Selection of Data for Remote Sensing Researches/Applications

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Every remote sensing research or application involves collection and analysis of data. Once the problem has been identified, it is necessary to collect the data, both in-situ and remotely sensed, in order to progress toward a solution. If data is to be useful, it must be collected/selected properly. Whatever the logic or technique is used, every problem has different data requirements. This topic is aimed to discuss the remote sensing data and their selection methods and related issues. It will also address the multi-data requirements of remote sensing applications.

1 Data for Remote Sensing Research

A researcher/analyst should know what sort of data is needed before setting out to collect or select it. While there may be situations which dictate either in-situ or remotely sensed data, many situations will require the researcher to collect both types of data (Jensen 2006). Other than the remote sensing imageries and in situ data, remote sensing research requires many types of ancillary data, e.g., census data, topographical maps, and data from existing geographic information system (GIS). However, this topic is primarily concentrated on the remote sensing data only.

Required data in any scientific research can be classified into two classes—primary and secondary. Primary data are collected by the investigator conducting the research. Secondary data are collected by someone other than the researcher. Important to realize that remote sensing data are generally not collected by the researcher her/him-self or by their team. Rather, the researcher selects the appropriate data from the available sensors. These data are collected by the respective agencies responsible to maintain and operate the remote sensing sensors. However, collection of ground truth is primarily to be conducted by the researcher. Other ancillary data are of secondary in nature—collected by people/organizations other than the researcher or their team. However, in remote sensing research, primary data are the remote sensing imageries, although they are not collected by the researcher. Remote sensing data are primary because they form the basis of analysis in such researches. In situ and other ancillary data are categorized as secondary, because they supplement the research. Common sources of secondary data for remote sensing research include ground truth, topographical and other conventional maps, GIS data layers, digital elevation models, censuses, surveys, organizational records, and data collected through other quantitative or qualitative research.

2 Factors Influencing the Selection of Remote Sensing Data

Important to realize, the format and quality of the remote sensing data varies widely. These variations are dependent upon the resolutions of the sensor (radiometric, spatial, spectral and temporal) (Jensen 2006;

Bhatta 2011). Sensors are also unique with regard to what portions of the electromagnetic spectrum they see. Different remote sensing instruments record different segments, or bands, of the electromagnetic spectrum. Therefore, determining the correct spatial, spectral, radiometric, and temporal resolution is crucial in any research. Further, whether the research requires optical, or thermal, or microwave data is similarly crucial to determine.

In many instances, remote sensing research requires integration of multiple data; for example, integration of microwave and optical imageries. However, among the influencing factors for the selection of remote sensing data, the resolution and region of electromagnetic spectrum are of high importance. Following sections address these issues in detail. Other factors will be addressed in the context of these two primary factors.

2.1 Resolution

Resolution (or resolving power) is defined as a measure of the ability of a remote sensing system or sensor to distinguish between signals that are spatially near or spectrally similar. Data collection system has four major resolutions associated with it. The major characteristics of an imaging remote sensing instrument are described in terms of its *spatial*, *spectral*, *radiometric*, and *temporal* resolutions. Jensen (2006) or Bhatta (2011) may be referred for a detailed discussion on these resolutions.

2.1.1 Spatial Resolution

The spatial resolution or the ground resolution cell size of one pixel as the finite image element is the most important characterisation for a remote sensing image (Bhuyan et al. 2007). The detail discernible in an image is dependent on the spatial resolution of the sensor and refers to the size of the smallest possible feature that can be detected. Spatial resolution of passive sensors depends primarily on their *instantaneous field of view* (IFOV). The IFOV is the angular cone of visibility of the sensor which determines the area on the earth's surface that is 'seen' from a given altitude at one particular moment in time. The IFOV may also be defined as the area on the ground that is viewed by a single instrument from a given altitude at any given instant of time (Jensen 2006; Bhatta 2011).

The information within an IFOV is presented by a picture element in the image plane usually referred to as pixel. For a homogeneous feature to be detected, its size generally has to be equal to or larger than the resolution cell. If the feature is smaller than this, it may not be detectable as the average brightness of all features within that resolution cell will be recorded. However, smaller features may sometimes be detectable if their reflectance dominates within a particular resolution cell allowing sub-pixel detection (Yue et al. 2006; Xian and Crane 2005; Brown et al. 2000; Phinn et al. 2002).

In the early days of remote sensing, aerial photography was conducted to obtain high resolution imageries; because satellite remote sensing could not provide very detailed data. Nowadays, not only these two platforms are complementary, rather satellite sensors are increasingly dominating many application domains.

Section of resolution and thus a sensor is crucial in every remote sensing research. In a low spatial resolution image, larger ground area makes a *mixed pixel* instead of homogeneous pixel. A mixed pixel is a pixel whose digital number (DN) represents the average energy reflected or emitted by several types of surface present within the area that it represents on the ground; sometimes called a *mixel*. However, very high spatial resolution is also not preferred in several instances. Although higher spatial resolution provides better interpretability by a human observer; but a very high resolution leads to a high object diversity which may end up in problems. For example, when an automated classification algorithm is applied to such data, extremely high computational power and longer computational time is required.

Selection of spatial resolution primarily depends on the level of detail required from the remote sensing data (Anderson et al 1976). Required level of detail further depends on the application area. For example, urban analysis generally requires more detail than a forest analysis; because the urban area is more heterogeneous than the forest. Therefore, the heterogeneity of landscape is a primary factor of choosing the spatial resolution. Another important factor is application scale. For example, the resolution requirement of a research that estimates global built-up area is essentially different for a similar study that concentrates on a city. In the later case, we need to select higher spatial resolution because it requires more detailed data and thus analysis at larger scale. Table 1 lists several remote sensing sensors and their application scales.

Table 1 Application scale for various remote sensing images (Neer 1999; Bhatta 2010)

Pixel size in m	Definition	Platform/Sensor*	Application scale
0.1–0.5	extremely high res.	airborne scanner, aerial photos, GeoEye-1 (pan), WorldView-1 (pan), WorldView-2 (ms)	1:500 – 1:5000
>0.5–1	very high res.	IKONOS (pan), QuickBird (pan), OrbView (pan)	1:5000 – 1:10000
>1–4	high res.	IKONOS (ms), QuickBird (ms), OrbView (ms), GeoEye-1 (ms), IRS (pan)	1:10000 – 1:15000
>4–12	medium res.	IRS (pan), IRS (LISS-IV ms), SPOT (pan)	1:15000 – 1:25000
>12–50	low res.	ASTER, IRS (ms), Landsat-TM/ETM+ (pan, ms), SPOT (ms)	1:25000 – 1:100000
>50–250	very low res.	Landsat MSS	1: 100000 – 1: 500000

>250	extremely low res.	NOAA	>1: 500000

* pan: panchromatic; ms: multispectral

2.1.2 Spectral Resolution

Not only the spatial resolution, but spectral and radiometric resolutions are also vitally important in remote sensing researches. Many earth-surface features have similar spectral characteristics; which means the objects give similar percent reflectance. This makes the object identification and analysis process more complicated.

The spectral resolution refers to the number of spectral bands, individual bandwidths, and the entire range of electromagnetic spectrum covered by the bands. Different classes of features and details in an image can often be distinguished by comparing their responses over distinct wavelength ranges (Jensen 2006; Bhatta 2011). High spectral resolution is achieved by narrow band widths which, collectively, are likely to provide a more accurate spectral signature for discrete objects than broad band-widths. Spectral resolution not only relates with the dimension of the bandwidth but also the number of bands. Individual bands and their widths will determine the degree to which individual targets can be discriminated on a multispectral image. The use of multispectral imagery can lead to a higher degree of discriminating power than any single band on its own. The ideal solution would be a hyperspectral scanner with a large number of bands each with a small bandwidth of 10 nm. But these remote sensing systems are limited and mainly in the experimental stage. Furthermore, these sensors are recent advancement; therefore, for the analysis of past, hyperspectral images are not available. It is important to realize that a lower spectral resolution does not create a mixed pixel; rather it creates *mixed class*, i.e., pixels representing different objects will belong to a single class. Class is a group of pixels relating to a narrow or broad category of objects over the earth surface.

Often, bands in the multispectral image provide redundant information; that means similar type of reflectance in different bands. Therefore, selection of band is very important for a specific project. For example, we require near-infrared (NIR) band for vegetation analysis, because vegetation provides highest reflectance in this band. For the purpose of discriminating different land surface features, firstly we emphasize the band in which highest intra-band variation is present. Intra-band variation refers to the variations in pixel values of different land surface features within a specific band. For example, to identify the water resources within a forested area NIR band is most appropriate; because, in NIR band, water provides lowest and vegetation provides highest reflectance. As a result, there will be a high contrast between the water and vegetation. Once we select the band with highest intra-band variation, the next band should be chosen with highest inter-band variation. Inter-band variation refers to the variations in pixel values between the first and second chosen bands. For example, we consider the NIR band at first for vegetation analysis because it gives highest reflectance in this band; no other objects provide such high reflectance in this band. The second band, for vegetation analysis, we emphasize the red one; because vegetation gives lowest reflectance in this band. As a result, in the first band we have highest intra-band variations among the objects and in the second band we have highest inter-band variations in comparison to the first band for an object to be analyzed.

2.1.3 Radiometric Resolution

The radiometric resolution is defined as the sensitivity of a remote sensing detector to differences in signal strength as it records the radiation flux reflected or emitted from the terrain (Jensen 2006; Bhatta 2011). It defines the number of just discriminable signal levels; consequently, it can have a significant impact on our ability to measure the properties of landscape objects. The radiometric resolution of an imaging system describes its ability to discriminate very slight differences in energy. The finer the radiometric resolution of a sensor, the more sensitive it is to detect small differences in reflected or emitted energy. Lower radiometric resolution is also responsible for mixed class instead of mixed pixel.

However, higher radiometric resolution does not always mean a higher quality image, in particular, while we are interpreting the image visually. This is because human beings can differentiate approximately 40 to 50 individual shades of grey in a black-and-white image. This means that we shall not be able to differentiate between the images having radiometric resolution of 6-bit (64 variations) and 8-bit (256 variations). Tucker (1979) showed that there was only a 2–3 per cent gain in distinguishing vegetation types using an 8-bit resolution compared to a 6-bit resolution. Slater (1980) illustrates that the signal-to-noise ratio decreases with the increase of radiometric resolution. Signal-to-noise ratio is a measure used to quantify how much a signal has been corrupted by noise. It is defined as the ratio of signal power to the noise power corrupting the signal (power of signal / power of noise). The higher the ratio, the less obtrusive the background noise is. That means lower signal-to-noise ratio causes more background noise. Then what is the utility of having higher radiometric resolution? This feature increases the overall clarity of the image. Further, while processing the image digitally in a computer, the full radiometric range can be utilized in some cases and a better result can be obtained. Unlike human being, computer can recognise all radiometric variations contained within an image.

2.1.4 Temporal Resolution

Temporal resolution refers to how frequently the sensor can capture the images for a specific ground area (Jensen 2006; Bhatta 2011). The temporal resolution is an important consideration for a number of monitoring researches, especially when frequent imaging is required (for instance, to monitor the spread of an oil spill or the extent of flooding). Analysis of multiple-date imagery provides information on how the variables change through time. Spectral characteristics of features may change over time and these changes can be detected by collecting and comparing multi-temporal imagery. For instance, during the growing season, most species of vegetation are in a continual state of change and our ability to monitor those subtle changes using remote sensing is dependent on when and how frequently we collect imagery. Each sensor associates an orbital calendar (refer Bhatta 2011). This orbital calendar can provide us the information about when and how frequently we can collect imagery.

Simonett (1983) argues that with some applications, temporal resolution is an important factor. For instance, to monitor crop growth/stress, image intervals of 10 days would be required, but intervals of one year or more would be appropriate to monitor urban growth patterns. The time factor in imaging is important when

- Persistent clouds offer limited clear views of the earth's surface (often in the tropics).
- Short-lived phenomena (floods, oil slicks, etc.) need to be imaged.
- Multi-temporal comparisons are required (e.g., the spread of a forest disease from one year to the next).
- The changing appearance of a feature over time can be used to distinguish it from near-similar features (wheat/maize).

2.2 Region of Electromagnetic Spectrum

Remote sensing can be performed in different regions of electromagnetic spectrum. Optical remote sensing is performed within the optical region (0.3–3.0 μm), thermal remote sensing uses the thermal region (3.0–5.0 and 8.0–14.0 μm), and microwave remote sensing is conducted within the microwave region (1 mm to 1 m). Optical sensors generally use the sun as a source of energy (an exception is LiDAR). Thermal and passive microwave remote sensing uses emitted energy from the earth's surface. However, active microwave remote sensing throws artificially generated energy to the earth's surface and then the backscattered energy is recorded by the sensor. The use of different wavelengths (and thereby techniques) is mainly because of different application areas.

2.2.1 Optical Region

Optical remote sensing makes use of visible, NIR and short-wave infrared sensors to form images of the earth's surface by detecting the solar radiation reflected from targets on the ground. Different materials reflect and absorb differently at different wavelengths. Thus, the targets can be differentiated by their spectral reflectance signatures in the remotely sensed images. Asrar (1989) presented the applications of optical remote sensing. Optical remote sensing data are perhaps most widely used because of their simple nature and easier analysis techniques. Optical remote sensing has emphasized practical applications such as crop inventories, land use classification, and mineral exploration. However, in the last several years, more emphasis has been placed on answering more fundamental scientific questions associated with the global environment, productivity of the oceans, and the composition and distribution of continental rocks (Goetz et al. 1985). Optical remote sensing data are very useful for geologic, vegetation, hydrologic, oceanographic, and urban applications. Optical sensors, unlike the others, can provide very high spatial resolution. Therefore, they are the obvious choice in studies of higher detail requirement.

2.2.2 Thermal Region

Thermal remote sensing records emitted energy from the earth's surface. Thermal imageries can be acquired during the day or night (because the radiation is emitted not reflected) and are used for a variety of applications such as military reconnaissance, disaster management (forest fire mapping), heat-loss monitoring, and several others (refer Prakash (2000)). For the analysis of earth-surface features, for example geologic applications, thermal data may be collected during a 24-hour period. Even multiple data are collected at different times of the day. Temperature extremes and heating/cooling rates can often furnish significant information about the type and condition of an object. For example, the temperature curve of water throughout a day is distinctive for two reasons. First, its range of temperature is quite small compared to that of soil and rocks. Second, it reaches its maximum temperature an hour or two after the other materials. As a result, the terrain temperatures are normally higher than water during the day; however, in the night water is warmer than other materials. Thermal inertia is a measure of the heat transfer rate across a boundary between two materials, e.g., air/soil. Because materials with high thermal inertia possess a strong inertial resistance to temperature fluctuations at a surface boundary, they show less temperature variation per heating/cooling cycle than those with lower thermal inertia. This implies that materials with high thermal inertia have more uniform surface temperatures throughout the day and night than materials of low thermal inertia. For example, water has higher thermal inertia than dry soil; therefore, temperature fluctuation is less in water. Therefore, while choosing the thermal data, one should consider the thermal properties of the objects under investigation and the time of day when the data should be collected. Another issue is important to remember that spatial resolution of thermal sensors is generally coarser. The amount of energy decreases as the wavelength increases (refer Jensen 2006). Therefore, thermal sensors generally posses larger instantaneous field of view (IFOV) compared to optical sensors, to ensure that enough energy reaches the detector in order to make a reliable measurement. IFOV is a measure of the area viewed by a single detector on a scanning system at a given moment in time. Thus, the spatial resolution of thermal sensors is usually fairly coarse, relative to the spatial resolution possible in the visible and reflective infrared.

Most thermal remote sensing applications, such as geologic and soil mapping, are qualitative in the sense. In such cases it is not usually necessary to know the actual temperature or emissivity of the ground-surface material, but simply to study relative differences in the radiant temperature within a scene. In such cases, thermal infrared images are used to (1) determine the type of material in certain instances based on its thermal emission characteristics, (2) discriminate different land surface features, and/or (3) evaluate if significant changes have taken place in the thermal characteristics of these phenomena through time.

However, some thermal remote sensing applications require quantitative data in order to determine absolute kinetic temperatures, for example, sea-surface temperature mapping. The digital data recorded by a thermal sensor, can be processed and calibrated to produce absolute temperature of the ground-surface material. Hence, calibration means developing correlation to relate sensor output values to the actual temperature of the ground objects. This calibration relationship can be applied to each point (pixel) in the digital image, producing a matrix of absolute temperature value. The output of a thermal sensor is the measured quantity of radiant temperature. It is important to realize that the actual radiant temperature cannot be measured by a remote sensing sensor. Atmosphere modifies the energy and thus the recorded amount varies from the actual radiant temperature of an object. Therefore, we need more sophisticated calibration. The precise form of a calibration relationship varies with the temperature range in consideration and the sensor in use. One may refer Malaret et al. (1985), Artis and Carnahan (1982), and Zhang et al. (2006) for further details.

2.2.3 Microwave Region

Microwave remote sensing can be conducted as both passive and active. Passive microwave remote sensing is similar in concept to thermal remote sensing. All objects emit microwave energy of very little magnitude. A passive microwave imager detects the naturally emitted microwave energy within its field of view. This emitted energy is related to temperature and moisture properties of the emitting object or surface. Passive microwave radiometers generally record energy in the region between 0.15 cm and 30 cm (between 1 GHz and 200 GHz), well beyond the thermal infrared region. Because the wavelengths are so long, the energy available is quite small compared to optical wavelengths. Thus, the IFOV must be large to detect enough energy to record the signal. Most passive microwave sensors are therefore characterized by low spatial resolution. The amount of radiation measured at different frequencies and polarizations can be analyzed to produce environmental parameters such as soil moisture content, precipitation, sea-surface wind speed, sea-surface temperature, snow cover and water content, sea ice cover, atmospheric water content, and cloud water content. Unlike optical imagers, microwave imagers can operate day or night through most types of weather.

Active microwave remote sensors create their own electromagnetic energy that is transmitted from the sensor towards the terrain (and is largely unaffected by the atmosphere), interacts with the terrain producing a backscatter of energy, and is recorded by the remote sensor's receiver. Imaging sensors can create two-dimensional images by measuring the intensity of backscattered energy. The most common form of imaging active microwave sensors is imaging RADAR. The RADAR is an acronym for RAdio Detection And Ranging, which essentially characterizes the function and operation of a radar sensor. As with passive microwave sensing, a major advantage of radar is the capability of the radiation to penetrate through cloud cover and most weather conditions. Because radar is an active sensor, it can also be used to image the surface at any time, day or night. The two primary advantages of radar are—all-weather see-through capability and day or night imaging. It is also important to understand that, because of the basic difference in the operation of an active radar compared to that of passive sensors, a radar image is quite different than the images acquired in the visible and infrared portions of the spectrum. Because of these differences, radar and optical data can be complementary to one another as they offer different perspectives of the earth's surface providing different information content.

While selecting the radar images, two considerations are of most importance—wavelength (or frequency) and polarization. The appearance of the image varies from band to band. For a given surface, longer wavelengths are able to penetrate more than shorter wavelengths. For example, short wavelength radars (3 cm) are reflected from the top of trees. Long wavelength radar (24 cm) can penetrate the vegetation canopy and travels down to the ground and is reflected back. Intermediate wavelengths (6 cm), in some instances, experience multiple scattering events between the canopy, the branches, and the ground. Therefore, it is possible to discern information about the canopy structure and estimate above-ground biomass by acquiring radar imagery of multiple wavelengths of a forested area. The functional capability of the longer L-band and P-band radar wavelengths is that they can penetrate the earth's surface. Space-borne Imaging Radar-C/X-Band Synthetic Aperture Radar (SIR-C/X-SAR) was a joint US-German-Italian project that used a highly sophisticated imaging radar onboard space shuttle to capture images of the earth's surface. The SIR-C/X-SAR obtained data of the Sahara desert that showed braided channels beneath the surface, and this completely surprised the scientists and engineers involved because although it was theoretically possible, they did not anticipate being able to see more than several metres into the surface.

Other than the penetration property, different wavelength is responsible for bright or dark appearance of an object on the imagery. Rough surface scatters more energy towards the sensor and appears brighter compared to smoother surfaces. Whether a surface appears rough (bright) in a radar image depends to a large extent on the radar wavelength. A particular surface may be rough for a short-wavelength radar but smooth for longer wavelengths. Thus, different types of surface can be distinguished by choosing appropriate wavelengths for imaging. In simple words, a surface appears 'smooth' if the height variations are much smaller than the radar wavelength. When the surface height variations begin to approach the size of the wavelength, the surface appears 'rough'.

Other than the wavelength, polarization of radiation is an essential consideration while selecting radar imagery. Polarization refers to the orientation of the electric field of electromagnetic energy. The polarization of the signal has an effect on the nature and magnitude of the backscatter. In a polarized radar, the antenna can transmit and receive signals in either horizontal (H) or vertical (V) mode. Similarly, the antenna receives either the horizontally or vertically polarized backscattered energy, and some radars can receive both. Once the transmitted energy from radar antenna hits the earth's surface, the polarization is modified. Some amount of the energy changes their polarization (called depolarization) while others do not. The amount of depolarization depends on the interaction at the target. Scattering at the earth's surface does not cause significant change in polarization; therefore, the cross-polarized receiving antenna (H send V receive or V send H receive), in general, receives little energy. The strength of like-polarized returns (H send H receive or V send V receive) from targets is stronger than that of cross-polarized. Therefore, radar imagery collected using different polarization and wavelength combinations can provide different and complementary information about the targets on the surface. The researcher should be aware of all these factors.

3 Multi-Concept in Remote Sensing Data Collection and Analysis

In the early days of remote sensing when the only remote sensing data source was aerial photography, the capability for integration of data from multiple sources was limited. Nowadays, with most data available in digital formats from a wide array of sensors, data integration is a common method used for interpretation and analysis. Data integration fundamentally involves the combining or merging of data from multiple sources in an effort to extract better and/or more information. This may include data that are in multiplatform, multistage, multiscaled, multispectral, multitemporal, multiresolution, multisensor, multiphase, multipolarization, etc. (refer Bhatta (2011)). Many remote sensing investigations include several of the aforementioned 'multi' categories. In essence, by analyzing diverse datasets together, it is possible to extract better and more accurate information in a synergistic manner than by using a single data source alone.

A word that naturally springs from the 'multi' concepts is merging. Data acquired by different platforms, with different sensors, at different resolutions, and during different times will tend to be incompatible in some respects. Most common is geometric: the pixel representing radiometric data in some spectral interval from some area on the ground or in the atmosphere is probably not of the equivalent size for the different sensors that monitor the target, be it the earth or a planetary surface, or the properties of the air above. In order to combine data sets from different sources, some adjustments or shifts in both geometric/geographic and radiometric values are required. Two pixels may partially overlap; they may vary in size. Their radiometric character may require modifications (e.g., correcting for atmospheric effects or for bidirectional reflectance). Thus, to successfully merge, both geometric and radiometric corrections must be applied. Some form of re-sampling is usually necessary. Distortions must be reduced or removed. Rectification to some planimetric standard (for instance, a suitable map projection) has to be incorporated. Moreover, fitting or stretching one image to properly overlay another is often vital, requiring ground control points or tie points.

Advantages of multisensors lead to merging an image produced by one sensor with that of another. Both may cover the same wavelength range but differ in, for instance, resolution or pixel size. Or they may be quite different types of sensors, e.g., radar and optical scanners. Different sensors often provide complementary information, and when integrated together, can facilitate interpretation and classification of imagery. An excellent example of merging multisensory images is the combination of multispectral optical data with radar imagery. These two diverse spectral representations of the surface can provide complementary information. The optical data provide detailed spectral information useful for discriminating between surface cover types, while the radar imagery highlights the structural detail in the image.

Merging of low-spatial resolution multispectral images with high-spatial resolution panchromatic images is very popular to obtain a high-spatial resolution multispectral image. The merging of panchromatic data of higher spatial resolution with multispectral data of lower spatial resolution can significantly sharpen the spatial detail in an image and enhance the discrimination of features. Thermal imagery also benefits from merging with other kinds of images.

Multispectral analysis is the study of data in different spectral bands. Multispectral data are essential for creating colour composites, image classification, indices/ratioing, principal component analysis, image fusion, etc. Each band of information in a multispectral data collected from a sensor contains important and unique data. We know that different wavelengths of incident energy are affected differently by each target—they are absorbed, reflected, or transmitted in different proportions. The appearance of targets can easily change over time, sometimes within seconds. In many applications, using information of several multispectral bands ensures that target identification or information extraction is as accurate as possible. The use of multiple bands of spectral information attempts to exploit different and independent ‘views’ of the targets so as to make their identification as confident as possible. Hyperspectral data, as an extension of multi-spectral data, are more useful to discriminate between different earth-surface features.

Information from multiple images taken over a period of time is referred to as multitemporal information. Multitemporal may refer to images taken days, weeks, seasons, or even years apart. Images taken in different seasons are often referred to as multiseasonal data. Monitoring land-cover change or growth in urban areas requires images from different time periods. Change detection is one of the most important applications of multitemporal data. In general, change detection involves the application of multitemporal datasets to quantitatively (or visually) analyze the temporal effects of the phenomenon.

Another valuable multitemporal tool is the observation of vegetation phenology (how the vegetation changes throughout the growing season), which requires data at frequent intervals throughout the growing season. Satellites are ideal for monitoring changes in the earth over time. The repeat cycles of those are measured either in days or a couple of weeks or so. This facilitates monitoring of crop growth and regional vegetation progression, as well as drought and stress conditions. Clear-cutting and environmental damage are also effectively monitored. The effects and status of flooding can also be assessed; particularly now, as there are a number of different satellites in operation, so that the likelihood of any area being imaged on a given day has increased. Of course, daily weather changes are the mission of most of the meteorological satellites. Long-period changes (in years) are also suited to the steady presence of the stable satellites in orbit. The mapping of growth of cities, population points, and other land-use categories are some straightforward uses. The drying up of lakes and the changes in coastal areas can be followed. Degradation and loss of wetlands generally are slow processes that still can be detected over shorter time, perhaps early enough to reverse the trend.

Multistage remote sensing is a strategy for landscape characterization that involves gathering and analyzing information at several geographic scales, ranging from generalized levels of detail at the national level through high levels of detail at the local scale. In remote sensing, a multistage sampling approach to image acquisition involves acquiring complete coverage of a study area with low-resolution imagery, and additional higher-resolution imagery from a sample of locations. Sampling is a method of estimating a measurement of numerous items by evaluating only a portion of them. There are a wide range of statistical sampling methods suited to different applications. Multistage sampling is one method commonly chosen for natural resource surveys using remote sensing. The inventory of forest resources and crop surveys are common examples. Multistage sampling is a hierarchical approach in which the statistical population is first subdivided into a number of primary sampling units, which is considered the first stage. Some of these units are then randomly selected as the sample of the first stage, and information is collected for every sample unit chosen. These units are then subdivided into a series of secondary sampling units, some of which are selected as the sample of the second stage. This process can be repeated for the third and further stages. In remote sensing, a multistage approach is often applied to image acquisition. Less expensive lower-resolution image coverage is obtained for an entire study area (the first stage). Then more expensive higher-resolution imagery is obtained for selected areas (the second stage). More detailed imagery or surface observations may then be acquired for a sample of these second-stage sites, resulting in third-stage data, and so on.

Multiscale images require a series of images at different scales, taken at the same time. Although simultaneous acquisition is difficult, it is often possible to acquire images from different sources that were taken at approximately the same time, i.e., within a few days of one another. Multiscale images could include satellite-based images, airborne images taken from different flying heights, or using different camera lenses. In general, for interpreting multiscale images, we use the larger-scale images to interpret smaller-scale imagery. Alternatively, smaller-scale imagery may be used for reconnaissance purposes and larger-scale imagery for more detailed analysis within selected sub-areas of the smaller-scale image.

Applications of multisource data integration generally require that the data be geometrically registered, either to each other or to a common geographic coordinate system or map base. This also allows other ancillary (supplementary) data sources to be integrated with the remote sensing data. For example, elevation data in digital form, called digital elevation or digital terrain models (DEMs/DTMs), may be combined with remote sensing data for a variety of purposes. The DEMs/DTMs may be useful in image classification, as effects due to terrain and slope variability can be corrected, potentially increasing the accuracy of the resultant classification. The DEMs/DTMs are also useful for generating 3D perspective views by draping remote sensing imagery over the elevation data, enhancing visualization of the area imaged.

Ground-truth activities are an integral part of the multi concept. Supporting ground observations should be obtained from many relevant, but not necessarily interrelated, sources (multisource). The collection of ground-truth data enables calibration (e.g., atmospheric correction, geometric correction, sensor design, etc.) of remote-sensing data, and aids in the interpretation and analysis of what is being sensed.

Combining data of different types and from different sources, such as those described earlier, is the pinnacle of data integration and analysis. In a digital environment, where all the data sources are geometrically registered to a common geographic base, the potential for information extraction is extremely wide. This is the concept for analysis within a digital GIS database. The integration with GIS allows a synergistic processing of multisource spatial data.

4 Endnote

Finally, different sensors generate different types of images that are often to be considered in the analysis that result in different images to be compared. Different image processing techniques (or algorithms) may also generate different results for the same image. Different classification schemes (level of classification) also generate different resultant maps. Further, the generation method of ancillary data that are often required for analytical or other purposes (e.g., validation) may also vary in a wide spectrum. Use of these varying data generation methods is a common practice in remote sensing data analysis; because data generation methods and resulting data are not designed to be consistent with different datasets. Although it is challenging no doubt, but an analyst/researcher has to understand that there is no alternative.

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