**2.5** **Information Extraction**

**Reading material**

|  |
| --- |
| In this session, you will find out what makes image a quality image. You’ll learn what very cell (pixel) on image represents, what and how many bands makes images. |
| **Images Resolutions – Dimensions of Remote Sensing:**  For earth observation, image resolutions have to be taken into consideration. The quality of remote sensing data consists of its   * Spectral resolutions * Radiometric resolutions * Spatial resolutions * temporal resolutions |
| **1. Spatial Resolution**  Spatial resolution refers to the size of the smallest object that can be resolved on the ground. In a digital image, the resolution is limited by the pixel size, i.e., the smallest resolvable object cannot be smaller than the pixel size. The intrinsic resolution of an imaging system is determined primarily by the instantaneous field of view (IFOV) of the sensor, which is a measure of the ground area viewed by a single detector element in a given instant in time. However, this intrinsic resolution can often be degraded by other factors which introduce blurring of the image, such as improper focusing, atmospheric scattering and target motion. The pixel size is determined by the sampling distance.  A "**High Resolution**" image refers to one with a **small Pixel size**. Fine details can be seen in a high-resolution image. On the other hand, a "**Low Resolution**" image is one with a **large Pixel size**, i.e., only coarse features can be observed in the image.  A diagram depicting high (small grid cell) versus low (large grid cell) spatial resolution. More in text above.  Source: <https://www.e-education.psu.edu/geog160/node/1959> |
|  |
| Source: Remote Sensing of the Environment: An Earth Resource Perspective, Book by John R. Jensen (2014) |
| **2. Spectral resolution**  Spectral resolution refers to the ability of a satellite sensor to measure specific wavelengths of the electromagnetic spectrum. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band. Wide intervals in the electromagnetic spectrum are referred to as Low spectral resolution, and narrow intervals are referred to as High spectral resolution. For example, a multispectral image breaks light into 4 to 36 bands.  Then, it assigns those bands names such as red, green, blue, and near-infrared. Each band may span 0.05 um in the electromagnetic spectrum. Similarly, hyperspectral imaging captures a spectrum of light. But it divides the light into hundreds of narrow spectral bands.  For hyperspectral images, spectral resolution is very high. Remember that every channel or band (colour) of electromagnetic spectrum contains specific information, it is always better to combine different to have maximum of information about features to be analysed.    Source: https://cdn.eo-college.org/2021/01/figure4.jpg |
| Besides Multispectral bands, a satellite dataset contains grayscale band with a high spatial resolution named panchromatic image. A panchromatic image uses a single band that combines Red, Green and Blue bands, allowing for a greater spatial resolution. The resulting image does not contain any wavelength-specific information.  Panchromatic images are produced by the same satellites that produce multispectral images. Since a panchromatic image is a combination of all three visible bands (red + green + blue), the total intensity of solar radiation is much higher in every pixel compared to a multispectral image. The use of the RGB bands sacrifices color for brightness which explains why all panchromatic images are greyscale images. |
| Two main types of band s combination are mostly known in remote sensing:  **Natural or True Colour Composites:** A natural or true colour composite is an image displaying a combination of visible red, green and blue bands. The resulting composite resembles what would be observed naturally by the human eye, many people prefer true colour composites, as colours appear natural to our eyes, but often subtle differences in features are difficult to recognize.    Source: https://gisgeography.com/remote-sensing-earth-observation-guide/  **False Colour Composites:** False colour images are a representation of a multi-spectral image produced using bands other than visible red, green and blue as the red, green and blue components of an image display. False colour composites allow us to visualize wavelengths that the human eye cannot see (i.e., near-infrared).    Source: https://gsp.humboldt.edu/olm/Courses/GSP\_216/sessions/composites.html |
| Using bands such as near infra-red increases the spectral separation and often increases the interpretability of the data. There are many different false coloured composites which can highlight many different features. For examples (see the table below for Landast8 dataset)    Source: https://www.esri.com/arcgis-blog/products/product/imagery/band-combinations-for-landsat-8/ |
| **3. Radiometric resolution**  Radiometric resolution refers to the smallest change in intensity level that can be detected by the sensing system. Sensor’s sensitivity to the magnitude of the electromagnetic energy. The intrinsic radiometric resolution of a sensing system depends on the signal to noise ratio of the detector.  In a digital image, the radiometric resolution is limited by the number of discrete quantization levels used to digitize the continuous intensity value. This quantization is expressed in number of bits, it is the one defining the radiometric coverage too.  The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in energy. |
| Source of picture: Canada Centre for Remote Sensing (CCRS)  We said that radiometric resolution characterizes how finely a given sensor can receive and divide the radiance between the different bands. In the picture above, we can see the difference between lower (8-bit) and higher (12-bit) radiometric at comparable spatial resolution. A greater resolution increases the range of intensities that a sensor can distinguish. |
| **4. Temporal resolution**  Temporal resolution refers to the frequency at which imagery is recorded for a particular geographic area. It is most relevant in time-series studies or phenomena monitoring. A major difference to the spatial domain is that the temporal resolution is not solely dependent on the sensor, but on the satellite platform that the sensor is mounted on.    https://cdn.eo-college.org/2021/03/S2L2A-timelapse\_SaudiArabia.gif |
| Now that you know what parts an image is made of, it's time to dive into how the image can be further processed.  **Digital Image processing in Remote sensing**  Remote sensing data are recorded in digital format, mainly as images or pictures, as you know a picture is worth a thousand words, Pictures concisely convey information about positions, sizes and inter-relationships between objects. They portray spatial information that we can recognize as objects.  As consequence, all image interpretation and analysis involve some levels of digital processing. 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 pixels a number known as Digital Number (DN) or Brightness value (BV) that depicts the average radiance of a relatively small area within a scene. A smaller number indicates low average radiance from the area and the high number is an indicator of high radiant properties of the area.    Source: Photogrammetry and Remote Sensing Division, Indian Institute of Remote Sensing |
| In remote sensing, most common image processing functions are grouped into the four categories:   1. Image Pre-processing 2. Image Enhancement 3. Image Transformation 4. Image Classification and Analysis |
| 1. **Image Pre-processing**: it involves those operations that are normally required prior to the main data analysis and extraction of information, and are generally grouped as ***radiometric or geometric corrections.***   * ***Radiometric corrections*** include correcting the data for sensor irregularities and unwanted sensor or atmospheric noise, and converting the data so they accurately represent the reflected or emitted radiation measured by the sensor. Radiometric correction is done to reduce or correct errors in the digital numbers of images. Done to improve interpretability and analysis of images and to standardize images. * ***Geometric corrections*** include correcting for geometric distortions due to sensor-Earth geometry variations, and conversion of the data to real world coordinates (e.g., latitude and longitude) on the Earth's surface. |
| 2. **Image Enhancement**: it is normally performed to improve the appearance/visibility /quality of the imagery to assist in visual interpretation and analysis. Examples of enhancement functions include contrast stretching to increase the tonal distinction between various features in a scene, and spatial filtering to enhance (or suppress) specific spatial patterns in an image.  There are also some other Image quality enhancement such as **Pansharpening**, which aims at increasing the resolution of satellite images: Pansharpening (short for panchromatic sharpening) is a fusion technique to combine a panchromatic image of high spatial resolution with multispectral image data of lower spatial resolution to obtain a high-resolution multispectral image. In other words, we use panchromatic image details to 'sharpen' the multispectral imagery while simultaneously preserving spectral information. |
| **3. Image Transformation:** this refers to operations performed to combine data from multiple spectral bands. Arithmetic operations (i.e., subtraction, addition, multiplication, division) are performed to combine and transform the original bands into "new" images which better display or highlight certain features in the scene. For example, the computation of different Indices (NDVI, VCI, NDWI, NDBI, NSMI, NDDI, NDI)   * ***Normalized Difference Vegetation Index (NDVI)*** describes the vegetation density and assessing changes in plant health. NDVI is calculated as a ratio between the ***Red (R)*** and ***Near-infrared (NIR)***. In this tutorial learn how to apply the NDVI formula and calculate vegetation patterns.   **NDVI =** **(NIR – R) / (NIR + R)**  NDVI values always range from **-1 to +1**     * ***Normalized Difference Built-up Index (NDBI)*** describes the Built-up density of any Geographic area. NDBI is calculated as a ratio between the ***short-wave infrared (SWIR)*** and ***Near-infrared (NIR).***   **NDBI = (SWIR – NIR) / (SWIR + NIR)**  NDBI values range from **-1 to +1**   * ***Soil Adjusted Vegetation Index (SAVI)*** is similar to NDVI, these enhancements to NDVI are useful because SAVI accounts for variations in soils. SAVI is calculated as a ratio between the **near-infrared (NIR), red (RED)**, and ***L (Vegetation cover current factor).***   **SAVI = (NIR– RED) \* (1+L) / (NIR+ RED+L)**  SDVI values range from **-1 to +1** |
| 4. **Image classification**: it is the process of reducing images to information classes. Classification divides the spectral or spatial feature space into several classes based on a decision rule to create one layer (thematic layer). |
| General Procedures:   * *Feature Extraction*: Transform the multispectral image by a spatial or spectral transform to a feature image (e.g. choice of some classes such as built up, forest, water bodies, agriculture land, bare soil, etc.). Alternatively, you can always look up for the established FAO land cover classification scheme as inspiration: https://www.fao.org/3/x0596e/X0596e02a.htm#P1974\_116516 * *Training:* Extract the pixels to be used for training the classifier to recognize certain categories, or classes. * Determine the discriminant functions in the feature space. Supervised or unsupervised * *Labeling*: Apply the discriminant functions to the entire feature image and label all pixels. The output consists of one label for each pixel. |
| Source of Picture: Remote Sensing of the Environment: An Earth Resource Perspective, Book by John R. Jensen (2014) |
| Two major categories of image classification techniques include unsupervised a supervised classification:  **Unsupervised classification** is where the outcomes (groupings of pixels with common characteristics) are based on the software analysis of an image without the user providing sample classes. The computer uses techniques to determine which pixels are related and groups them into classes. The user can specify which algorism the software will use and the desired number of output classes but otherwise does not aid in the classification process. However, the user must have knowledge of the area being classified when the groupings of pixels with common characteristics produced by the computer have to be related to actual features on the ground (such as wetlands, developed areas, coniferous forests, etc.). |
| **Supervised classification** is based on the idea that a user can select sample pixels in an image that are representative of specific classes and then direct the image processing software to use these training sites as references for the classification of all other pixels in the image. Training sites (also known as testing sets or input classes) are selected based on the knowledge of the user. The user also sets the bounds for how similar other pixels must be to group them together. These bounds are often set based on the spectral characteristics of the training area, plus or minus a certain increment (often based on “brightness” or strength of reflection in specific spectral bands). The user also designates the number of classes that the image is classified into. Many analysts use a combination of supervised and unsupervised classification processes to develop final output analysis and classified maps. |
| **Data processing levels**  Recently, operational processing of remote sensing data has led to multiple processing levels.  “Standard” types of pre-processing:   * Radiometric calibration * Geometric calibration * Noise removal * Formatting   Generic description:   * Level 0: raw, unprocessed sensor data * Level 1: radiometric (1R or 1B) or geometric processing (1G) * Level 2: derived product, e.g., vegetation index |

**Exercise materials and tasks**

**Quiz questions**

Instructions: As a recap and deepening of the previous session’s content, we have prepared this quiz. Please answer the following three questions to test your knowledge retention:

1. What is spatial resolution?

1. **It describes the smallest angular (horizontal) separation between two objects**
2. It describes the ability of sensors to detect grey values
3. It describes the number of bands, that a sensor provides

2. What is the maximum value of the digital number which could be represented for an image with a radiometric resolution of 6 bits?

1. 256
2. 8
3. **64**
4. 2048

3. Temporal resolution – pick the right answer(s)!

1. **Temporal resolution describes the time interval between two overpasses at given point**
2. Temporal signatures of two different land cover types are the same
3. Remote sensing instruments with high temporal repetition are less suited for disaster monitoring

4. Which two of the following are correct statements with respect to sensor design?

1. **For high spatial resolution, the sensor has to have a small IFOV**
2. **A small IFOV increases the amount of energy that can be detected within the IFOV**
3. Narrowing the wavelength range detected for a particular channel or band increases the amount of energy detected without reducing spatial resolution but this reduces the spectral resolution of the sensor
4. Coarser spatial resolution reduces radiometric and/or spectral resolution