

GNR-602 Advanced Satellite Image Processing

Paper Review

A Fast Iterative Algorithm for Implementation of Pixel Purity Index (IEEE 2006)

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Aim of the Paper

The paper aims to improve the currently used algorithm of Pixel Purity Index (PPI) for endmember selection by a Fast Iterative Pixel Purity Index (FIPPI) algorithm. The PPI algorithm was available in the Environment for Visualizing Images (ENVI) software system and due to its proprietary the detailed implementation is not made public. The major issues in the PPI algorithm are its sensitivity to input parameters, k (number of skewers) and t (cut-off threshold value), random initialisation of skewers, computational complexity, requirement of human intervention to select final endmembers and not being an iterative process leading to asymptotic convergence. The paper is aimed at devising a new algorithm iterative algorithm FIPPI for endmember selection which would use Virtual Dimensionality (VD) to estimate number of endmembers required to be generated and Automatic Target Generation Process (ATGP) for initialisation of endmembers. Towards the end the paper has compared the results of endmember selection by PPI and FIPPI algorithm with random and ATGP initialisation.

Methodology

The paper applied a Fast Iterative Pixel Purity Index (FIPPI) algorithm for endmember selection. The algorithm is divided into 5 main steps. The steps are as follows:

1. *Initialisation:* The number of endmembers required was calculated using *Harsanyi-Farrand-Chang* (HFC) Method.
2. *Dimensionality Reduction:* *Maximum Noise Fraction* (MNF) transform was used for dimensionality reduction and initial set of skewers were generated by selecting those pixels which correspond to target pixels generated by ATGP.
3. *Iterative Rule:* At each iteration, all sample vectors were projected on each of the skewer and the ones at extreme positions would form the extrema set. At each iteration, the sample vectors that produced the largest PPI were kept in a separate set.
4. *Stopping Rule:* The algorithm is stopped when no new endmembers are added to the skewer set.

Mathematical Techniques Used

The paper hasn't discussed much of new mathematical techniques or transforms. However, the following are few mathematical extracts from the paper:

- *Extrema Set:* For a particular skewer, extrema set is set of all sample vectors which when projected on the particular skewer, are at the extreme positions.
- *Indicator Function (specifically used in the paper):* Function defined on a set for a sample vector. This function is 1 if the input sample vector belongs to the set and 0 otherwise.
- *PPI Score of sample vector:* Sum of Indicator functions over all the extrema sets with the sample vector for which PPI score is to be calculated as input.

- Apart from these, the paper used *Maximum Noise Fraction* (MNF) transform for dimensionality reduction.
- The *Automatic Target Generation Process* (ATGP) was used for initialisation of endmembers.
- *Virtual Dimensionality* (VD) was used to decide the number of endmembers required in the FIPPI algorithm.
- *Spectral Angle Mapper* (SAM) was used to measure similarity between the extracted endmember pixels.

Sample Data Used and Other Implementation Details

The image dataset used in the experiment was the *Cuprite AVIRIS* image scene collected over the Cuprite mining district, Nevada, in 1997. The 224-band scene data was available in reflectance units.

The experiments were conducted in a PC with AMD Athlon 2.6-GHz processor and 512 MB of RAM. (*This information is relevant to get a comparative idea about the computational complexity involved in PPI and FIPPI*).

The ENVI software was used for PPI implementation.

Assumptions made by authors

The author has not made any major assumptions in the paper. Even the initialisation was suggested to be using ATGP but can be changed to something else as per the user.

Major Findings of the Paper

The paper has succeeded in devising an algorithm better than PPI for endmember selection. The new algorithm FIPPI has produced, as suggested by finding made in the paper, results which appreciably coincide with the results from PPI in much less time. The results from FIPPI also matched to some extent with the ATGP initialised endmembers. Also, the computational complexity involved in the FIPPI algorithm proved to be less than PPI algorithm.

Overall, the algorithm suggested by the paper managed to overcome the major issues in the then current PPI algorithm.