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Application of Remote Sensing in Mining

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Abstract

Mines need a controlling system in many places to improve the production of the mine, to manage and enhance safety of workers as well environment. The important goal of this paper is first to acquaint the remote sensing technology, then secondly to introduce the available technologies in the field of mining. Multiple case studies and imageries have been used to show the techniques.

Keywords**: Remote Sensing; Mining; Monitoring; Electromagnetic Energy**

1. Introduction

Remote sensing technology is widely used in detection of earth resources, prediction of earthquake and volcanic eruption, monitoring of environmental pollution as well as departments such as metallurgy, geology, oil, agriculture, forestry, water conservancy, surveying and mapping, weather, ocean and so on. Remote sensing technology is superior with characteristics of wide range, fast speed and low cost in monitoring and is convenient for long-term dynamic monitoring, etc. In mine monitoring, remote sensing data such as MSS, LandsatTM, ETM, SPOT, IKINOS, QUICKBIRD and so on are commonly used(Cheng Ting, 2006)

Electromagnetic energy, when incident on a certain feature of earth surface, the energy can be reflected, absorbed, or transmitted, which will vary in proportion depending upon the material type and conditions of different earth features. The distinctions allow recognizing diverse elements on a satellite image. At different wavelengths, extent of three basic energy interactions would differ even within a given feature type. In one spectral range two features may be distinguishable but altogether different on other band of wave- length. The resultant optical effect due to spectral differences within the visible portion of the spectrum is called "color." To discriminate among various objects, spectral differences in the extent of reflected energy are utilized by human eyes

Remote sensing has been utilized as a device for finding potential exploration targets from the initial stage of photogeology. The quality of remotely detected information has expanded as the level of technology has improved. Aerial photographs were used in the early days for wide area topographic survey. The technique steadily progressed to be sub stantially more refined and it was only post World War II, obtaining of ground geological information was initiated. Using stereoscopes it was possible to interpret geological structures from the aerial photographs. The essential utilization of remotely sensed information was relative.

If mining was being carried out for a specific sort of deposit in an area, use of aerial photographs would be made to find comparable geological elements somewhere else in the same area.

This paper will show the fundamental idea of remote sensing technology and will be going to deal with the various applications of remote sensing technology in the mining industry particularly in slope instability(Vanneschi, 2017), management of mine lands(Koruyan et al., 2012), reclamation of mines (Karan, Samadder, & Maiti, 2016)and the monitoring of mine disasters(Fan, 2009).

2. Overview of Remote Sensing Technology

2.1. The Basic Concept of remote sensing

Remote sensing is a process to acquire, prepare, and decipher information of spectral and spatio-temporal nature on objects, phenomenon or areas under investigation without being in direct physical contact. Transfer of information is carried out using "electromagnetic radiation" (EMR) in remote sensing.(Sabins, F.F., 2007) stated "EMR is a form of energy that reveals its presence by the observable effects that are produced when it strikes the matter."

It can also simply be defined as an electromagnetic emission with specific wavelengths of an object i.e. in this case the earth from ultraviolet ray to microwave. It is the use of modern carrier, electronic and visual instrument in an active or passive manner as illustrated in figure 1 to receive as well as process electromagnetic wave of certain crossed wavelengths from UV ray to micro-wave transmitted or reflected by navigated object at deep or on the earth's surface to finally comprise valuable information.

2.2. Remote Sensing Data Gathering Systems

Remote sensing data gathering systems are divided into two different types, viz.,
(1) Passive Remote Sensing and (2) Active Remote Sensing

(Levin, 2011) states "A passive Remote Sensing system records the energy naturally radiated or reflected from an object. An active Remote Sensing system supplies its own source of energy, which is directed at the object in order to measure the returned energy. Flash photography is active Remote Sensing in contrast to available light photography, which is passive. Another common form of active Remote Sensing is radar, which provides its own source of Electromagnetic energy in the microwave region. Airborne laser scanning is a relatively later form of active Remote Sensing, operating in the visible and near infrared wavelength bands."

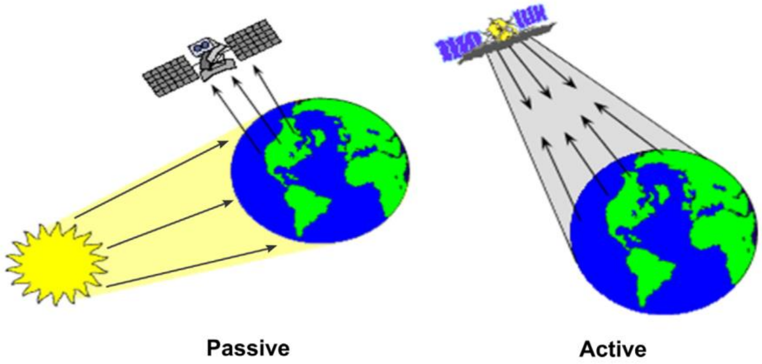

Figure 1.Passive and Active remote sensing

2.3. Major Remote Sensing Satellite Systems

Most of the satellites orbit at an altitude between 700 and 920 km. The earth rotates and the satellites scan 185 km length of its swath. The remote sensing systems and their capabilities in the world is presented below as from(Taranik, 2009)

LANDSAT (Introduced by US Government)
First generation (Landsats 1, 2, and 3 of 1972), Landsats 4 and 5 of 1984, Landsat MSS (repeat coverage: 16 days), Landsat Thematic mapper (TM) (repeat coverage: 16 days), and Landsat 6, Landsat enhanced TM, launched in 1999 (repeat coverage: 16 days).
SPOT (Introduced by French Government)
Multispectral scanner (XS) multispectral mode acquires three bands of data green, red, reflected IR wavelength with spatial resolution of 20 m.
Panchromatic (Pan) acquires a single band of data, primarily green and red wavelengths with spatial resolution of 10 m; both image modes cover 60 3 60 km of terrain (repeat coverage: 26 days).
AVIRIS (Advanced Visible/Infrared Imaging Spectrometer):
Conventional multispectral scanning systems, such as Landsat TM, SPOT XS, record up to 10 spectral bands and bandwidths of 0.10 µm. Hyperspectral scanners are a special type of multispectral scanner that record many tens of bands with bandwidths on the order of 0.01 µm. At visible wavelengths and at reflected IR wavelengths, many minerals have distinctive spectral reflectance patterns. Many minerals may be identified on suitably processed hyperspectral data. AVIRIS image strips are 10.5 km wide and several tens of kilometers long.
ASTER (Advanced Space borne Thermal Emission and Reflectance Radiometer); ATLAS (Airborne Terrestrial Applications Sensor) JV US & Japanese Govts, launched in 1999 VNR: 3 bands, 15 m resolution; SWIR: 6 bands, 30 m resolution; TIR: 5 bands, 90 m resolution. ASTER is a multispectral sensor with 14 “geoscience-tuned” spectral bands which provide geological information far superior to that available from Landsat TM but at lower accuracy and mineralogical detail compared with hyperspectral systems, such as the 126 channel airborne HyMap sensor Thailand Launch Theos: 4 bands R, G, B, IR; 2 m; Panchromatic, 15 m, color

Taiwan FormoSAT-2: Launched in 2008; 4 bands; R, G, B, IR0; 2 m; Panchromatic, 8 m, color; guaranteed acquisition with tasking, 3-day revisit capability. Hyperspectral scanners

3. Application of Remote sensing in Mines

The use remote sensing in rock characterization, spatial analysis and monitoring deformation process uses different technologies, such as Light Detection and Raning(LiDAR) and Structure from motion, for data integration. LiDAR is a modern scanner measure distance by utilizing an Electronic Distance Measurement(EDM) unit and electronically capture angular measurements to compute a position.

3.1. Application in Slope Instability

A structure from motion is a photogrammetric process that leads to realization of a three dimensional model developed from a two dimensional model to permit the acquisition of three dimensional coordinates of points located in the overlapping zone of two photos of the same area taken from two different viewpoints.

After remote sensing have been integrated analyses such as compliance rock trap geometry, monitoring slope regression and material deposition, spatial analyses can be used for identification of critical areas of potential slope instabilities. As instance monitoring rock trap geometry and spatial analyses of an open pit mine is presented below.

3.1.1.Monitoring Rock Trap Geometry

The different scans in the figure below were locally aligned from a mines using ICP algorithm onsepatare constraints with a specific mean absolute error. The local registration was then referenced and surveyed ising Differential Global Navigation Satellite(DGNSS).

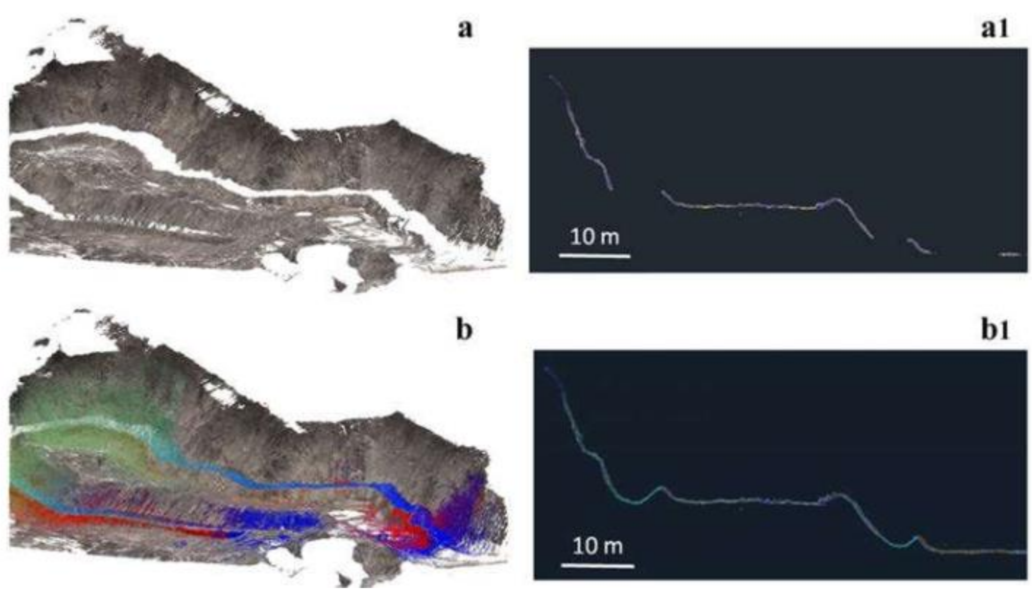

Figure 2.a) Example of cloud data as part of the slope a1) cross section of point cloud in a b) Infill of cloud point data using hand held ZEBI b1) Cross section of figure b

*3.1.2.*Spatial Analyses in an open pit mines

Spatial data about geometry of slope by AL and hand0held data can also be combined with geological data. The next example combines slope geometry attributes with spatial distribution of alteration grade within an open pit. For design purposes an initial analysis was required to highlight slope benches with high alteration and with slope angles greater than 45 degrees.

The slope angle analysis was undertaken in a Geographic Information System (GIS) environment. Figure 3 shows the result of such an analysis using a high resolution Digital Terrain Model (DTM) and integrated with ML information in order to have sufficient resolution at a single bench.

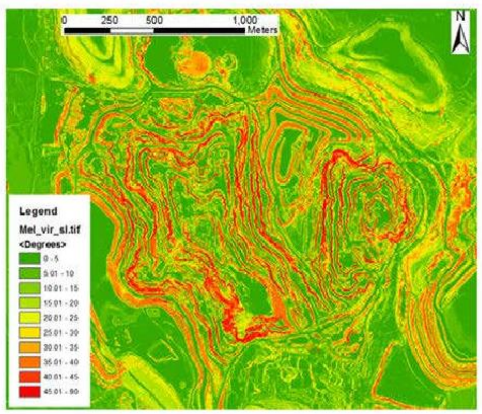

Figure 3.Slope angle analysis in an open pit mine

3.2. Remote Sensing in mine management

Studies show that changes in the natural vegetation as a function of production rate were determined using the NDVI. Tucker[23] reported that the NDVI changes between -1.0 and +1.0 in general, and more specifically between +0.1 and +0.7. NDVI values were calculated using the (4–3) / (4+3) band ratio for Landsat images and the (3–2) / (3+2) band ratio for the ASTER images. The effect of marble quarries activities on vegetation from 8 years are determined using NDVI images and vector data from quarry boundaries for each years. The subset method was used to calculate the yearly changes by converting the vector data into an area of interest layer (AOI). To determine the extent of vegetation loss, NDVI images from one year to the next were subtracted from the AOI images. Figure 4 shows the result of this transformation from 2001 to 2003.

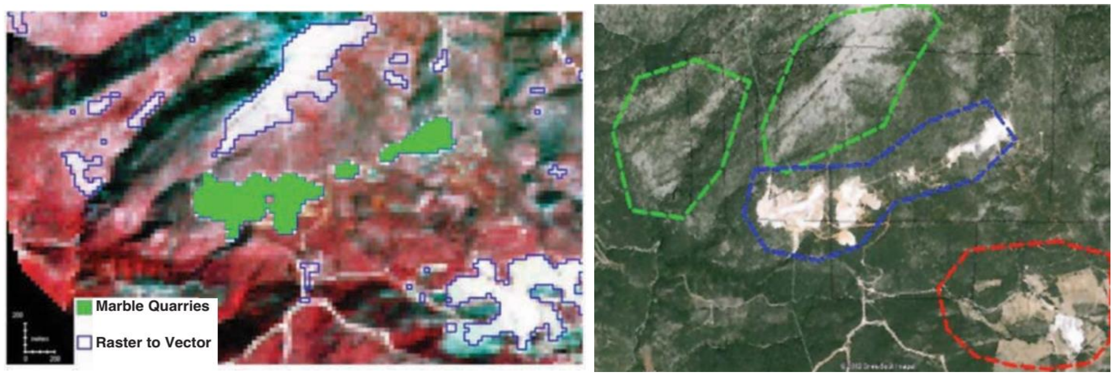

Figure 4. A vectorized data by ASTER RGB images and sharpened boundaries of Marble quarries

The results reveals a five fold increase in quarrying activity in the intervening specific years and it is interpreted as an increasing in quarry activities are identified from the area and associated vegitatin resuction were also calculated.

3.3. Monitoring of Mine Disasters

*3.3.1.*Insar Monitoring Used In Slope Deformation

Haizhou opencast mine is located in the urban of Fuxin, Liaoning province, it is 3 km away from Fuxin. 4 km from east to west of the mine, 2 km wide from north to south, 350 meters deep, with a total area of 30 square kilometers. Slope instability and deformation lead to deformation and crack of the surface rock and form large cracks, endanger the safety of nearby buildings. At the same time, in opencast mining, the accumulation of stagnant water in the pit at the bottom of the surrounding water level caused by changes in water infiltration of harmful substances, severe pollution of groundwater resources in Fuxin region and groundwater environment. So, we must monitor its real-time information change to ensure that people's lives and property.

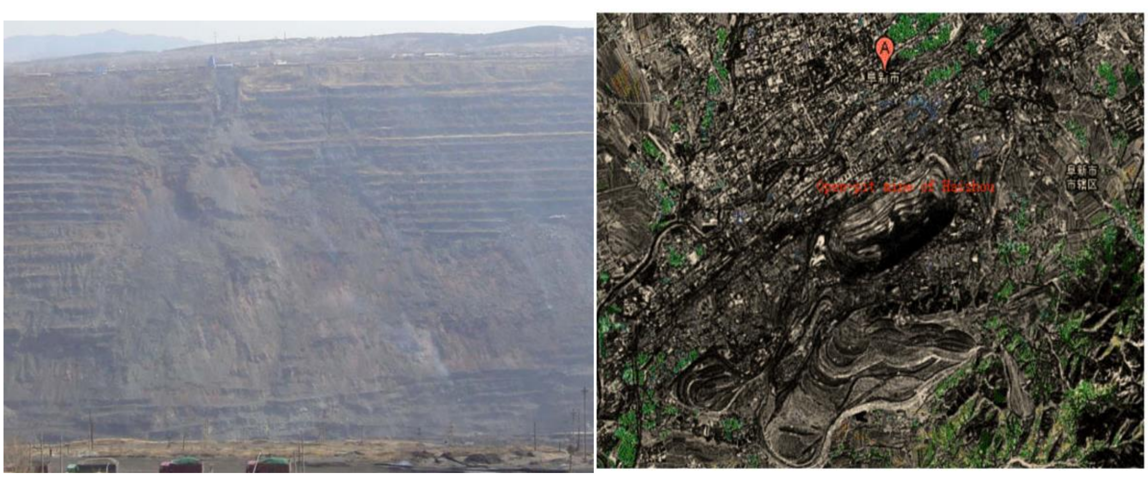

Figure 5.Satellite and location map of Haizhou open pit mine

The technology of synthetic aperture radar interferometry (referred to as InSAR), has developed in the 1960s with characteristics of all-weather, all-day, high-resolution and continuous space coverage. It can provide subsidence areas for space surface deformation information for a short period of the time, meet the requirements of slope monitoring and make up for the lack of discrete points of conventional ground measurement. This tech could descend the cost, so it is a useful supplementary means for slope monitoring and has great advantages and good applications in mining areas (Kazuhide, SawadaFuruta Ryoichi, 2012)

At the same time, Technology of satellite radar interference used in open-pit slope observation also achieves a very good result. The following pictures are the use of Japanese Earth satellite in Haizhou open-pit mine of Fuxin and Fushun open pit test.

Both get very good observation results. From the chart below, we can see the deformation location, scope and size of Haizhou open-pit mine in the abovementioned period. The largest amount of deformation is up to 24 centimeters.

Observation period is from June 18, 2007 to September 18, 2007, about 3 months. For Fushun's open-pit slope deformation, Observation period is from August 24, 2007 to October 12, 2007, about 50 days. It can be seen from the chart that the deformation location, scope and size of Fushun open-pit mine during the above-mentioned period. The largest amount of deformation is up to 24 centimeters

3.3.2. **Monitoring Of Harmful Gases**

Under man-made or natural conditions the harmful gas produced for biology, such as SO_2, fluoride and so on, is usually signed by indirect interpretation. The capability of the infrared reflection can decline after the vegetation is contaminated; even its color, texture and dynamic signs are used to be different from the normal vegetation, such as dark color in infrared images, decreases in tree canopy density and normal individual vegetation etc. These traits can be directly used to analyze contaminated instance. For the ground pollution, such as in farmland pollution, the polluted crops growth would have special changes and groundwater pollution would lead to changes of vegetation on the ground, which has different spectrum performance from crops in the normal growth areas. Multi-spectral imaging instrument can monitor these changes, thereby could delineate the distribution scope of the ground pollution, and make further prevention plans on ground pollution(Tan, 2008)

3.3.3. **Vegetation monitoring**

Vegetation is an important component factor of the environment, as well as one of the best sign of reflecting the regional ecological environment, and also the interpretation signs of soil, hydrology and other elements [7-8]. The use of RS image allows carrying out temporary researching, and could provide the full details of the surrounding area.

Particularly it has better effect to extract the vegetation information by using the hyper spectral image. The outstanding trait of Hyper spectral image is that it has much higher spectral resolution than the previous Landsat TM, SPOT and other multispectral image, its spectrum resolution could reach up to 10nm and its monitoring survey range is 400nm ~ 2500nm. Its appearance is a major leap forward in using RS technology. Because of the advance of spectral resolution, originally many of problems cannot be solved by only using the space information and under the multi-spectral circumstances, but now it can be satisfactorily way to resolve problems by utilizing hyper spectral data.

*3.3.4.*RS monitoring in Land dynamic use

RS monitoring of land dynamic use, utilizes Landsat TM data, bases on data and picture of surveys on land changes, uses the technologies of processing GIS spatial data and analysis of RS image and extract movement information by processing and analysis software from the RS image. The work flow is based on the multi-spectral and the multi-temporal data received by RS technology, and gets help from interrelated software of geographic information system (such as MAPGIS, SUPERMAP, ENVI, ER-DAS, etc.) to have images correct, register, inlay, multi-source data fusion, acquire change information, analyze and contrast to the former survey data of land change, and then instruct fieldwork through the global positioning system to make data validation and verification, finally complete the work of land-use dynamic monitoring.

4. Conclusion

Remote sensing has got in various fields such as geography, land surveying and in common earth science disciplines such as oceanography, glaciology, geology and mining. This paper shows the applications of remote sensing in mining ranging from slope stability for monitoring rock trap geometry and spatial analysis in open pit mines, in monitoring mine management and disasters by Insar monitoring system, monitoring of harmful gases, vegetation monitoring and monitoring land dynamic uses.

In conclusion, the applicability of remote sensing in mining has many folds and the main task in is put aside in managing and interpreting the handled data accurately and integrating this indispensable data to other databases and technology systems.

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