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Application of Remote Sensing Technologies in Environmental Monitoring and Geological Surveys

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Abstract. Remote sensing technology is an emerging observation technology. By applying various sensing instruments to electromagnetic wave information radiated and reflected by distant targets, it is collected, processed, and finally imaged. The resulting images allow people to detect and identify various scenes on the ground. It can dynamically reflect changes in the ground, monitor weather conditions, natural disasters, etc. This paper combines the relevant literature to synthesise the technical theory and specific applications of remote sensing technology in four areas: vegetation, soil, water resources and geology. The analysis of the vegetation index allows for the classification and dynamic monitoring of vegetation. Soil indicators can be monitored to determine the condition of the soil in an area, including soil contamination, soil erosion and land salinisation. The distribution of water resources in an area, runoff prediction and water quality monitoring can also be monitored by remote sensing technology. The technology can also be effective in mineral exploration and monitoring geological disasters. Although remote sensing technology has unique strengths in these four fields, there are still some technical limitations and shortcomings.

Keywords: Remote Sensing Technologies; Environmental Monitoring; Geological Surveys.

1. Introduction

Traditional environmental and geological surveys rely on human labour to gather information, which results in the information resources eventually collected often being one-sided and incomplete. In the event of factors such as severe weather, complex terrain and other factors that cannot be countered by human power, monitoring and survey work cannot be carried out successfully. The accuracy of survey results was often not guaranteed due to interference from various knowable and unknown factors.

Remote sensing is a new technology that not only captures ultraviolet, infrared, and other microwave information but can also identify features of objects that are not recognisable to the human eye. The advent of remote sensing technology not only breaks down geographical limitations but also reduces the impact of climate and weather factors on monitoring environmental and geological problems, increasing efficiency and convenience. The application of remote sensing technology makes the volume and accuracy of information significantly better than manual information collection.

Therefore, this paper lists some traditional and new remote sensing techniques and discusses their applications in environmental monitoring and geology.

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2. Remote sensing techniques

Remote sensing technology uses the reflection and radiation of electromagnetic waves from objects to collect and summarise data on monitoring targets. The data collected and analysed are collated and transformed into image data by technical means, enabling a more visual and intuitive presentation of the monitoring target. It is a technology that uses aircraft, satellite equipment or other relevant flying devices as a carrier to collect, collate and analyse electromagnetic information from ground targets through specialised sensors, to determine the environment of the area and the related cadastral information.

2.1. Visible light remote sensing

a more widely used form of remote sensing. Remote sensing of visible light with a wavelength of 0.4 to 0.7 microns generally uses photosensitive film or photodetectors as the sensing element. Visible photographic remote sensing has a high ground resolution but can only be used in clear daylight.

2.2. Infrared remote sensing

Near-infrared remote sensing, with wavelengths of 0.7 to 1.5 microns, is directly sensed by a photosensitive film. Mid-infrared remote sensing, with a wavelength of 1.5 to 5.5 microns. Far-infrared remote sensing, the wavelength is 5.5 ~ 1000 microns. Mid, far infrared remote sensing is usually used for remote sensing the radiation of objects with the ability to work around the clock. A commonly used infrared remote sensing device is the optomechanical scanner.

2.3. Multi-spectral remote sensing

Using several different spectral bands to remotely sense the same feature (or area) at the same time, to obtain various information corresponding to each spectral band. By combining remote sensing information from different spectral bands, more information about the object can be obtained, which is useful for interpretation and identification. Commonly used multispectral remote sensing devices include multispectral cameras and multispectral scanners.

2.4. Ultraviolet remote sensing

The main remote sensing method for ultraviolet light with a wavelength of 0.3 to 0.4 microns is ultraviolet photography.

Microwave remote sensing: remote sensing of electromagnetic waves(microwave) with wavelengths of 1 to 1000 mm. Microwave remote sensing can work day and night but has a low spatial resolution. Radar is typically an active microwave system, and synthetic aperture radar is often used as a microwave remote sensing device.

2.5. Unmanned aerial vehicle (UAV) remote sensing

It uses unmanned aircraft as an aerial platform to obtain information by means of airborne remote sensing equipment. A computer is used to process the image information and produce an image according to certain accuracy requirements. The system has outstanding features in terms of design and optimal combination and is a new application technology that integrates high-altitude photography, remote control, telemetry, microwave transmission of video images and computer image information processing. Compared with traditional remote sensing technology, aerial photography by UAV has the advantages of high definition, large scale, small area and high presentability.

3. Application of remote sensing in vegetation

Remote sensing technology can monitor vegetation, including vegetation classification, cover, vegetation dynamics, etc [1]. The vegetation classification and cover contain further information on the quantity and quality of vegetation. Vegetation dynamics means observing changes between years (pasture degradation, declines in forest area).

The main source of data on vegetation is satellite maps, which can give a rough snapshot of the vegetation in an area relatively quickly. Aerial photography from drones and fieldwork findings is other

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valuable data to recognize vegetation distribution. Although the accuracy of drone and field survey data is relatively high, the information is less coherent than in the case of satellite maps. Therefore, a proper combination of different data sources can give a more accurate and smooth result. Most information on vegetation cover (90%) is obtained mainly through various combinations of red and near-infrared band images from remote sensing data. The vegetation index is the value consisting of linear and non-linear combinations between the bands.

3.1. Vegetation classification and cover

The main remote sensing analysis techniques for classifying vegetation include supervised image element-based classification and hierarchical multi-scale segmentation object-oriented classification methods [2].

3.1.1. Supervised classification. Supervised classification is a type of remote sensing image classification. It is the process of using sample elements of the identified class to identify other unknown class elements. The sample elements of the identified category are those located in the training area. In this classification, the analyst selects a certain number of training areas on the image for each category. The computer calculates statistical or other information for each training region. Each image element is compared with the training sample. It is classified into the sample class that is most similar to it according to different rules. The first is to select the study area, and a training sample is planted to obtain its characteristic parameters. The vegetation species in the remote sensing image are then determined from the sample feature data. The bend differences can be used as a reference.

This method was used by Chuanhua Xia et al. to classify the vegetation of the Caohai wetland in Weining, Guizhou [3]. The training sample was determined by field survey and the points were selected by field measurements. The coordinates of each measured point were obtained and recorded using GPS instruments, and the points were superimposed on the images in ENVI (The Environment for Visualizing Images). The region of interest is created from the measured data, and the training samples are selected with very high accuracy. This study chose the minimum distance classification method for supervised classification. The principle is to use the training sample data to calculate the mean vector and standard deviation for each class. The mean vector is then used as the centre of the class in the feature space to calculate the distance from each image element in the input image to the centre of each class. The distance to the centre of each class is then calculated for each image element, and the image element is assigned to the class with the smallest distance to the centre of the class.

However, there are uncertainties in this method because it relies more on the operator's experience to determine the vegetation type. It is, therefore, highly subjective. When the operator is inexperienced, the accuracy of the results is reduced.

3.1.2. Object-oriented classification. Image classification is carried out with the object as the smallest unit [2]. A suitable segmentation scale is chosen to cut the remote sensing image. The information features and parameters of the objects in the different images are collected. These parameters (spectral features, texture features, shape features) are then used to classify and identify different kinds of vegetation.

Tian Tian et al. used remote sensing images as data and formed image objects by bottom-up segmentation using an object-oriented multi-scale segmentation method [4]. Spectral features, texture features and vegetation index information were extracted from the segmented objects and used to select feature training samples. Based on the differences in features between the objects, rules were established, and the performance of the categories was analysed. The corresponding category information was extracted from the different levels of feature types using defined affiliation functions and decision tree classification rules. From this information, the classification of different vegetation types in Sanle Forestry, Sanming City, Fujian Province has proceeded

This method can appropriately avoid the loss of accuracy caused by the operator's inexperience.

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3.2. Dynamic monitoring of vegetation

This method is mainly based on the Normalised Difference Vegetation Index (NDVI), which is used to detect vegetation growth status, and level of vegetation cover, and to eliminate some radiometric errors [5]. The difference between vegetation and non-vegetation features on NDVI imagery is quite pronounced. NDVI calculations can transform multispectral data into a single image band that can be used to show vegetation distribution. By comparing the distribution of vegetation in different years, it is possible to show the changes in vegetation in the study region.

By comparing the distribution of vegetation in different years it is possible to show changes in vegetation in the study area. This method was used by Mingguo Ma et al. to monitor and simulate northwest China [6]. The images were projected sinusoidally at low latitudes and Mollweide at high latitudes. When counting NDVI values for the study area and some of the priority areas, they used the mean value method for the calculations. This means that the NDVI values are averaged over all grids in the statistical region. The difference method is used to quantify the change in maximum NDVI values between two years which is the NDVI values of all grids in the latter period are subtracted from the NDVI values of all grids in the former period. The maximum NDVI value on each grid was used to calculate the slope of the regression (the average annual NDVI increase from 1981-2001) by the one-line reversion method. Based on the declining linear regression trend line it was concluded that there is a general trend of vegetation degradation in Northwest China in the last 21 years.

Combining the two vegetation study technics above gives more detailed information on the vegetation within an area. The ecological boundaries of different plant species can be determined by vegetation classification and cover. Dynamic monitoring is used to compare changes in the ecological boundaries or the area of different plants in different years. These two instruments combine spatial and temporal to give a detailed time-based spatial variation of vegetation in an area.

4. Applications of remote sensing in the soil

Soils are a very important natural resource. Not only do they provide food and raw materials, but they also play a crucial role in maintaining the stability of the climate and terrestrial ecosystems. Remote sensing technology plays a large part in soil monitoring, mainly for monitoring soil erosion, pollution, and salinisation.

Different soils have specific electromagnetic wave properties depending on the type, structure, and location. Remote sensing can be used to recognise the type of target according to these electromagnetic properties. Soil is a complex multiphase material, and its physical and chemical properties usually change during the degradation process. Its spectral characteristics are a comprehensive reflection of its physical and chemical properties, which can be identified to some extent by remote sensing [7]. Soil properties are reflected by direct indicators (mineral composition, organic matter content, surface roughness and soil water content) but can also be mapped by indirect indicators such as vegetation characteristics and land use.

4.1. Monitoring soil erosion

Soil erosion monitoring is generally carried out using remote sensing techniques combined with data based on fieldwork. The main data include remote sensing images, precipitation information, soil information and basic geographic data. The remote sensing images are first radiometrically corrected, orthorectified, fused, mosaicked, and segmented for land use and soil conservation analysis. Aerial photography of the areas to be investigated in detail is carried out with the aid of unmanned aerial photography to verify the results. The analysis results are combined with local information to calculate rainfall erosion rates, soil erodibility, slope gradient, slope length, vegetation cover and soil and water conservation measures [8]. For example, the Chinese soil erosion equation CSLE was used to calculate the soil erosion modulus, evaluate the soil erosion intensity, and count the area of soil erosion.

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4.2. Monitoring soil contamination

Remote sensing technology can provide a prompt reflection of the physicochemical properties and ecological status of contaminated soil. Soil reflectance properties can be used to evaluate the degree of soil contamination. Hyperspectral remote sensing has shown advantages and has become an important means of monitoring soil contamination at present. When heavy metals are present in the soil at low concentrations, they do not characterise in the spectrum. However, it is possible to estimate the heavy metal content since they readily bind to iron oxides, clay, and organic matter [9].

There are various other analytical methods, including multiple linear stepwise regression, partial least squares regression and artificial neural network methods. These approaches model predictions of heavy metal content based on the identification of spectrally sensitive bands or various indices of their transformation [8]. Heavy metal contamination of soils can inhibit the growth of vegetation and affect its normal physiological characteristics. Three of the variables that have the most significant impact on the spectrum are the internal structure of the plant, the chlorophyll content, and the water content of the leaves. Therefore, the inversion of soil heavy metal content by constructing models based on vegetation indices becomes another important method of applying remote sensing technology to soil pollution assessment.

4.3. Monitoring soil salinisation

Soil salinisation is one of the most important manifestations of soil degradation. It often occurs in arid and semi-arid regions. In these areas, rainfall is insufficient to allow the soil to infiltrate properly so that soluble salts can accumulate on the surface. In addition, irrigation may also lead to an increase in the salt content of the surface, which affects the soil structure and other properties and causes soil salinisation.

The main techniques used for soil salinity assessment using remote sensing are aerial photography, multispectral remote sensing, hyperspectral remote sensing, and microwave remote sensing [7]. Aerial photography can provide high-resolution images containing soil colour information and distinguish saline from non-saline soils. Hyperspectral can be used to identify and analyse the surface mineral and vegetation characteristics of saline soils, resulting in a more accurate assessment of soil salinity. Microwave remote sensing is currently a more effective method of evaluating soil salinity. It is mainly based on the permittivity of the soil, which is closely related to soil salinity.

5. Applications of remote sensing in Hydrology

Remote sensing techniques commonly used in water ecology management include infrared, microwave, hyperspectral, and UAV remote sensing.

5.1. Surveying water resources

Rivers, lakes, and water levels on the ground are monitored and recorded using remote sensing technology. The information collected is integrated to form clear images in order to accurately distinguish the basic shape and topography of lakes and rivers, thus deriving the impact of different topography and landforms on rivers and lakes [10].

For the monitoring of groundwater resource systems, remote sensing techniques are more likely to be used by monitoring the geology of the area. Based on the information resources fed back, the integrity and volume of the groundwater resource system are analysed to derive the extent and characteristics of the distribution of groundwater resources. Thus, the internal equilibrium relationship of the groundwater resource ecosystem can be further obtained, and the goal of optimising water resource surveying and protection can be achieved.

5.2. Forecasting and prediction of runoff

Remote sensing technology is fast in processing information data. By entering model information about the water resources in the area being monitored, the corresponding data information can be calculated. Therefore, combining remote sensing technology with data from hydro-meteorological stations allows

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runoff prediction and forecasting. Remote sensing does not enable accurate river runoff data to be measured. Predicting and forecasting river runoff are based on factors such as soil, topography, geomorphology, and vegetation, combined with data on precipitation and evaporation in the area [10].

5.3. Water quality monitoring

In addition to monitoring light and topography to obtain hydrological water resources, remote sensing technology can also identify the quality of hydrological water resources in a region by the suspended solids on the surface of the hydrological water resources. The settlement, amount, distribution, and dispersion of suspended solids directly impact the water quality of the region's hydrological water resources and affect the ecological environment of the region's lakes and rivers. When water bodies in the region are polluted, the water body's temperature, humidity, transparency, colour and brightness will change, mainly in terms of its reflectivity. Remote sensing technology obtains information about water bodies by monitoring changes in reflectance. Depending on the form, texture and hue, information such as the area of the water body where pollution occurs, the source of the pollution and the concentration of the pollution is inferred [11].

5.3.1. Dissolved organic matter in water. It is caused by a large amount of acid released from decaying material. As the content of dissolved organic matter increases, the water body will take on a yellow-green to green colour. Remote sensing technology is based on the optical reflection wavelengths of the water body to measure the amount of dissolved organic matter in the water [12].

5.3.2. Chlorophyll content. Chlorophyll in the water column affects the spectral characteristics. When a water body becomes eutrophic, the chlorophyll content of the water body will increase. The reflectance of the water body will grow, and the peak reflectance will change, showing a reflection peak as well as an absorption trough [12].

6. Applications of remote sensing in Geology

6.1. Geological and mineral exploration

Remote sensing techniques are usually used to spectroscopically detect areas where minerals are located from high altitudes and long distances. This process is very susceptible to interference from various external conditions such as vegetation, cloud cover, snow, and image distortion, and therefore has the potential to produce a certain amount of error. To minimise errors, the remote sensing surveyor needs to scientifically analyse the surrounding environment for possible interferences. The selection of images at the suitable season and time of year with less cloud cover, combined with field surveys and other means to reduce the level of interference from these factors, maximises the accuracy of the remote sensing results.

Multispectral remote sensing applies remote sensing technology to geological and mineral exploration. By observing and identifying some of the colours and shapes of the remote sensing images, it is possible to identify the part of the altered rocks and mineral outcrops in the area, which can be used as an important marker for finding mineral sources [13]. The multispectral remote sensing system focuses on the extraction of spectral anomalies from altered rocks caused by endogenous mineralisation, such as hydrothermal mineralisation. This method is generally not applicable to exogenous mineralisation, nor to large areas of vegetation cover.

The basic principle of hyperspectral remote sensing to identify the composition of surface rock and minerals is that each mineral, due to differences in crystal structure and chemical composition, exhibits a unique spectral profile of reflection and emission spectra, called diagnostic spectral features, according to which the spectral profile of the acquired features can be used to identify minerals [14]. Data processing mainly includes data pre-processing, atmospheric correction and spectral reconstruction, data downscaling, end element spectral extraction, spectral identification, and other major aspects. Hyperspectral remote sensing can acquire continuous spectra of hundreds of bands of features, and a

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spectral curve can be extracted from each image element. It is possible to identify features that cannot be identified by multispectral remote sensing based on some fine spectral features.

Unmanned aerial vehicles (UAVs) can obtain real-time high-resolution image data by carrying various types of sensors. This allows for more comprehensive and complete information to be interpreted, thus increasing the efficiency of data acquisition. The data obtained by drones can be used to quickly construct three-dimensional visualisation models, which in turn provide a more realistic reproduction of the actual situation in the mining ecosystem [15]. UAV remote sensing technology can obtain high-resolution, real-time image data. The data can be used to visually reflect the real topography and environmental problems of the mine. In the process of collecting data, manual field surveys are basically not required, thus greatly improving the efficiency of the survey.

6.2. The investigation and assessment of geological hazards

As a special adverse geological phenomenon, geological hazards are not only individual manifestations of disasters such as landslides, debris flows and avalanches, but also group manifestations of disasters in various forms of integration. The occurrence of geological hazards has a certain background. With its unique meteorological satellites, remote sensing technology can monitor the intensity and amount of local rainfall in real time. In addition to comprehensive and systematic detection of surface objects, remote sensing technology's unique infrared and microwave bands can also capture the characteristics of objects in shallow underground areas. Other inception contexts can be clarified with the help of land resource satellites and combined with local field survey information. Remote sensing is used to investigate the mudslide and landslide conditions in the study area by means of pseudo-colour compositing and enhancement of the three bands of remote sensing imagery, combined with field surveys and established zoning criteria for remote sensing interpretation and classification of development. The survey is then used to predict the development trend of each type of landslide and debris flow area. High-resolution remote sensing images before and after the landslides are used in combination with digital landslide technology to obtain the surface characteristics, boundaries, and movement characteristics of the landslides. High-resolution aerial images are obtained using an unmanned aerial photography system, which is used as a base map for interpretation and combined with fieldwork to carry out a geological hazard survey. Multi-temporal remote sensing images can reflect different surface landscapes and sometimes provide more geological information than can be displayed in a single time phase. Multiple time phases of data are required for applications such as geohazard investigation and monitoring and environmental investigation [16].

7. Conclusion

Remote sensing technology allows for the capture of a wide range of light sources (visible and invisible), regardless of geographical limitations, free from harsh environmental influences, and allows for efficient information collection.

Remote sensing technology has been widely used in vegetation classification and monitoring studies. Some achievements have been made in identifying plant species and their biological boundaries. Dynamic monitoring allows the researcher to observe changes in the state of the vegetation.

Remote sensing technology has achieved good results in land monitoring such as soil erosion, pollution and salinisation. Current remote sensing techniques can only obtain information on the surface layer of the soil. Although microwave remote sensing could penetrate to a certain extent below the ground surface, it is currently limited to soil moisture. Therefore, obtaining information on multiple indicators of the soil profile is still one of the directions that need to be broken in applying remote sensing technology to soil degradation in the future.

Remote sensing technology is well used and effective in the monitoring and management of water bodies. Water pollution is monitored by observing the reflectivity of water bodies and collecting information of data on contaminated water resources. The imaging technology then is enabled real-time tracking of the water resources in the area to determine the amount and type of polluting substances

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contained. The application strategy is tailored to the level of contamination in the water body so that it can be effectively managed in an integrated manner.

Remote sensing technology has been generally used in geological and mineral exploration. The direct application refers to the extraction of information on the alteration of surrounding rocks, while the indirect application refers to the extraction of information on geological structures and the analysis of plant spectra. Hyperspectral techniques can be used to obtain the mineral distribution information required for geological applications. It is noted that the resolution of commonly used information sources is small, a complete theoretical system has not yet been formed, insufficient research in disaster monitoring and early warning, and a single research component in disaster assessment.

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