret and analyze the pictures you take, which is a problem if you want to study the Earth from space or the air.

Geometric Distortion:

- **Terrain Relief Distortion:** This occurs due to the curvature of the Earth's surface, which can cause objects on the ground to appear distorted in oblique aerial or satellite imagery. Terrain relief distortion is most pronounced when images are taken from a low angle.
- **Parallax Distortion:** Parallax is the apparent shift in the position of objects when viewed from different angles. It can cause distortions in stereoscopic imagery, especially in areas with significant topographic relief.
- **Sensor Geometric Distortion:** The sensor used to capture the image may introduce geometric distortions due to factors like lens distortion, misalignment, or inaccurate sensor calibration.

Radiometric Distortion:

- **Sun Angle and Shadows:** The angle of the sun can create shadows and variations in illumination, affecting the appearance of objects and their radiometric characteristics in the image.
- **Sensor Noise:** Electronic and sensor noise, such as quantization noise, can introduce unwanted artifacts and distortions in the image.

Atmospheric correction , radiometeric corection , geometric correction →

Atmospheric Correction:

Atmospheric correction is a process used in remote sensing to remove the effects of Earth's atmosphere from satellite or aerial imagery. When light from the sun interacts with the atmosphere before reaching the Earth's surface, it can cause distortions in the image. Atmospheric correction aims to adjust the image so that it accurately reflects the true surface properties. This correction helps in applications like land cover classification, where accurate reflectance values are needed. It involves using atmospheric models and sensor information to account for the scattering and absorption of light by the atmosphere.

Radiometric Correction:

Radiometric correction involves adjusting the pixel values in an image to ensure that they accurately represent the true reflectance or radiance values of the objects or surfaces being observed. This correction is important because various factors, including sensor characteristics, illumination conditions, and atmospheric effects, can cause distortions in the recorded radiometric values. Radiometric correction aims to standardize these values so that they can be compared across different images or used for quantitative analysis. This process involves removing sensor-related noise, normalizing pixel values, and converting them to physical units (e.g., radiance or reflectance).

Geometric Correction:

Geometric correction is the process of rectifying or aligning remote sensing images to their correct geographic locations on the Earth's surface. It corrects distortions that may result from various factors, such as the curvature of the Earth, sensor tilt, and sensor distortion. Geometric correction ensures that each pixel in the image corresponds to a specific geographic coordinate. This correction is vital for accurate spatial analysis and the integration of remote sensing data with geographic information systems (GIS). It typically involves processes like orthorectification and registration to establish a precise spatial relationship between the image and the Earth's surface.

Image Enhancement →

Image enhancement in remote sensing refers to the process of improving the quality and interpretability of satellite or aerial images, making them more suitable for analysis and visualization. Enhancing images can reveal hidden details, reduce noise, and improve the overall quality of the data.

- Enhancement Types
  - **Point Operations (**Contrast enhacement, histogram equalization etc)
    - Modification of brightness values of each pixel in an image data set independently. (radiometric enhancement**)**
    - Brings out contrast in the image
  - **Local operations** (Filtering techniques)
    - Modification of pixel values based on the values of surrounding pixels. (spatial enhancement)
  - **Image Transformations (Ratioing, PCA, Image merging etc)**
    - Enhancing images by transforming the values of each pixel on a multiband basis (spectral enhancement)

Point Operations and Local Operations →

Point operations and local operations are two fundamental approaches in image enhancement, each with its own characteristics and applications. Here's a comparison of these two methods:

Point Operations:

1. **Characteristics:**
   - Point operations are simple and straightforward methods of enhancing images.
   - They operate on individual pixels in the image independently, without considering neighboring pixels.
   - Point operations are typically applied uniformly across the entire image.
   - Examples of point operations include contrast stretching, brightness adjustment, histogram equalization, gamma correction, and histogram matching.
2. **Applications:**

- Point operations are suitable for enhancing images with global issues, such as overall low contrast or brightness.
- They are often used for improving the visual quality of images, making them more pleasing to the eye, and preparing them for further analysis.
- Point operations are effective when the characteristics to be enhanced are evenly distributed throughout the image.

Examples of Point operations →

CONTRAST STRECHING , LINEAR STRECHING , Contrast Enhancement Linear Contrast Stretch and Histogram Equalisation →

Contrast Stretching, Linear Stretching, Contrast Enhancement, Linear Contrast Stretch, and Histogram Equalization are techniques used in image processing to enhance the contrast and visibility of details in an image. Here's an explanation of each of these methods:

1. **Contrast Stretching:**

CONTRAST STRECHING

RECORDING AND DISPLAY DEVICES OPERATES OVER 128/256 GREY LEVEL IMAGES

INTENTION IS TO EXPAND THE NARROW RANGE OF DISPLAY LEVEL

OUTPUT ACCENTRIATES THE CONTRAST

•Linear strech

•Histogram equlaisation

•Special stretch

- **Description:** Contrast stretching, also known as dynamic range adjustment, is a simple point operation that enhances the contrast in an image. It works by linearly stretching the range of pixel values in an image to span the entire available dynamic range (usually 0 to 255 for an 8-bit image).
- **How it works:** The process involves finding the minimum and maximum pixel values in the original image and mapping them to the minimum (0) and maximum (255) values, respectively, in the output image. All other pixel values are linearly scaled between these two extremes.
- **Applications:** Contrast stretching is commonly used to improve the visibility of details in images that have a limited contrast range. It's particularly effective for images with low contrast, such as faded photographs or satellite images with underexposed or overexposed regions.

2. **Linear Stretching:**

LINEAR STRECHING

EXPAND THE RANGE OF IMAGE LEVELS (60-158) TO FILL THE RANGE OF DISPLAY LEVLES (0-255)

DN’ =(DN-MIN/MAX- MIN) * 255

Where, DN’ = output image pixel value

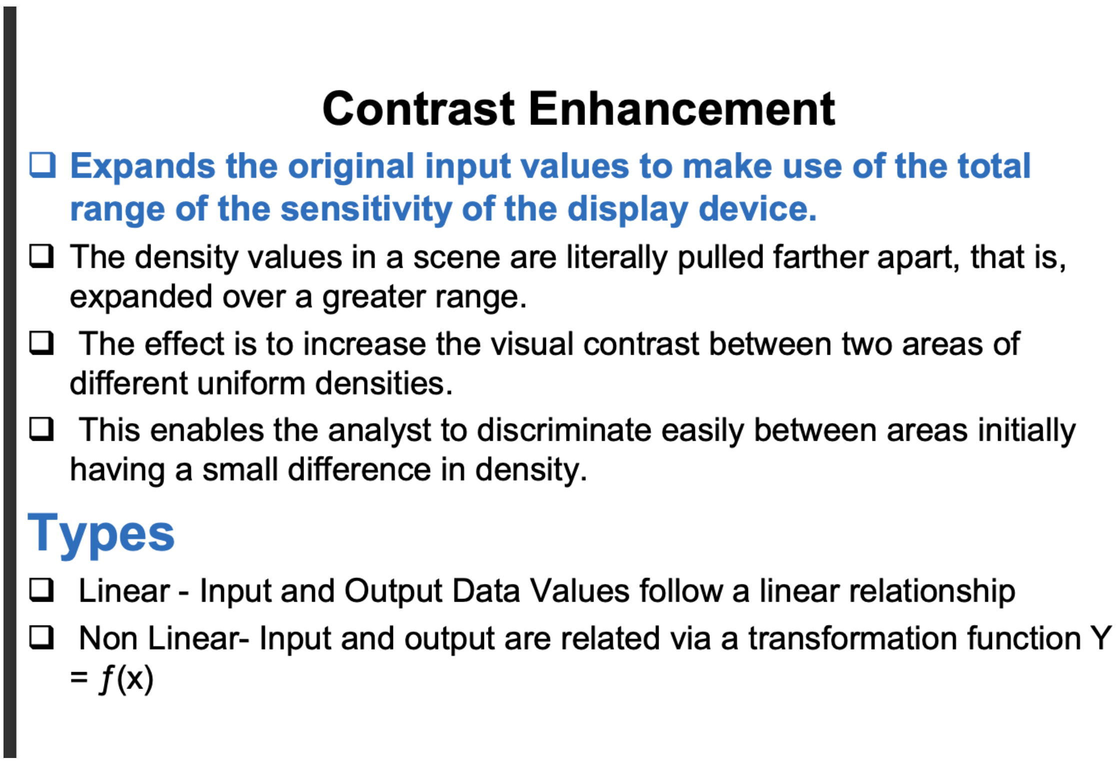
DN = original pixel value

MIN = Minimum value in the image value (60)

MAX = Maximum value in the image (158)

- **Description:** Linear stretching is a variation of contrast stretching. It aims to enhance contrast by stretching the pixel values using a linear transformation while maintaining a specific slope and intercept for the transformation.
- **How it works:** Linear stretching can adjust the slope and intercept of the line formed by the minimum and maximum pixel values. This allows for controlled adjustment of the contrast and brightness in a way that is not as aggressive as simple contrast stretching.
- **Applications:** Linear stretching is useful when you want to enhance contrast and brightness in a controlled manner. It can be applied to various types of images to bring out details without causing harsh changes.

3. **Contrast Enhancement:**



- **Description:** Contrast enhancement is a general term used to describe techniques that improve the visual contrast of an image. It encompasses various methods, including contrast stretching, histogram equalization, and others.

- **How it works:** Contrast enhancement techniques aim to adjust the pixel values in an image to make the dark areas darker and the bright areas brighter, ultimately improving the visibility of details.
- **Applications:** Contrast enhancement is used to make images more visually appealing and informative. It is applied to a wide range of images, including medical images, satellite imagery, and photographs.

4. **Histogram Equalization:**

Histogram Equalisation

➢ In this technique, histogram of the original image is redistributed to produce a uniform population density.

➢This is obtained by grouping certain adjacent gray values.

➢Thus the number of gray levels in the enhance image is less than the number of gray levels in the original image.

➢Contrast is increased at the most populated range of brightness values of the histogram (or "peaks").

➢It automatically reduces the contrast in very light or dark parts of the image associated with the tails of a normally distributed histogram.

- **Description:** Histogram equalization is a contrast enhancement technique that improves the contrast in an image by redistributing pixel values to achieve a more uniform histogram. It can enhance details in both dark and bright areas of an image.
- **How it works:** Histogram equalization involves creating a cumulative distribution function (CDF) of the image's histogram and then remapping pixel values based on this CDF. It stretches the histogram to fill the entire dynamic range.
- **Applications:** Histogram equalization is useful for enhancing images with varying levels of brightness and contrast, particularly when details are

distributed across a wide range of pixel values. It is commonly used in medical imaging, satellite imagery, and other fields where enhancing details is crucial.

Each of these techniques has its strengths and applications, and the choice depends on the specific needs of the image enhancement task and the characteristics of the image being processed.

Local Operations:

1. **Characteristics:**
    - Local operations take into account the surrounding pixels of a target pixel in the image.
    - They apply a specific operation to each pixel based on the values of neighboring pixels within a defined neighborhood or window.
    - Local operations can vary in terms of the size of the neighborhood and the specific operation applied (e.g., filtering, convolution).
2. **Applications:**
    - Local operations are used for tasks that involve enhancing image features that vary across the image and are related to local structures.
    - They are effective for reducing noise, sharpening edges, and highlighting fine details in the image.
    - Local operations are often applied in image processing techniques like smoothing, edge detection, and texture analysis.

Example of Local Operation →
Filter Techniques →

Filtering techniques in remote sensing are like using special tools to make pictures from satellites or planes look better and clearer. These tools help in two main ways:

1. **Smoothing Filters:** They work like softening brushes and help make images less bumpy. They can remove tiny specks that make the picture look grainy.

2. **Edge Enhancement Filters:** These tools are like outlining pens. They make edges of things in the picture stand out more. They help us see where things start and end more clearly.

- Low-pass filter → for large area → high frequency is blocked.
- high-pass filter → for precise & small area → high frequency is preserved.

A **low-pass filter** is designed to emphasize larger, homogeneous areas of similar tone and reduce the smaller detail in an image. Thus, low-pass filters generally serve to smooth the appearance of an image. Average and median filters, often used for radar imagery are examples of low-pass filters.

High-pass filters do the opposite and serve to sharpen the appearance of fine detail in an image. One implementation of a high-pass filter first applies a low-pass filter to an image and then subtracts the result from the original, leaving behind only the high spatial frequency information.

Directional, or edge detection filters are designed to highlight linear features, such as roads or field boundaries. These filters can also be designed to enhance features which are oriented in specific directions. These filters are useful in applications such as geology, for the detection of linear geologic structures.

Filter Types

- Low Pass Filters
- block high frequency details
- has a smoothening effect on images.
- Used for removal of noise
- Removal of “salt & pepper” noise
- Blurring of image especially at edges.
- High Pass Filters
- Preserves high frequencies and Removes slowly varying components
- Emphasizes fine details
- Used for edge detection and enhancement
- Edges - Locations where transition from one category to other occurs

Image Division and Spectral ratioing →

"Image division" and "spectral ratioing" are both image processing techniques commonly used in remote sensing and spectral analysis to extract valuable information from multispectral or hyperspectral imagery. Let's explore these techniques in simple terms:

1. **Image Division:**

    - **Description:** Image division is a mathematical operation that involves dividing the pixel values of one image by the corresponding pixel values of another image on a pixel-by-pixel basis. Typically, the two images involved in the division represent different spectral bands or wavelengths.
    - **Purpose:** Image division helps highlight relationships between the two spectral bands. For example, it can be used to assess how one spectral band compares to another or to emphasize certain spectral features.
    - **Applications:** Image division is often used in remote sensing to create new images that reveal specific information. For instance, it can be used to calculate vegetation indices, like the Normalized Difference Vegetation Index (NDVI), which assesses the health of vegetation based on the ratio of

near-infrared to red reflectance. In this case, image division helps emphasize the presence and health of vegetation in an image.

2. **Spectral Ratioing:**
    - **Description:** Spectral ratioing involves dividing the pixel values of one spectral band by the pixel values of another spectral band within the same image. The result is a new image in which each pixel represents the ratio between the two spectral bands.
    - **Purpose:** Spectral ratioing is used to identify spectral characteristics or properties of materials or objects. By comparing the reflectance or absorption at different wavelengths, it can reveal information about the composition or conditions of the materials.
    - **Applications:** Spectral ratioing is commonly applied in remote sensing for tasks like mineral identification. For example, when examining a spectral image, spectral ratioing can help identify specific minerals based on their unique spectral signatures in certain bands.

In both image division and spectral ratioing, the goal is to create new images that highlight specific spectral information or relationships between spectral bands. These techniques are valuable tools in remote sensing and spectral analysis for tasks such as land cover classification, environmental monitoring, and geological studies. They help analysts extract meaningful insights from the spectral properties of remote sensing data.

Image Division/spectral ratioing

- The most common transforms applied to image data.
- On a pixel-by-pixel basis carry out the following operation
  - Band1/Band2 = New band
  - Resultant data are then rescaled to fill the range of display device
- Very popular technique, commonly called **'Band Ratio'**

  Mathematically $BV_{i,j,r} = BV_{i,j,k} / BV_{i,j,l}$

Where

$BV_{i,j,k}$ Brightness value at the location line i, pixel j in k band of imagery

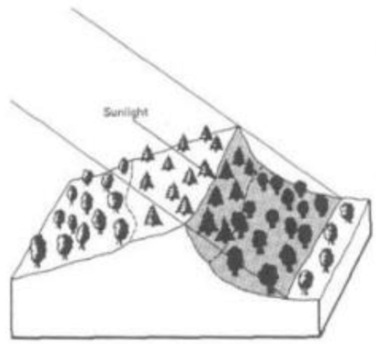
$BV_{i,j,l}$ Brightness value at the same location in band l

$BV_{i,j,r}$ Ratio value at the same location

(Note: If Denominator is 0 (zero) then Denominator BV is made 1)

Application of Ratios

- Undesirable effects on recorded radiances (e.g. variable illumination) caused by variations in topography.
  - Sometimes differences in BV's from identical surface material are caused by topographic slope and aspect, shadows or seasonal changes
  - These conditions hamper the ability of an interpreter to correctly identify surface material or land use in a remotely sensed image.
- Ratio transformations can be used to reduce the effects of such environmental conditions



To reduce topographic effect

Landcover/ Illumination	Digital Number		Ratio
	Band A	Band B	
Decidous			
Sunlit	48	50	.96
Shadow	18	19	.95
Coniferous			
Sunlit	31	45	.69
Shadow	11	16	.69

Principal Component Analysis PCA →

PCA is used to simplify complex data by transforming it into a new coordinate system, where the most important information is captured in the first coordinate (called the first principal component), the second most important in the second coordinate (the second principal component), and so on. In simple terms, it helps reduce data while keeping the essential information.

Principal Component Analysis (PCA)

- Different bands of multispectral data are often highly correlated and thus contain similar information.

- We need to Transforms the original satellite bands into new “bands” that express the greatest amount of variance (information) from the feature space of the original bands

- PCA is accomplished by a linear transformation of variables that corresponds to a translation and rotation of the original coordinate system.

Image Fusion/Image Mergin →

IMAGE FUSION/IMAGE MERGING

- Most of the sensors operate in two modes: multispectral mode and the panchromatic mode.
- The panchromatic mode corresponds to the observation over a broad spectral band (similar to a typical black and white photograph) and
- the multispectral (color) mode corresponds to the observation in a number of relatively narrower band.
- Usually the multispectral mode has a better **spectral resolution** than the panchromatic mode.
- Most of the satellite sensors are such that the panchromatic mode has a better **spatial resolution** than the multispectral mode,
- Better is the spatial resolution, more detailed information about a landuse is present in the imagery
- **To combine the advantages of spatial and spectral resolutions of two different sensors, image fusion techniques are applied.**

multispectral mode →

• In multispectral mode, a remote sensing instrument or satellite sensor captures images in multiple spectral bands or wavelengths simultaneously. These spectral bands are usually selected to represent different parts of the electromagnetic spectrum, such as visible, near-infrared, and shortwave infrared.

panchromatic mode. →

Panchromatic mode involves capturing high-resolution images in a single, broad spectral band, typically in the visible or near-infrared range. Unlike multispectral mode, which uses multiple bands, panchromatic mode focuses on a single band.

Spectral Resolution (Think of Colors):

- Spectral resolution is like having many crayons of different colors in your box.
- It's about how well you can tell apart different colors, like blue, green, and red.
- High spectral resolution means you have lots of crayons with different colors to work with.

- You can use it to identify specific things, like telling different types of trees or crops apart.

Spatial Resolution (Think of Details):

- Spatial resolution is like how closely you can zoom in with a camera to see small details.
- It's about how sharp and clear the picture is, like seeing fine lines or small objects.
- High spatial resolution means you can see tiny details, like individual cars on a road or even people's faces.

Multi-temporal data merging

- Same area but different dates → composites → visual interpretation
  - e.g. agricultural crop
    - NDVI from Landsat-7 ETM+
      - March 7 → blue
      - April 24 → green
      - October 15 → red
    - GIS-derived wetland boundary → eliminate the interpretation of false positive areas
  - Enhance the automated land cover classification
    - Register all spectral bands from all dates into one master data set
      - More data for classification
      - Principal components analysis → reduce the dimensionality → manipulate, store, classify, …
  - Multi-temporal profile
    - Fig 7.54: greenness. (t_p, σ, G_m, G_0)

Multi-sensor image merging

- Multi-sensor image merging

  IHS multisensor image merger of SPOT HRV, landsat TM and digital orthophoto data
- Multi-spectral scanner + radar image data

Multitemporal Data Merging:

Multitemporal data merging, also known as temporal fusion, is a technique used in remote sensing to combine and integrate data captured by the same sensor or sensors at different time points. The goal is to create a composite image or dataset that represents the Earth's surface as it has changed over time. Here's a simple explanation:

- **Data from Different Time Points:** Multitemporal data merging involves collecting data from the same area at different moments in time. This can be from the same satellite sensor or sensors with similar characteristics.
- **Combining for Change Detection:** By merging data from different times, you can create images or datasets that highlight changes that have occurred. This is useful for tracking seasonal changes, land cover changes, urban expansion, and more.
- **Applications:** Multitemporal data merging is used in agriculture to monitor crop growth, in forestry to track changes in forests, in environmental studies to observe changes in water bodies, and in disaster management to assess the impact of events like floods or wildfires.

Multisensor Image Merging:

Multisensor image merging, also known as sensor fusion, is a technique used in remote sensing to combine data from different sensors, each capturing information in various spectral bands or from various perspectives. The goal is to create a more comprehensive and informative view of the Earth's surface. Here's a simple explanation:

- **Data from Different Sensors:** Multisensor image merging involves collecting data from multiple sensors, each specialized in capturing information in different ways. These sensors can be on different satellites or platforms.
- **Combining for a Comprehensive View:** By merging data from different sensors, you can create composite images that provide a more complete picture of the Earth's surface. Each sensor contributes unique information.
- **Applications:** Multisensor image merging is used in various fields. In environmental monitoring, it combines optical, radar, and thermal data for a comprehensive view of landscapes. In disaster management, it helps in

assessing the impact of events using data from different sensors. In agriculture, it provides detailed information about crop health and soil moisture.

In both cases, the goal is to make better use of the available data to understand changes over time (multitemporal data merging) or to get a more complete view of the Earth's surface (multisensor image merging). These techniques are crucial for applications ranging from agriculture and environmental monitoring to disaster assessment and urban planning.

Image Classification →

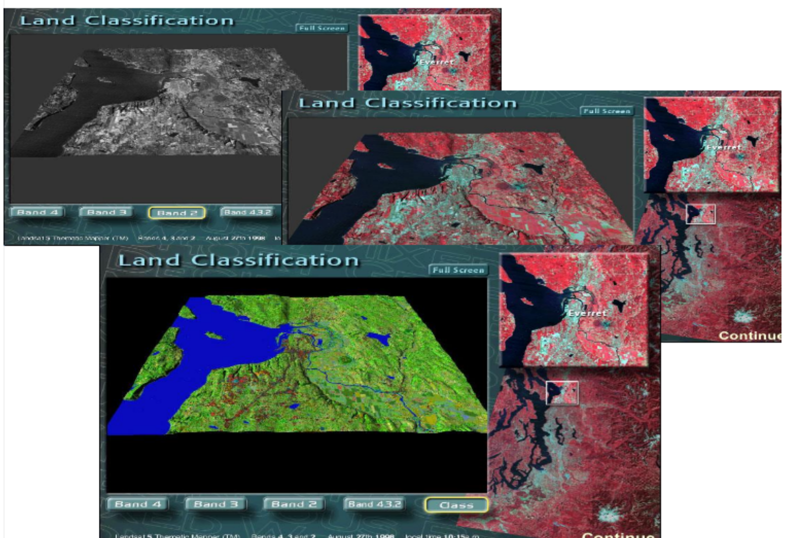
IMAGE CLASSIFICATION

- Why classify?

- Make sense of a landscape
  - Place landscape into categories (classes)
    - Forest, Agriculture, Water, etc

- Classification scheme = structure of classes
  - Depends on needs of users

Image Classification



What is a Classified Image

- Image has been processed to put each pixel into a category
- Result is a vegetation map, land use map, or other map grouping related features
- Categories are defined by the intended use of the map
- Can be few or many categories, depending on the purpose of the map and available resources

Training Stage and Supervised Classification →

The training stage in remote sensing, also known as the training phase or classifier training, is a critical step in supervised image classification. Supervised classification is a process in which a computer algorithm learns to classify or categorize pixels or objects in an image based on user-provided training samples. The training stage involves the following key steps:

1. **Selection of Training Samples:**
   - Remote sensing experts or analysts select representative samples from the image. These samples are pixels or regions that are known and labeled according to the land cover or land use classes of interest.
2. **Labeling of Training Samples:**
   - Each selected sample is assigned a specific class label. For example, a sample may be labeled as "water," "forest," "urban," "cropland," or any other relevant land cover class.
3. **Feature Extraction:**
   - Features are extracted from the training samples. These features can include spectral information from different spectral bands, texture characteristics, or other relevant attributes. The goal is to describe the properties of the selected samples.
4. **Training the Classifier:**
   - Using the labeled training samples and their associated features, a supervised classification algorithm is trained. Common classification algorithms include maximum likelihood, support vector machines, decision trees, and neural networks.
5. **Model Calibration and Validation:**
   - The classifier may be calibrated and validated to ensure its accuracy. This is done by applying the trained model to a separate dataset (validation set) to assess its performance.
6. **Adjustment and Refinement:**

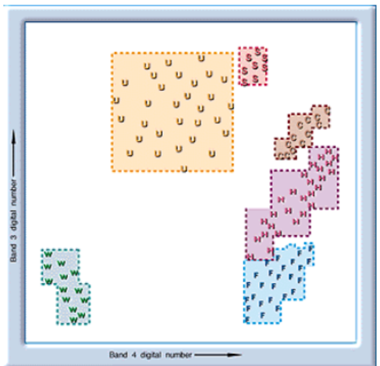
- Based on the validation results, the model may be fine-tuned, and the training process may be repeated to improve classification accuracy.

The primary purpose of the training stage is to teach the classifier how to recognize and differentiate between the various land cover or land use classes in the image. Once trained, the classifier can be applied to the entire image or to other similar images to classify pixels or regions into the predefined classes. The quality of the training stage, including the selection of representative training samples and the accuracy of the classifier, has a significant impact on the accuracy of the final land cover classification in remote sensing applications.

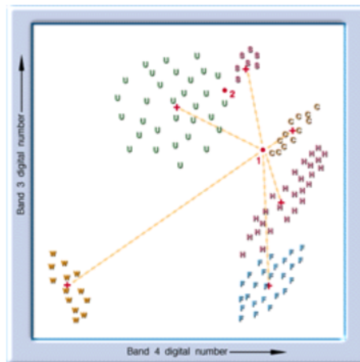
Supervised Classification Types →

> **SUPERVISED CLASSIFICATION**.
>
> Classification stage
>
> Scatter plot using two band data for the training area training data set.
>
> **TYPES**
>
> Minimum Distance to Mean Classifier
>
> Parallelepiped Classifier
>
> Gaussian Maximum Likelihood Classifier

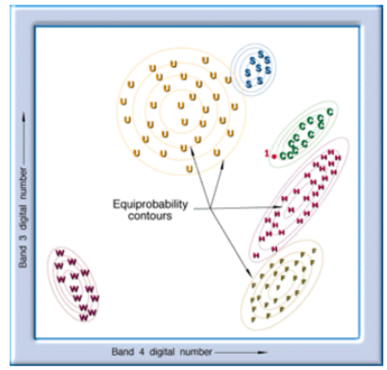
Decision Rules
in Spectral Feature Space



Parallelpiped



Minimum Distance to Means



Maximum Likelihood (Discriminant Analysis

The "Minimum Distance to Mean" classifier, the "Parallelepiped" classifier, and the "Gaussian Maximum Likelihood" classifier are all common methods used in supervised image classification in remote sensing. Let's briefly explain each of these classifiers:

1. **Minimum Distance to Mean Classifier:**
    - **Description:** This classifier assigns each pixel to the class whose mean vector (average of feature values) is closest to the pixel's feature vector in feature space.
    - **How it works:** For each class, a mean vector is calculated from training samples. When classifying a pixel, the classifier computes the Euclidean distance between the pixel's feature vector and the mean vectors of all classes. The pixel is assigned to the class with the shortest distance.
    - **Use Cases:** The Minimum Distance to Mean classifier is a simple and easy-to-understand method. It's often used for initial classification efforts but may not perform well in cases of overlapping class distributions.

2. **Parallelepiped Classifier:**
    - **Description:** The Parallelepiped classifier is a geometric classification method that assigns a pixel to a class based on ranges or boundaries defined in feature space.
    - **How it works:** For each class, parallelepiped boundaries are defined by specifying minimum and maximum feature values for each class. Pixels are assigned to the class whose feature values fall within these defined boundaries.
    - **Use Cases:** The Parallelepiped classifier is suitable when class distributions in feature space are well-separated. It is often used for land cover classification.
3. **Gaussian Maximum Likelihood Classifier:**
    - **Description:** The Gaussian Maximum Likelihood classifier is a statistical approach that assumes class distributions in feature space follow a Gaussian (normal) distribution.
    - **How it works:** For each class, the classifier estimates the mean and covariance matrix of feature values from training samples. When classifying a pixel, it calculates the likelihood of the pixel's feature vector belonging to each class's distribution and assigns it to the class with the highest likelihood (maximum likelihood).
    - **Use Cases:** This classifier is effective when class distributions are assumed to be normal or approximately normal. It is commonly used in remote sensing for land cover classification and is robust in handling class overlap.

These classification methods are part of the family of supervised classifiers used in remote sensing. The choice of classifier depends on factors such as the nature of the data, the characteristics of the classes, and the specific classification task. Practitioners often experiment with different classifiers and select the one that performs best for their particular application.

Unsupervised Classification →

Unsupervised classification is a technique used in remote sensing and image analysis to categorize or group pixels or regions in an image into clusters or classes without prior knowledge of what those classes represent. Unlike supervised classification, where predefined training samples are used to teach the classifier, unsupervised classification identifies patterns or natural groupings in the data on its own. Here's how unsupervised classification works:

1. **Cluster Formation:** Unsupervised classification algorithms analyze the pixel values (e.g., spectral characteristics) of the image and look for similarities between pixels. They group together pixels that are similar in some way.
2. **Class Labeling:** Each cluster is assigned a class label, typically represented by a number. The algorithm doesn't know what these clusters represent in the real world; it's up to the user to interpret them.
3. **Cluster Analysis:** The user must then interpret the clusters and determine the land cover or land use class that each cluster corresponds to. This involves examining the spectral characteristics of the pixels in each cluster and making educated guesses about their meanings.
4. **Visualization and Post-Processing:** The results of the unsupervised classification can be visualized as an image where each cluster is assigned a color or shade. Additional processing steps, like noise reduction or merging similar clusters, may be necessary to improve the classification.

Unsupervised classification is particularly useful when you don't have prior knowledge about the land cover classes in the area you're analyzing or when you want to identify new or unexpected patterns. It's often a starting point for further analysis and can provide valuable insights into the structure of the data.

Common algorithms for unsupervised classification include K-Means clustering and Hierarchical clustering, among others. These methods can help identify patterns and groupings in remotely sensed data, making it a valuable tool for exploratory analysis and hypothesis generation. However, it typically requires expert interpretation to assign meaningful class labels to the clusters that are discovered.

ISODATA Procedure →

ISODATA, which stands for "Iterative Self-Organizing Data Analysis Technique," is an unsupervised classification algorithm widely used in remote sensing and image analysis to cluster or categorize pixels or regions in an image based on their spectral characteristics. It's particularly useful for finding natural groupings in data without prior knowledge of the classes. Here's an overview of the ISODATA procedure:

Pattern Recognition →

Pattern recognition in remote sensing is the process of automatically identifying, classifying, or extracting meaningful patterns, structures, or features from remotely sensed data, which includes satellite imagery, aerial photography, radar data, and more. This field of study plays a crucial role in understanding and interpreting Earth's surface and its changes. Here are some key aspects of pattern recognition in remote sensing:

1. **Objectives of Pattern Recognition:**
    - Identifying land cover and land use categories, such as forests, urban areas, water bodies, and agricultural fields.
    - Detecting changes over time, including urban expansion, deforestation, and natural disasters.
    - Mapping and monitoring environmental parameters, such as vegetation health, soil moisture, and temperature.
    - Recognizing specific objects or features, like buildings, roads, and geological formations.
2. **Data Sources:** Pattern recognition in remote sensing is typically applied to data sources such as:
    - Optical imagery (visible, infrared, and multispectral data).
    - Synthetic Aperture Radar (SAR) data.
    - Hyperspectral imagery (high-dimensional spectral data).
    - LiDAR data (point clouds for 3D modeling).
3. **Methods and Techniques:** Pattern recognition in remote sensing involves various techniques and methods, including:
    - **Supervised Classification:** Using labeled training samples to teach a computer algorithm to classify pixels or objects into predefined categories (e.g., maximum likelihood classification).

- **Unsupervised Classification:** Employing algorithms to identify natural groupings or clusters in the data without prior class information (e.g., K-Means clustering).
- **Change Detection:** Identifying and characterizing differences between two or more images taken at different times, helping monitor land cover changes.
- **Object Detection:** Locating and delineating specific objects or features within an image, such as vehicles, buildings, or ships.
- **Feature Extraction:** Extracting relevant information or attributes from remote sensing data for further analysis (e.g., texture, shape, or spectral indices).

4. **Applications:** Pattern recognition is applied cin various domains, including:
    - Urban planning and development.
    - Agriculture and crop management.
    - Environmental monitoring and conservation.
    - Disaster management and response.
    - Geology and mineral exploration.
    - Forestry and land management.
    - National security and defense.
5. **Challenges:** Pattern recognition in remote sensing faces challenges related to data quality, variability in lighting and atmospheric conditions, scale, and data interpretation. Machine learning and deep learning techniques are being increasingly used to improve classification accuracy and automate feature extraction.

Overall, pattern recognition in remote sensing is a powerful tool for understanding and managing our environment. It allows for the extraction of valuable information from Earth observation data, aiding decision-making processes in various fields.

Change Detection →

Change detection is a process of identifying and analyzing differences or changes in the characteristics of objects, areas, or phenomena over time. This technique has a wide range of applications in various fields, including remote sensing, environmental monitoring, surveillance, and more. Here are some common applications of change detection:

1. **Environmental Monitoring:**
    - **Deforestation and Land Use Change:** Change detection is used to monitor changes in forest cover, urban development, and land use to understand the impact on ecosystems and biodiversity.
    - **Glacier and Ice Cap Monitoring:** Detecting changes in the size and shape of glaciers and ice caps to assess the effects of climate change.
2. **Agriculture:**
    - **Crop Health Assessment:** Monitoring changes in crop health, vegetation growth, and land use can help optimize farming practices and detect crop diseases or stress early.
3. **Urban Planning and Development:**
    - **Land Use Planning:** Identifying changes in urban development, infrastructure, and transportation networks for effective city planning and resource allocation.
    - **Illegal Construction and Zoning Violations:** Detecting unauthorized construction or zoning violations in urban areas.
4. **Disaster Management:**
    - **Flood and Fire Monitoring:** Identifying changes in water levels, fire outbreaks, and flood extents to respond quickly to natural disasters.
    - **Earthquake Damage Assessment:** Assessing structural damage in the aftermath of earthquakes.
5. **Infrastructure Maintenance:**
    - **Road and Bridge Inspection:** Monitoring changes in road and bridge conditions to plan maintenance and repairs.
    - **Power Line and Pipeline Monitoring:** Detecting changes in the condition of power lines and pipelines to prevent failures and leaks.
6. **Forensic Analysis:**

- **Crime Scene Analysis:** Detecting changes in crime scenes and accident sites to gather evidence and reconstruct events.

7. **Remote Sensing and Earth Observation:**
    - **Satellite Imagery Analysis:** Identifying changes in land cover, topography, and vegetation over large geographic areas using satellite imagery.
    - **Meteorology:** Tracking changes in weather patterns, including storm development and atmospheric conditions.
8. **Surveillance and Security:**
    - **Security Camera Analysis:** Detecting changes in surveillance footage for security purposes, such as identifying intruders or suspicious activities.
9. **Healthcare:**
    - **Medical Imaging:** Detecting changes in medical images over time to monitor disease progression or treatment effectiveness.
10. **Natural Resource Management:**

- **Water Resource Management:** Monitoring changes in water quality, water levels, and aquatic ecosystems in lakes, rivers, and oceans.

Change detection typically involves the use of remote sensing technologies, such as satellite imagery, aerial photography, LiDAR, and other sensors, combined with advanced image processing and data analysis techniques. These applications are critical for decision-making, risk assessment, and resource management in various domains.

Change Detection

Change detection applications:

1. Deforestation assessment,
2. Vegetation phenology
3. Urban expansion
4. Damage assessment
5. Crop stress detection
6. Snow melting

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Change Criteria

Before a change detection technique is applied, the analyst has to define what is considered to be a change.

Considerations before implementing change detection

- Before implementing change detection analysis, the following conditions must be satisfied:
  i. precise registration of multi-temporal images;
  ii. precise radiometric and atmospheric calibration or normalization between multi-temporal images;
  iii. selection of the same spatial and spectral resolution images if possible

Good change detection research should provide the following information:

i. area change and change rate
ii. spatial distribution of changed types
iii. Change trajectories of land-cover types
iv. accuracy assessment of change detection results.