A Novel Approach for Band Selection Using Firefly Algorithm in Hyperspectral Images for Classification

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***Abstract*---With the emerging airborne hyperspectral imaging systems, hyperspectral imaging finds wider application in remote sensing. It also finds applications in resource management, agriculture and environmental monitoring. Hyperspectral data pose challenges to image interpretation because of need for calibration, redundancy in information, and high data volume. HyperSpectral Image(HSI) is very useful when compared to other imaging techniques, due to its high dimensionality. However, high dimensionality of hyperspectral image leads to increase in computational complexity. Hence, Dimensionality Reduction (DR) is an essential preprocess in all hyperspectral image analysis. Band selection based DR is deployed in this work because there is no compromise in originality of the data. There exists a another issue in finding the number of bands to be selected. The concept of Virtual Dimensionality (VD) is used to resolve the problem. This paper presents a novel approach of band selection in hyperspectral image using firefly algorithm by interpreting the band selection as an optimization problem. Support Vector Machine (SVM) is used in classification phase. Simulations results indicate that the proposed firefly algorithm provides superior performance in band selection for better classification.**

Keywords--Band selection; Virtual Dimensionality; Hyperspectral image classification; Firefly Algorithm; Support Vector Machine

I. INTRODUCTION

Multispectral and Hyperspectral images have been used around the world in various fields of laboratory,agricultural and airborne applications[1][5].The main difference between multispectral and hyperspectral images is the number of bands.Multispectral images usually have 3 to 10 different bands whereas hyperspectral images have hundreds to thousands of bands[2][3].Hence ,hyperspectral images have higher level of spectral details.This pose a great threat to select discriminant bands to reduce higher dimensionality[4]. The dimensions of the hyperspectral images have to be reduced without any loss of information. DR techniques are broadly categorized into two types namely transform based DR and band selection based DR. In the former approach, the image is transformed into a lower dimensional space in which the originality of the data is agitated. Also, the transform based DR for extracting endmembers from the hyperspectral image has been used in,which increases the computational cost. But, in later approach, a subset of bands is selected without changing their originality . Band Selection methods are broadly categorized into two types namely Supervised and Unsupervised. Supervised band selection requires aforementioned knowledge on data set, which may not be available practically[10]. But Unsupervised band selection selects informative bands from the larger band set, without prior information. There exist two issues in band selection. The first issue is estimating the number of bands, which is resolved by the concept of VD using Noise-Whitened Harsanyi-Farrand-Chang (NWHFC) method. The second issue is identifying criteria to select the bands. There are several algorithms available for band selection[9]. In this paper, Band selection is accomplished using FIREFLY algorithm[6] as the convergence rate is less compared to other algorithms. Further, the hyperspectral image is classified using SVM classifier[12].

The rest of the paper gives a detailed description as follows: In section II,VD estimation is done to estimate the number of bands. In section III, FIREFLY algorithm is proposed to perform selection of informative bands in hyperspectral images . The proposed method is explained in Section IV. In section V, experimental results are discussed. Finally conclusion is given in section VI.

II. VD ESTIMATION

Virtual dimensionality (VD) was developed for estimating the number of spectrally distinct signatures in hyperspectral images. With the interpretation of one signal source can accomaodate only one single and distinct dimension, VD can be used as an effective measure for estimating the number of dimensions required for DR. The two methods used for estimating VD are Harsanyi-Farrand-Chang (HFC) method [13] and noise whitened version (NWHFC). HFC method uses Neyman–Pearson detection theory for VD estimation with given false alarm rate P_F. Noise-Whitened HFC (NWHFC) method[15] is an alternative for estimating VD exactly because HFC does not have noise-whitening process.

III.FIREFLY ALGORITHM

Firefly Algorithm (FA) is a nature inspired metaheuristic algorithm like Particle Swarm Optimization. It is developed by Xin-She-Yang at Cambridge University in the year 2007.The algorithm is inspired by behavior of fireflies. All fireflies are unisex so that one firefly will be attracted to other fireflies irrespective of their sex.Though, Firefly algorithm have some similarities to that of the Particle Swarm Optimization it is proved to have less computational cost and reduced convergence rate. The attractiveness of fireflies is proportional to the brightness, they both decrease when their distance increases. Thus ,for any two flashing fireflies, the less brighter firefly will move towards the brighter firefly. If there is no brighter one then that particular firefly will move randomly.Here,the Brightness of the fireflies are determined by the objective function.

The working principle of firefly algorithm is given as follows,

1.Initialize Objective Functionf(xi)

- In the simplest form, the light intensity I(r) varies according to the inverse square law.

$$I(r) = \frac{I_s}{r^2} \qquad (1)$$

Where, I(r) is the intensity at the source
r is the observers distance from source.

- Considering absorption coefficient γ , the light intensity I varies with the square of distance r

$$I = I_0 e^{-\gamma r^2} \qquad (2)$$

2.Generate Initial Population of fireflies

- Initialize the Population of fireflies

$$x_{t+1} = x_t + \beta_0 e^{-\gamma r^2} + \alpha\varepsilon$$

Where the second term is due to the attraction and third term is randomization with α being the randomization parameter.

3. Determine the Light Intensity Ii

- Now determine the light intensities of each of the fireflies to find out the brightness of each and every fireflies.

$$I = I_0 e^{-\gamma r^2}$$

4. Calculate the attractiveness of fireflies

- Evaluate the attractiveness of fireflies

$$\beta = \beta_0 e^{-\gamma r^2}$$

5. Movement of Lesser Brighter Fireflies towards brighter one

- The movement of the firefly i is attracted to another more attractive (brighter) firefly j is determined by

$$x_i = x_i + \beta_0 e^{-\gamma r_{i,j}}(x_j - x_i) + \alpha\varepsilon$$

6.Update the light intensities ,rank the fireflies and find the current best

IV.PROPOSED METHODOLOGY

In the proposed work,the hyperspectral image is first read and removal of low SNR bands is done. The VD estimation is used to decide the number of bands to be selected for the subsequent process of band selection.Since the hyperspectral image cube is composed of hundreds of bands,the dimensionality reduction should be performed. Dimensionality reduction is accomplished in this work using band selection method based on Firefly algorithm.Firefly algorithm is swarm-intelligence based, so it has similar advantages to that of the other swarm-intelligence algorithms. Firefly algorithm has major advantages of automatical sub-division and ability of dealing with multimodality compared to other algorithms such as clustering algorithm,Continous Genetic algorithm,Ant Colony Optimization algorithm[14], Particle Swarm Optimization[8]. FA is based on attraction and brightness and this decreases with increasing distance.This leads to the fact that the whole population can automatically subdivided into groups and these group can swarm around each mode or an local optimum.Among all the modes,the best global solution can be found.In addition to this the parameters in FA can be tuned to control the randomness as iterations proceed, so that the covergence can also speed up making it flexible to deal with optimization problems.Hence,Firefly algorithm based band selection is proposed for effective selection of bands in hyperspectral images. With the selected bands , the image is classified.The classification is done using Support Vector Machine (SVM) classifier[11].SVM is primarily a classifier method which performs classification by constructing hyperplanes in multidimensional space that seperates cases of different class labels.SVM supports both regression and classification tasks and can handle multiple continous categorical variables.

The flow diagram of the proposed work has been depicted in Fig.1.

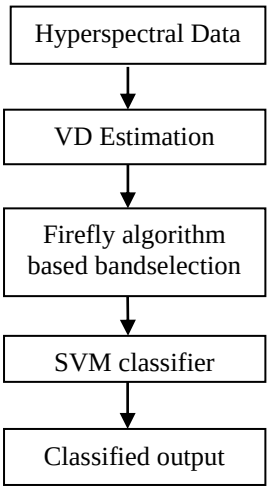

Fig.1 Block diagram of proposed methodology

V.EXPERIMENTAL RESULTS

Indian Pines image is a popular hyper spectral data,considered in this work. As the original image is too large, which is very expensive, a region of Indian pines comprising 145×145×200 pixels is used. Out of sixteen classes, eleven classes in this image,i.e.("#1Alfalfa","#2Corn-notill","#3Corn-mintill", "#4Corn","#5 Grass Pasture","#6Grass trees", "#7Grass pasture mowed","#8 Hay windrowed", "#9Oats","#10 Woods","#11Stone-steel-towers") are considered.The Indian Pines image has been shown in Fig.3 and its ground truth has been shown in Fig.4

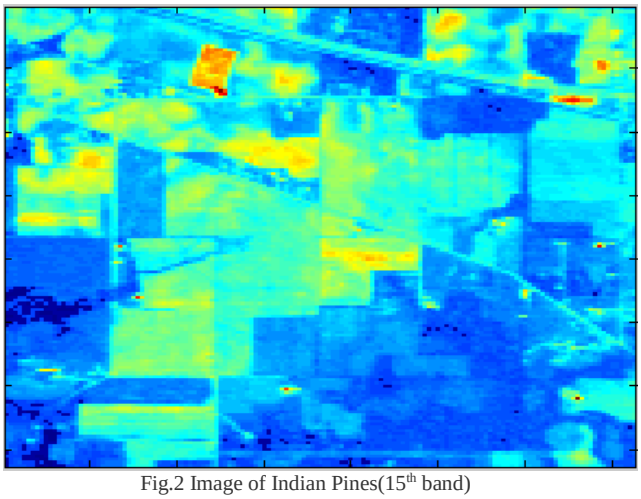

Fig.2 Image of Indian Pines(15th band)

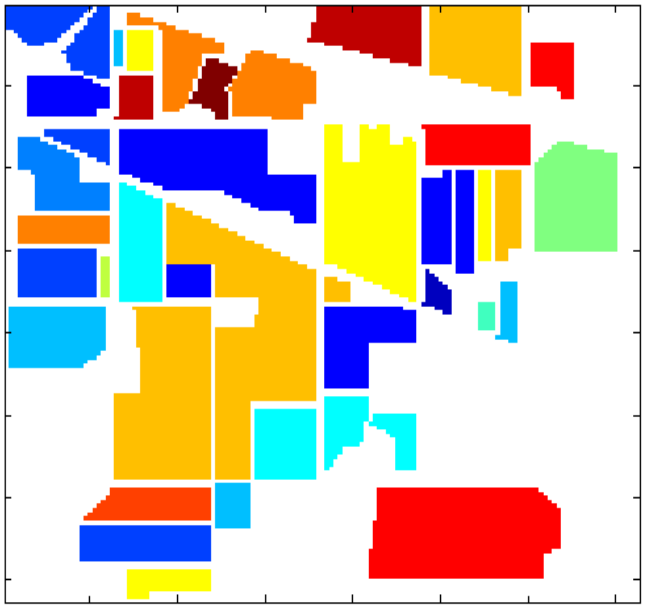

Fig.3 Groundtruth of Indian Pines image

Using the VD estimation, the number of bands to be selected has been determined and it is given in table1.

Table 1. VD Estimation

P_F	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
VD	33	29	26	19	16	16

The highly informative bands in Indian Pines image is selected using the proposed FIREFLY algorithm and the result has been given in table 2.

Table 2. Selected bands from Indian Pines data

ALGORITHM	SELECTED BANDS (16 BANDS)
FIREFLY ALGORITHM	18 4 162 24 55 123 30 44 20 152 114 39 19 200 161 60 53

The selected bands will be given as input to the SVM classifier for classification and the classified output is shown in the Fig.4

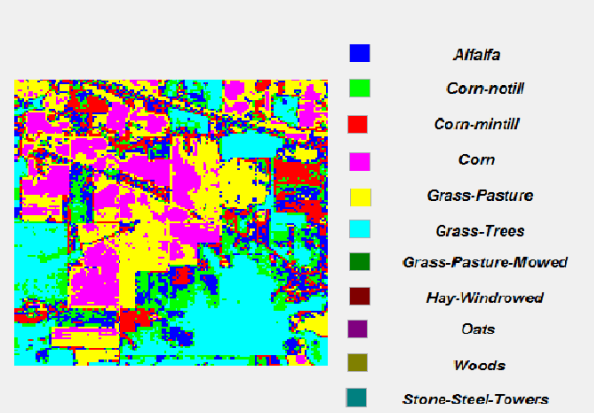

Fig.4 Classified map of Indian Pines

The Classification Accuracy of SVM has been calculated using the formula:

ACC = (TP+TN)/(TP+TN+FP+FN)

TP-number of true-positive decisions
TN-number of true-negative decisions
FP-number of false-positive decisions
FN-number of false-negative decisions

VI. CONCLUSION

Obtaining rich informative bands and highly discriminant bands is a major task of band selection in hyperspectral image analysis. In this paper, Firefly algorithm has been proposed for band selection. Firefly algorithm is one of the recent artificial intelligence algorithms developed. This algorithm is fascinating because it is not only faster than Particle Swarm Optimization (PSO), but also provides better search ability and more consistent results than PSO. The classification accuracy of Indian Pines image with Particle Swarm Optimization based bandselection using SVM classifier is 97.22%. The classification accuracy obtained for Indian Pines image using the proposed Firefly based band selection method and SVM classifier is 98.81%. Hence, from the results, it has been proved that the proposed Firefly algorithm based band selection is indeed a superior algorithm in selecting high informative bands for better classification than existing algorithms.

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