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A NOVEL APPROACH FOR OPTIMAL WEIGHT FACTOR OF DT-CWT COEFFICIENTS FOR LAND COVER CLASSIFICATION USING MODIS DATA

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ABSTRACT

Presently, there is a need to explore the possibility to maximize the use of MODIS (Moderate Resolution Imaging Spectroradiometer) data as it has very good spectral (36 bands) and temporal resolution whereas its spatial resolution is moderate i.e. 250m, 500m, and 1km. Because of its moderate spatial resolution, its application for land cover classification is limited. Therefore, in this paper, an attempt has been made to enhance its spatial resolution and utilize the information contained in the different bands together to achieve good land cover classification accuracy, so that, in future, MODIS data can be used more effectively. For resolution enhancement, modified dual tree complex wavelet transform (DT-CWT) has been employed, where DT-CWT has been modified by critically analyzing the effect of weight factor of the DT-CWT coefficients on land cover classification. For this purpose, image statistics parameter like Mean of the image has also been considered. The proposed technique has been applied on the six bands of MODIS data which have spatial resolution of 500m. It is observed that weight factor of the high-frequency sub-bands is quite sensitive for computation of classification accuracy.

***Index Terms*—** DT-CWT, Resolution enhancement, wavelets, weights, MODIS

1. INTRODUCTION

Satellite images are being used in various applications such as geoscience studies, astronomy and geographical information systems where their resolution plays a critical role but on the other hand, directly obtaining a high resolution data is an another herculean task because of high cost of sensor. Land cover classification from satellite data is a central topic in satellite imaging applications. Therefore, it becomes a necessity to develop and utilize a reliable resolution enhancement technique to obtain accurate information as much as possible as per application from the freely available moderate resolution satellite data. In this regard, many image resolution enhancement techniques have been developed which are interpolations (nearest neighbor, bilinear and bicubic) and wavelets (DWT, SWT, WZP etc.) based. Interpolation techniques [1] have been widely used for resolution enhancement but it results in loss of edges (i.e., high frequency components) of an image.

Nowadays, resolution enhancement is being carried out in the wavelet domain. There are many wavelet transforms which have acquired the place. Discrete wavelet transform (DWT) [2] has also been widely used in order to preserve the high-frequency components of the image but its disadvantage is that it ends up with some ringing artifacts into the image since it is not found to be shift-invariant because of decimations and suppression of wavelet coefficients exploited by DWT. It basically suffers from four shortcomings i.e., oscillations, shift variance, aliasing and lack of directionality which can lead to some artifacts in the image and difficulties in signal modeling. Hence, the DWT has somewhat disappointed the researchers for satellite images. Therefore, in order to alleviate all these drawbacks of DWT [2,3], a new kind of wavelet was introduced by Kingsbury which is known as DT-CWT (Dual tree complex wavelet transform) [1,3]. It possesses shift-invariant property and has the capability of improving directional resolution (because of good directional sensitivity) as compared to that of the decimated DWT. That's why, DT-CWT has been employed in this paper for resolution enhancement of moderate resolution satellite images.

It is foremost to discover the possibility of maximizing the use of freely available satellite data like MODIS. It consists of several bands in which different information is present, but has certain limitations as well like low spatial resolution i.e. 500m which is a major obstacle in obtaining that information accurately. Many researchers have worked on resolution enhancement techniques for visualization enhancement whereas in this paper, main motive is to enhance the land cover classification accuracy which is not reported much for satellite images like MODIS yet. Variance minimization [4] has also been explored by several researchers for weights optimization but it is somewhat complex method. Therefore, it is important to develop such a technique by which resolution of such type of images can be enhanced and information of different bands could be used together. It will be able to enhance some of the special properties of land so that better land cover information could be provided to the user. The challenge lies in optimizing the weight factor of DT-CWT coefficients (obtained by applying DT-CWT) for utmost possible resolution enhancement for achieving good classification accuracy by obtaining hidden land cover information. So, in the present paper, it has been attempted to explore the sensitivity of weight factor of the wavelet coefficients which may be useful for enhancing the land cover classification with MODIS images. Then it has been tested and attempted to obtain optimal weight factor.

2. STUDY AREA AND DATA SET USED

The area under study comprises of some regions of Uttar Pradesh and some of Uttarakhand state, India. The region is bounded by latitudes 29°59'44.70" N and 29°47'15.69" N and longitudes 77°51'17.60" E and 78°03'42.60" E. Moderate Resolution Imaging Spectroradiometer (MODIS), optical data sets are used for study and classification, which have been acquired in the duration of 15-22nd April, 2011 and 6-13th March, 2015. The GCPs (ground control points) used for classes viz., water, vegetation, bare soil and urban are 440, 327, 420, 385 respectively. Out of which, 50% points are used for development, 30% for testing and 20% for validation of the algorithm.

3. THEORETICAL BACKGROUND AND IMPLEMENTATION

Information of different bands utilized, modified DT-CWT based resolution enhancement technique, development of algorithm proposed and implementation of algorithm on a new data set are discussed in the following sub-sections.

3.1. Information of bands of MODIS Data

MODIS data consist of 36 spectral bands [5] where six bands i.e. bands 1-4,6,7 are quite important for land cover classification, which are available at 500m resolution. These six bands have different properties for vegetation and land cover characteristics. If information of different bands could be used together by some possible means then certainly overall accuracy of land cover classes could be increased. So, it has been attempted to use all six bands' information by combining the bands.

3.2. Dual-Tree Complex Wavelet Transform Based Optimal Weight Representation

DT-CWT decomposes the signals into real and imaginary parts in the transformed (complex wavelet) domain in different directions (six complex-valued high-frequency sub-bands) by employing two trees of DWT. It offers many features like shift invariance and directional selectivity, unlike DWT (Discrete Wavelet Transform). Because of the directional selectivity of DT-CWT, the resolution enhancement is obtained since high frequency details, such as sharper edges, are contributed by those high frequency sub-bands present in six different orientations (15°, 45°, 75°, 105°, 135°, and 165°) [6].

Wavelet transform allows us to separately process the high frequency components of the image, which is the prime cause of its superior performance. Hence, weight factors are employed on each of the obtained high-frequency sub-bands (H) in the following way:

$$\mathbf{H_w = (\alpha) * (H)} \qquad \mathbf{(1)}$$

where,
α - Weight factor varied between [-0.5 2]
H - High-frequency sub-bands obtained after decomposition of MODIS bands using DT-CWT
H_w - Weighted high-frequency sub-band

3.2.1 Algorithm Development

Input: MODIS data set of six bands (1-4,6,7) at 500m resolution of size : 206 x 252
Output: Classification with resolution enhanced image of size : 824 x 1008
For each MODIS data set, following steps are followed:

1. **Analyze high-frequency sub-bands' weight (α) effect:**
   For α= -0.5 to 2 with step size: 0.1
   A) For each band of MODIS as input image,
      i) Transform the image from spatial domain to complex wavelet domain using DT-CWT.
      ii) Six high-frequency sub-bands are obtained.
      iii) For each high-frequency sub-band i.e. H, find weighted high-frequency sub-band H_w using Equation (1).
      iv) Now, these 6 weighted high-frequency sub-bands are used along with Lanczos interpolated input image (as low frequency sub-bands) for the reconstruction of image using inverse DT-CWT.
      v) Resolution enhanced (4 times enhanced i.e., from 500m to 125m) band is obtained.
      vi) Repeat i) to v) for all considered bands i.e. 6 bands.
   B) Information fusion of all the six resolution enhanced bands has been done.
   C) Classify the fused image using maximum likelihood

classifier.

D) Classified image at 125m resolution is obtained.

E) Overall accuracy is determined.

After performing step 1 for five MODIS data sets recursively,

2. Sensitivity of α may be checked for enhancement of the overall accuracy as shown in Figure 1.
3. Overall accuracy (OA) depends on the image behavior also. So, it has been tested while taking average Mean of the whole bands as the parameter and observed that if Mean value changes, it affects the accuracy too.
4. Curve fitting is carried out for developing a relationship between α, average Mean (average of Means of 6 input bands at 500m) and OA.
5. Following relation is obtained:

$$\mathbf{OA = 57.450 - (1.505 * \alpha) + (193.064 * M_{av})} \qquad \mathbf{(2)}$$

with regression coefficient (R^2) obtained as 0.745.

6. Determine optimized value of α at which maximum OA has been achieved by putting value of M_{av} as their respective average Means in Equation (2).
7. Therefore, user can know the value of α by just mentioning how much accuracy one requires in the range of 75% to 90% along with the statistics of images (M_{av}). Using that value of α, image can be enhanced accordingly.

The complete flowchart of the proposed methodology for a new data set is shown in Figure 2.

4. RESULTS AND DISCUSSION

Variations in overall accuracy has been observed with changes in α. After performing experiments with five MODIS data sets exhaustively, it has been found that overall accuracy is very sensitive in respect to α. Overall accuracy seems to be increased as α is varied from [-0.5 0.5] and then it started decreasing for α onwards. So, variation of α is not considered after 2. Optimal values obtained for the two test data sets are 0.5 and 0.7 at which maximum classification accuracies have been achieved.

The resultant fused images obtained for 500m resolution and for 125m resolution using optimal weight factors are classified using maximum likelihood classification technique. The classes considered for classification are water, vegetation, bare soil and urban. The classified images for low and resolution enhanced MODIS data of two data sets considered are displayed in Figures 3(a,b) and 4(a,b) for optimal weight factors (α) i.e. 0.5 and 0.7 respectively, where blue, yellow, red and green colors represent water, bare soil, urban and vegetation regions respectively. The overall accuracies (in percentage) and Kappa coefficients obtained for respective classified images are mentioned in the Table II. These Figures and Table clearly indicate the superiority of the proposed approach qualitatively and quantitatively, as the water canal passing through the Roorkee city is also clearly visible as highlighted in the

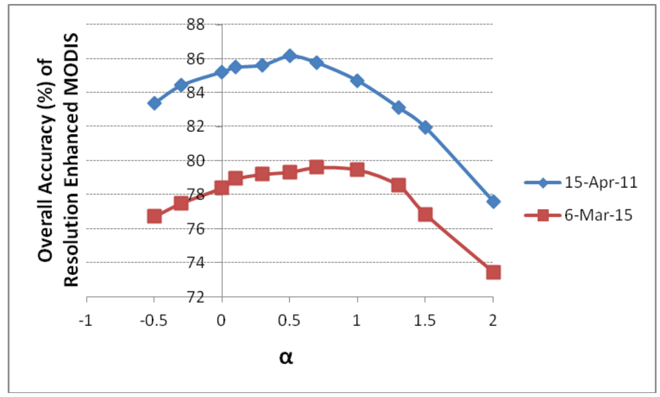


Fig 1. Variation of overall accuracy of resolution enhanced MODIS data sets with respect to weight factor of wavelet coefficients (α)

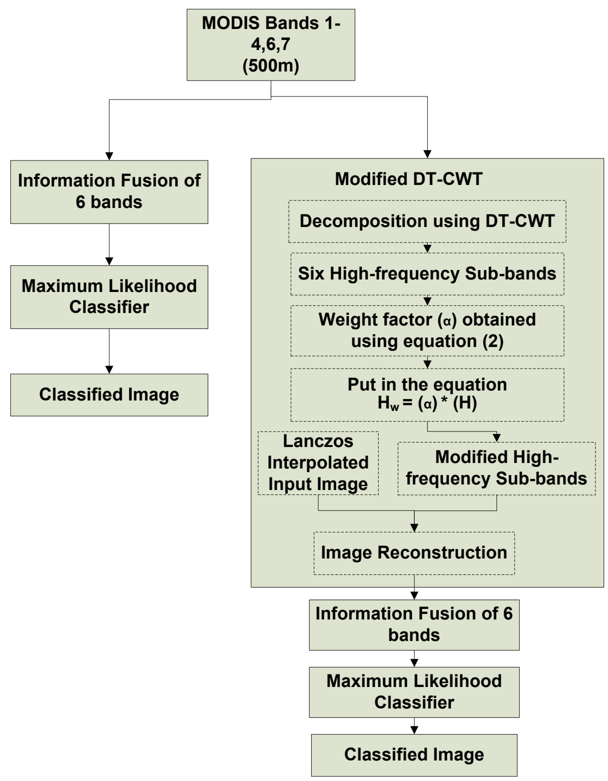
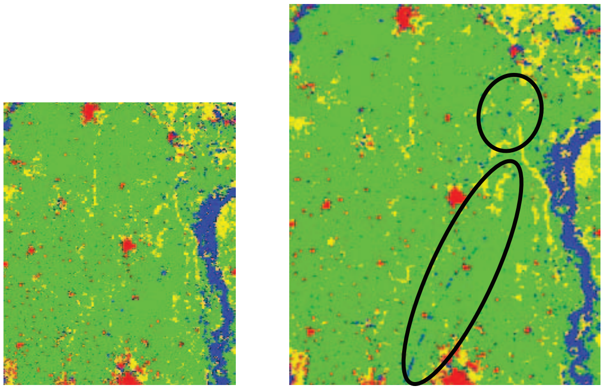


Fig 2. Flowchart of proposed methodology

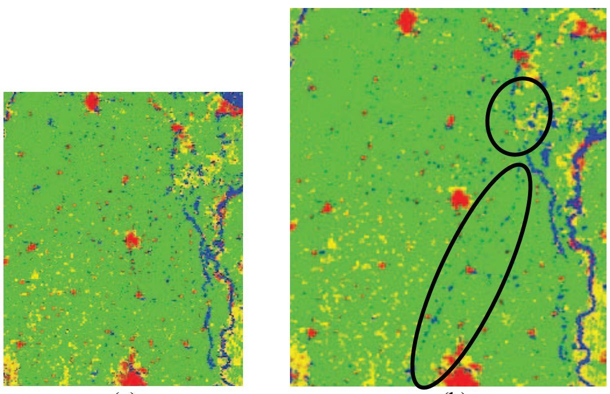
Figure 3(b) and 4(b) which is not visible in the Figure 3(a) and 4(a) and the classification accuracy has also been improved significantly.

Validation of the algorithm has also been carried out for separate data set (MODIS of 7-14th April, 2011) by giving required OA as 85% and average Mean of the respective data as 0.13819 then α obtained is -0.5784 using Equation (2) and using that value further, quite good results are obtained.



(a) (b)

Fig 3. (a) Classified input MODIS (15th April, 2011) 6 bands composite image at 500m resolution (b) Classified output MODIS 6 bands composite image after resolution enhancement at α =0.5 (now at 125m resolution); color representation : blue-water, yellow - bare soil, red- urban, green- vegetation regions



(a) (b)

Fig 4. (a) Classified input MODIS (6th March, 2015) 6 bands composite image at 500m resolution (b) Classified output MODIS 6 bands composite image after resolution enhancement at α=0.7 (now at 125m resolution); color representation : blue-water, yellow - bare soil, red- urban, green- vegetation regions

5. CONCLUSION

In this paper, automated optimal weight factor selection technique for resolution enhancement and information fusion for better land cover classification using DT-CWT on freely available moderate resolution (500 m) MODIS 6 bands data has been proposed. The weight factor of DT-CWT coefficients representation is presented here because DT-CWT allows us to separately process the real and imaginary parts of high frequency components of the image at different orientations. For the experimental study, two sets of satellite data of MODIS at 500m were used to test the efficacy of the proposed approach. The results show better visualization and a significant increase in the classification accuracy of the land cover over that produced by the algorithm without resolution enhancement. It has also been validated by applying on third image and quite good results are obtained.

Table II. Overall Accuracies for MODIS Data Sets

Data	**MODIS 6 Bands Composite Data (Resolution)**	**Overall Accuracy(%)**	**Kappa Coefficient**
Data I (15th April, 2011)	MODIS (500m)	77.4845	0.6957
	Resolution-enhanced MODIS (at optimal α=0.5) (125m)	86.1660	0.8153
Data II (6th March, 2015)	MODIS (500m)	70.2786	0.5969
	Resolution-enhanced MODIS (at optimal α=0.7) (125m)	79.6078	0.7279

Using this proposed approach, user can be able to enhance the image accordingly just by mentioning the overall accuracy (OA) required and image statistics. It is further intended to evaluate the use of optimal weight factor with DT-CWT to improve class (land cover classes) wise accuracy as part of the future work.

6. ACKNOWLEDGEMENT

Authors are thankful to IFCAM for providing the funds to support this work.

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