Unmixing of hyperspectral data and mapping of alteration zones in Erongo, Namibia

Majid Mohammady Oskouei

Abstract

The study aims to detect and map alteration halos in Erongo, Namibia by means of Hyperion and ASTER data. First of all a comprehensive investigation about previous studies was conducted. Pre-processing requirements to prepare high quality data for analysis purposes then performed on data. In this section the apparent reflectance of earth surface is calculated from radiance data using by Atmospheric CORrection Now (ACORN) package. The data quality assessment is then applied for discriminating poor channels which possess weak Signal to Noise Ratio (SNR); the bad bands are therefore deleted from dataset to attain only 166 informative bands for successive processing.

Regarding to nature of geological structures at all, an algorithm based on geostatistic has been presented to boost and improve absorption features on spectral profiles. The algorithm has shown helpful performance in noise whitening and absorption features boosting of spectral profile.

Determination of endmembers or virtual dimensionality (VD) of data is the next step. Principle Component Analysis (PCA), Minimum Noise Fraction (MNF), and HFC methods are examined for this purpose. The number of detectable endmembers calculated from PCA and MNF are 13, however, successive analysis in N-Dimensional visualizer implicated that 11 endmembers can be distinguished which 10 of them are related to alterations. The VD computed by HFC method is 37 and is used for accomplishing of ICA studies.

Alterations identified by PPI and N-dimensional visualizer are compared spectrally to the United States' Geological Survey (USGS) mineral spectral library with the use of spectral feature fitting algorithm in short wave infrared range of wavelength. Matched filtering method was applied to estimate abundances of each endmember to produce final map.

Regarding to geological settings around Erongo complex and its sophisticated facieses this study has proved possibility of using Hyperion datasets to detect and map alteration halos by linear unmixing methods. Although low signal to noise ratio of Hyperion sensor could make some difficulties but comparing to high cost and time consuming field sampling and geochemical studies, it could be an advantageous tool for primary steps of exploration. Enough side information during the estimation of endmembers number and determination of their mineralogy could help us to conduct more accurate processes. Specially decision making about comparing wavelength range is very important and differs related to the aim of investigation and group of target minerals.

Independent Components Analysis (ICA) method also was evaluated for detection and mapping alteration halos by Hyperion data. Therefore two methods were used to achieve Independent Components (ICs) map. The first one is the algorithm of Wang and Chang which prioritize resultant ICs after running FastICA program to gain 37 prior ICs. These ICs were normalized to obtain abundances map and the extreme pixel for each IC is then determined. Since some ICs share in extreme pixels, the final extremes by this method were ended up whit 9. Then the Hyperion scene is classified by Spectral Angle Mapper (SAM) method with the use of the spectral profiles of 9 extreme pixels as endmembers. This classifier revealed that distribution of only 6 of 9 endmembers are considerable in the classification map and the total numbers of assigned pixels for other 3 endmembers are negligible.

Another method presented here differs slightly from first one. In this method extreme pixels for all 166 ICs are determined and prioritization of ICs bands takes place afterward. Therefore by this method 24 different extreme pixels were recognized and like the first method SAM classifier was used for classification. Distributions of only 8 endmembers from 24 were considerable on resultant map. The maps produced by these two methods demonstrate that the second method has better performance because in addition to ability map more endmembers, the mapped zones match lithological structures better.

Regarding to essence of ICA which use higher order statistical parameters, it was expected to achieve more detail results, but the outcome was not satisfactory although for detecting of a specific minor mineral it could have reliable performance. Because the variance based methods generally ignore features with small abundances. The failure of ICA in this case could emanate from two factors. First due to sensitivity of ICA to noise portion in dataset or in other words signal to noise ratio of data which is low for Hyperion sensor comparing to airborne hyperspectral sensors. Second factor is about FastICA programme performance which result negative values for output IC bands. This is meaningless from physical point of view. Although the method used here for obtaining ICs abundances uses absolute amount of them, but it also suffers from weak mathematical pretext.

Finally the result from Hyperion dataset unmixing processes is extended to the ASTER scene with the aim of achieving an alterations map in a much broader area. Therefore, the mapped alterations in the Hyperion dataset are used as training datasets for classification of the ASTER scene. For this purpose they were geographically registered based on ASTER dataset as region of interests (ROIs). This has been done for both maximum and over 30% maps. Because of difference between ASTER and Hyperion ground resolutions, during this process they were also resampled to match pixel size of ASTER dataset. The result of separability computations of ROIs of two maps was an implication for applying of over 30% map for subsequent process because it is more satisfactory from that viewpoint; however, it was necessary to combine some classes. At first, the classification of the ASTER data is performed with the use of four classification systems (SAM, maximum likelihood, minimum distance, and Mahalanobis distance). The accuracy evaluation showed that among these the Mahalonobis distance method yields the best performance.

Meanwhile, the capability of combined classification is also investigated, and a new method (Selective Combined Classification (SCC)) is presented with the aim of achieving the highest possible overall accuracy (OA). Other combined classification methods always suffer from two problems. These emanate from the lack of certain criteria for selecting base classifiers and for calibrating posterior probabilities which result from the use of different base classifiers. The reliability of combined classification functionality therefore differs from case to case. The SCC algorithm, however, provides distinct solutions for the two problems and thus always yields a more accurate classification than do base classifiers. The approach presented in this study provided robust performance in comparison with both base and combined classifiers and resulted in the best OA.

Keywords: Alteration mapping, ASTER, Atmospheric correction, Classification, Combined classification, Data quality assessment, Erongo, Geostatistical analysis, Hyperspectral, Hyperion, Independent component analysis, Matched filtering, Mineral detection, Mixture tuned matched filtering, Namibia, Remote sensing, Spectral profile, Unmixing analysis, Virtual dimensionality.