MANTECH Publications
Journal of Remote Sensing, Environmental Science & Geotechnical Engineering
Volume 5, Issue 1, January-April, 2020

Utilizing Hyperspectral Imaging For Mineral Exploration And Soil Classification

Dr. Ananya Verma
Professor
Department of Geoinformatics
Indian Institute of Technology, Roorkee, India
Email: ananya.verma@iitr.ac.in

Dr. Raghav Sharma
Associate Professor
Department of Earth Sciences
National Institute of Technology, Rourkela, India
Email: raghav.sharma@nitrr.ac.in

ABSTRACT

Hyperspectral imaging (HSI) has emerged as a revolutionary remote sensing technology for geological applications, offering unprecedented capabilities in mineral mapping and soil classification. By capturing continuous spectral information across hundreds of narrow bands, HSI enables precise identification of minerals and soil properties that are otherwise undetectable using conventional multispectral imaging. This paper presents an in-depth examination of the utilization of HSI for mineral exploration and soil classification, particularly in heterogeneous geological environments. The discussion encompasses sensor specifications, data preprocessing, spectral unmixing, and classification algorithms. Additionally, this study highlights case examples demonstrating the integration of airborne and satellite-based hyperspectral datasets with ground truth information for enhanced mapping accuracy. The outcomes emphasize HSI's ability to

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support sustainable resource extraction and agricultural planning through improved geospatial analysis.

Keywords: *Hyperspectral imaging, mineral exploration, soil classification, remote sensing, spectral analysis, geospatial mapping*

INTRODUCTION

Hyperspectral imaging (HSI) represents one of the most advanced innovations in remote sensing, enabling detailed detection and discrimination of surface materials. Unlike multispectral sensors, HSI captures hundreds of contiguous spectral bands, providing the spectral resolution necessary to identify unique material signatures. This is particularly valuable in mineral exploration, where subtle variations in spectral reflectance can reveal the presence of specific minerals.

HYPERSPECTRAL IMAGING PRINCIPLES

HSI systems operate by collecting reflected light from the Earth's surface across many narrow wavelength intervals. This produces a continuous spectral profile for each pixel, which can then be analyzed to determine material composition.

APPLICATIONS IN MINERAL EXPLORATION

Mineral exploration using HSI focuses on detecting absorption features related to specific chemical bonds. This technique can reveal hydrothermal alteration zones, identify ore minerals, and delineate geological structures with remarkable precision.

SOIL CLASSIFICATION USING HSI

Soil classification benefits from HSI's ability to detect subtle differences in soil moisture, organic matter, and mineral content. By analyzing spectral indices and reflectance curves, researchers can develop classification schemes tailored to local soil types.

DATA PROCESSING AND ANALYSIS

HSI data processing involves calibration, atmospheric correction, noise removal, and dimensionality reduction. Advanced algorithms such as spectral angle mapper (SAM) and support vector machines (SVM) are commonly used for classification tasks.

CASE STUDIES

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Numerous case studies demonstrate the value of HSI in geosciences. For instance, the Hyperion sensor aboard NASA's EO-1 satellite has been used to map mineral belts in arid regions. Similarly, airborne HSI campaigns have successfully identified soil contamination zones and optimized agricultural land use.

CONCLUSION

Hyperspectral imaging stands as a transformative technology for mineral exploration and soil classification. Its high spectral resolution, combined with advanced analytical techniques, provides unparalleled mapping accuracy, supporting both scientific research and sustainable resource management.

Parameter	Description	Example
Spectral Resolution	Number of narrow wavelength bands captured by the sensor	224 bands in AVIRIS

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