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New Generation Space Technology: Hyperspectral imaging technology

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Abstract— **Hyperspectral imaging technology also known as imaging spectroscopy, which is concerned with the measurement and analysis of reflectance spectra obtained by sensors from airborne or satellite. Hyperspectral data sets are generally composed about 100s of spectral bands with 5-10 reasonably narrow bandwidths at 0.4 - 3 µm wavelength region. The growth of remote sensing technology and the increasing demand by the user's for higher resolution data sets leading to advances of highperspectral remote sensing. Regional mineral mapping and exploration are the core applications that will benefit from the hyperspectral technology. Minerals and rocks show diagnostic absorption characteristic throughout the electromagnetic spectrum that aid to identify and map the chemical composition and relative abundance. The recent advances in hyperspectral data collection, processing, analyzing and investigating minerals from the earth and inner planets are discussed in the paper.**

***Keywords*— Hyperspectral, spectroscopy, electromagnetic spectrum.**

I. INTRODUCTION

Hyperspectral measurements have a long history in the study of the earth and planets (e.g., [1], [2]). In the early 1990s remote sensing based spectroscopic measurements of the earth and planets have been dominated by multispectral imaging experiments that collect high quality images with broad spectral bands. Hyperspectral remote sensing is a tool that has been used to detect minerals, rock types, chemical properties of the earth and other plant surface. Hyperspectral imaging sensors capture data from the visible to near infrared wavelength regions, accordingly providing hundreds of narrow spectral bands from the same area (Fig. 1). The detailed spectral information collected by hyperspectral sensors increases the capability of discriminating between different land-cover classes with increased accuracy. A number of operational hyperspectral imaging systems are currently available, providing a large volume of image data that can be used for a wide variety of applications such as Minerals and rock types mapping, hydrological science, agriculture, environmental science and military applications [3]. Minerals and rock types are used to identify based on the absorption features due to specific chemical bonds. Recent advancement of remote sensing technology, new generation of sensors are available that combines imaging with spectroscopy to create the new discipline of imaging spectroscopy (e.g., [4]). Imaging spectrometers acquire data with enough spectral range, resolution, and sampling at every pixel in a raster image so that individual absorption features can be identified and spatially mapped.

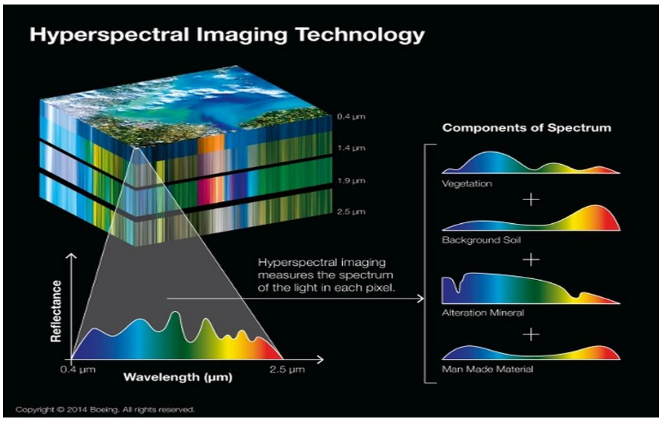

Fig. 1 Concept of hyperspectral remote sensing technology (Source: Hexapolis)

II. HYPERSPECTRAL REMOTE SENSING OF THE EARTH

Scientific interest in the earth sciences has been grown for mapping minerals and rock types for the purpose of the geological exploration, crustal studies, water resource mapping, etc. Traditional mapping methods to obtain high-resolution measurements in the global scale are impractical. Instead, satellite sensors provide the most effective means for frequent, synoptic observations over large areas with high spectral, spatial and radiometric resolutions. Hyperspectral imaging emerged on the remote sensing prospect with the development of the Airborne Visible Infrared Imaging Spectrometer (AVIRIS) followed by Hyperion on NASA's EO-1 satellite. In earth science application sensors are onboard on satellite and some sensors are on aircraft (Table 1). In addition, new instruments such as the Next Generation Hyper Spectral Imaging Satellite (HysIS), AVIRIS (AVIRIS-NG), Hyperspectral Thermal Emission Spectrometer (HyTES) and Portable Remote Imaging Spectrometer (PRISM), which all recently conducted their first science missions. The

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growing number of hyperspectral programs and instruments are functioned by government agencies and universities, such as the NASA Ames Research Center and the Carnegie Airborne Observatory (CAO). Various airborne sensors operated by commercial organizations, such as the Galileo Group, SpecTIR, HyVista and ITRES. Number of new satellite-based sensors including HysIS (ISRO), HyspIRI (NASA), EnMAP (Germany), PRISMA (Italy) and HISUI (Japan) are potential operation satellites. Since hyperspectral imaging has evolved into a robust remote sensing discipline, with satellite and airborne sensors contributing to numerous applications in earth observation, and other similarly sophisticated sensors being used for missions to the Moon and Mars.

Table 1. Major hyperspectral sensor.

Sensors Name	Number of bands	Spectral range [µm]
Hyper Spectral Imaging Satellite (HysIS)	256	0.4-0.95 & 0.9-2.5
HSI - Hyperspectral Instrument	232	0.42-1 & 0.9 -2.45
Hyperion - High Resolution Hyperspectral Imager	220	0.40 - 2.5
FTHSI - Fourier Transform Hyperspectral Imager	256	0.35-1.05
Hyperspectral Imager for Coastal Ocean sensor (HICO)	128	0.35-1.080
Compact High Resolution Imaging Spectrometer (CHRIS)	18-62	0.41-1.020

III. Hyperspectral remote sensing of Planetary Surface

Remote sensing based imaging spectroscopy is a key technique and used to study the planets. It allows for identification, mapping and characterization of minerals, as well as volatile species, whose presence often provide clues for the geological issues (e.g., [5]–[9]). Planetary chemistry is established during its formation processes of differentiation and later magma formation. The chemical nature of a planetary surface can be determined from returned samples, experimental instrument placed on the surface and by remote sensing orbital experiments. Orbital remote sensing techniques allow global surveys; therefore it is complements surface measurements. Few major hyperspectral satellite/sensors are given in the Table 2.

Table 2. Hyperspectral sensors on Moon and Mars orbitalsatellites

Sensors Name	Number of bands	Spectral range[µm]
Moon Mineralogical Mapper (M3) - Chandrayaan-1,	85	0.43–3.0
Hyperspectral Imager (HySI)-Chandrayaan-1	64	0.42–0.96
OMEGA-Mars Express	352	0.36–5.2
CRISM-Mars Reconnaissance Orbiter	554	0.4–4.0

The current decade has seen reinforcement in the field of planetary exploration with several new initiatives by various space agencies like Indian Space Research Organization (ISRO), European Space Agency (ESA), China National Space Administration (CNSA), Japan Aerospace Exploration Agency (JAXA) and National Aeronautics and Space Administration (NASA). Each agency is developing sensor for studying and understanding of the origin, evolution, geological history of plants and its surface.

IV. Hyperspectral data processing

The hyperspectral imaging has been transformed in less than 30 years from being a sparse research tool which is available to a broad user community. Currently, globally standardized and enhancement of data processing techniques is take into account on special properties of hyperspectral data [10]. Hyperspectral imagery has been used to detect and map a wide variety of materials having characteristic reflectance spectra. The imaging spectroscopy approaches wherein the presence of specific target materials in the image is detected by matching the corrected pixel spectra with reference spectra from a spectral library. Techniques like spectral angle mapper are used for matching the pixel spectra with the reference spectra. Further, the reference spectra can also be used to define target classes of interest and determine the relative proportion of pure classes within mixed pixels. Mixed pixels are characterized by being different from all known spectra in the spectral library and being comparable in distance to more than one reference spectrum (e.g., [11], [12]). Materials are identified from hyperspectral remote sensing images by comparing their spectra to a set of reference spectra. Several libraries of reflectance spectra of natural and man-made materials are available at e.g. http://speclib.jpl.nasa.gov. The spectral library like ASTER has been made available by NASA as part of the advanced space borne thermal emission and reflection radiometer (ASTER) imaging instrument programme. It includes spectral compilations from NASA's Jet Propulsion Laboratory, Johns Hopkins University, and the United States Geological Survey. The ASTER spectral library

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currently contains nearly 2000 spectra, including minerals, rocks, soils, man-made materials, water and snow, covering the entire wavelength region from 0.4 to 14 µm (e.g., [12], [13]).

A. Tetracorder techniques for mineral detection

The earth and plant surface, few materials have spectra with less intense and/or subordinate absorption features in addition to stronger diagnostic absorptions. The diagnostic absorptions may be detectable if the abundance of the material is high enough. However, certain place low abundances of the material may indicates weaker absorptions of the material. Tetracorder is a recent techniques in spectroscopic to detect materials that every feature is assigned as either diagnostic or optional. If a feature is defined as diagnostic or optional, and it is detected in the spectrum, its weighted fit will be included in the analysis and decision process. If an optional feature is not detected, its fit and depth are set to zero and the material might still be identified by the presence of other absorption features. If material is not indicated by the spectrum, it is declared as undetected [14]. For example, the key spectral features of iron oxides are in the visible, while clay minerals exhibit diagnostic features between 2 and 2.5 microns. The presence of multiple materials may dilute the strength of their spectral features relative to those in a reference spectrum, but in many important and frequent cases the signatures do not confound each other. Tetracorder identifies materials by comparing them to a large spectral library and spectral signatures are significant only in their diagnostic wavelengths allows detection of more than one material in a remotely sensed spectrum for common and important combinations of materials (Fig.2). More detailed discussion and analysis may be referred [14].

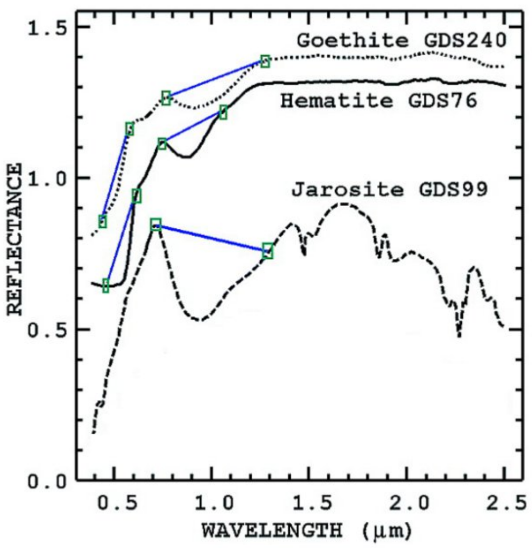

Fig. 2 Tetracorder techniques for mineral detection (modified after Clark et al., 2003 [14]). Continuum removals of three reference spectra's are shown: goethite, jarosite, and hematite.

B. Parallel computation for hyperspectral data analysis

The rapid development of space and computer technologies has made possible to store and process a large amount of remotely sensed images, collected from heterogeneous sources. For example, NASA is continuously gathering imagery data with hyperspectral earth observing sensors such as the Airborne Visible-Infrared Imaging Spectrometer (AVIRIS) or the Hyperion imager aboard earth Observing-1 (EO-1) spacecraft and space mission's data. The development of fast techniques for transforming the massive amount of collected data into scientific understanding is critical for space-based earth science and planetary exploration. Present applications of remote sensing in earth science, space science, and soon in exploration science will require real- or near real-time processing capabilities [15]. The parallel computing based data analysis strategies for hyperspectral imagery is a new emerging area of information extraction from hundreds of spectral bands at different wavelength channels for the same area on the surface of the earth. The high-performance parallel computer process and extract the information's from hyperspectral imagery in near real time. In the near future, these systems may introduce significant advances in the way hyperspectral data sets are processed, stored, information extracted.

V. Conclusions

Hyperspectral imaging technology provides hundreds of narrow spectral bands of an area which is appropriate for discriminating the surface material with increased accuracy. A number of operational hyperspectral imaging systems are currently available, providing a large volume of image data that can be used for wide range of applications such as minerals and rock types mapping, hydrological science, agriculture, environmental science, military applications and planetary science. Advances in the science and technology the tetracorder is a recent techniques in spectroscopic to detect materials of the hyperspectral image. The parallel computing based data analysing strategies is a new emerging era for extracting the information from hyperspectral imagery.

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