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A hybrid (IIHSF-LSM) approach to detect vegetation

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As the region of interest is only on vegetative cover areas of satellite images, Panchromatic and Multispectral images are scanned for this purpose. A modified method of IHS fusion result is focused to be better in the method of traditional IHS fusion. Here in this study, a combination of improved IHS fusion and Coarse to Fine level segmentation is deployed to identify the vegetation area with less computational complexity and comparatively higher accuracy.

[Keywords: Improved IHS fusion, Coarse to fine level set segmentation, Vegetation area, panchromatic image, Multispectral image]

Introduction

The frequently used fusion technique is based Intensity-Hue-Saturation (IHS) transformation. In this fusion technique, Multi Spectral images with three bands namely Red, Green, and Blue are used. Near Infrared (NIR) band is widely applied in agriculture for determining grains, vegetables and other agriculture products. When NIR band is used the fusion technique, then it is termed as General IHS or GIHS[1]. Major flaw occurring in IHS and GIHS fusion techniques is image distortion. The methodology presented in this paper will overcome the image distortion problem. Fusion algorithm used here, will preserve the PAN image's spatial resolution and MS image's spectral properties. Some spectral adjustment is done in the fusion technique. This paper presents the Improved IHS fusion technique and the required features are extracted from the fused image. Vegetation Indices (VI) are specifically used to enhance the vegetation changes[2]. Normalized Difference Vegetation Index (NDVI) is a process of enhancing the vegetation index that depends upon the chlorophyll sensitivity. Using 3 different vegetation indices like Normalized Difference Vegetation Index (NDVI), the Green Normalized Difference Vegetation Index (GNDVI), and the Normalized Difference Red Edge Index (NDRE), classification of different crops is done using machine learning algorithms like Support Vector Machine (SVM)[3], Random Forests (RF), and Artificial Neural Networks (ANN) [4].

In this paper, the image enhanced with High Resolution NDVI (HRNDVI) is segmented to get vegetated areas. At the end of the procedure, Coarse to Fine Level Set method is used to segment the region of interest i.e. the vegetation area of any image of any surface like barren lands, coastal regions, and all the urbanized regions. As per the coastal region observed during the research, it is found that the proposed IHS fusion method produced a better quality image with rich spatial and spectral resolution. From the fused image of the coastal regions, the land remained after some natural disasters can be easily identified. With the help of these method, the areas which cannot be reached by the humans can also be analysed for the vegetation existence, land migration, resources mining and the disaster management. Because, the satellite images can be acquired globally and when it is enhanced and processed using the proposed method, the above said problems are solved with ease.

Materials and Methods

Multispectral image captured at 3.2m resolution and panchromatic image of the same area captured at 0.82m resolution provided by the IKONOS satellite sensor, a high resolution satellite. Mapping of natural resources and natural disasters, and change detection. It can also procure relevant data for nearly all aspects of environmental study (http://www.satimagingcorp.com/satellite-sensors/ikonos/). Hence, these particular IKONOS satellite images of nearby vital coast line of Tamilnadu are chosen for this research study. Applications of this satellite is more specific on agriculture and forestry analysis, urban and rural

The procedure of segmenting the vegetation area comprised of the following phases:

(i) The first phase of the procedure is to fuse the MS and Pan Images using the proposed method improved IHS fusion

(ii) Fused image is then subjected to Vegetation enhancement using High Resolution NDVI (HRNDVI)

(iii) The vegetation area is segmented using Coarse-to-Fine level set segmentation.

The detailed implementation procedure is shown in the Fig.1.

Improved IHS fusion

The most commonly used fusion technique is IHS transformation based fusion, where the values of RGB space (Red, Green, and Blue) are transformed into IHS (Intensity, Hue, Saturation) space. And the resultant image is subjected to inverse transformation to get the fused image.

R', G', B' are modified with respect to the original RGB in the traditional fusion technique. Traditional IHS transformation based fusion technique is given in the Equation.1 and Equation.2.

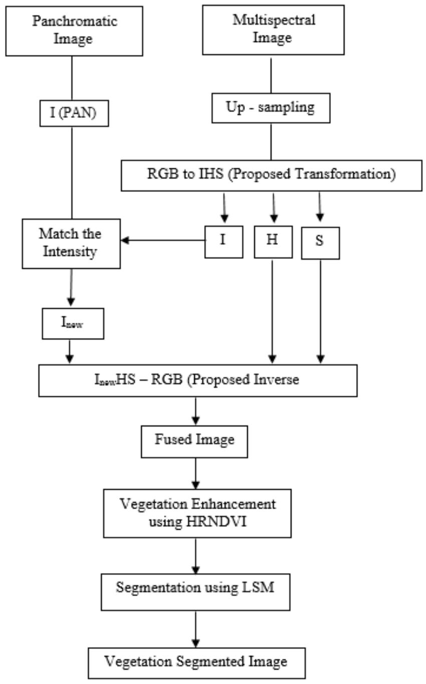

Fig.1 – Procedure of the proposed method

IHS transformation

$$\begin{bmatrix} I \\ v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \\ \frac{-1}{\sqrt{6}} & \frac{-1}{\sqrt{6}} & \frac{2}{\sqrt{6}} \\ \frac{1}{\sqrt{6}} & \frac{-1}{\sqrt{6}} & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$H = \tan^{-1}\left[\frac{v_1}{v_2}\right], \quad S = \sqrt{(v_1)^2 + (v_2)^2} \quad (1)$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} \frac{1}{3} & \frac{-1}{\sqrt{6}} & \frac{1}{\sqrt{6}} \\ \frac{1}{3} & \frac{-1}{\sqrt{6}} & \frac{-1}{\sqrt{6}} \\ \frac{1}{3} & \frac{2}{\sqrt{6}} & 0 \end{bmatrix} \begin{bmatrix} I \\ v_1 \\ v_2 \end{bmatrix} \quad (2)$$

where v_1 and v_2 are Cartesian components of hue and saturation. Intensity of pan image is combined with the intensity of MS image to preserve both the spatial and spectral details.

In this work, an optimized IIHS fusion is derived and implemented. As initial step, the intensity difference (δ) between the pan image and MS image is calculated. Because of the high δ value, colour distortion problem[2, 15] occurs. Hence, spectral adjustments is done by adding the δ value to the multispectral image. Colour distortion problem is reduced considerably with spectral adjustments as Equation.3 and Equation.4.

$$\delta = I(Pan) - I\,(MS) \quad (3)$$

I (Pan) = intensity of panchromatic image
I (MS) = intensity of multispectral image

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} R+\delta \\ G+\delta \\ B+\delta \end{bmatrix} \quad (4)$$

Modified IIHS transformation given in Equation. 5 and 6 is applied to the image in which the spectral adjustments is done.

$$\begin{bmatrix} I \\ v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{-1}{2} & \frac{-1}{2} & \frac{1}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix}$$

$$H = \tan^{-1}\left[\frac{v_1}{v_2}\right],$$

$$S = \sqrt{(v_1)^2 + (v_2)^2} \quad (5)$$

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{3}} & \frac{-1}{2} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{-1}{2} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{1}{2} & 0 \end{bmatrix} \begin{bmatrix} I \\ v_1 \\ v_2 \end{bmatrix} \quad (6)$$

The NIR band is included in the image and it will add spectral weights to the other bands. On adding NIR band, color information of all the bands are enhanced such that we can extract the vegetation are accurately. Now, Equation.4 becomes,

$$\begin{bmatrix} R' \\ G' \\ B' \\ NIR' \end{bmatrix} = \begin{bmatrix} R+\delta' \\ G+\delta' \\ B+\delta' \\ NIR+\delta' \end{bmatrix} \quad (7)$$

where δ' = I(Pan) - I_{new} and I_{new} = (R+G+B+NIR)/4. The transformation is done and the fused image is then subjected to vegetation enhancement. In this step, the intensity of vegetation area is enhanced. We fetch the NIR (Near Infrared) band of image to do spectral adjustments in the fused image. This is done using the following Equation.8.

$$I = \frac{(R+G+B+NIR)}{4} \quad (8)$$

NIR band is mostly used in Generalized IHS fusion method[16]. Then, the green band and blue band are added more weights, so that the greenery is highlighted in the output image clearly. G band is enhanced by 75% and B band is enhanced by 25%. Formulation of spectral adjustment after adding weights is given in the Equation (9).

$$I = \frac{(R+aG+bB+NIR)}{4} \quad (9)$$

where a = 0.75 and b = 0.25. The calculated I value is used to find vegetation index. High resolution Normalized Difference Vegetation Index (HRNDVI) is used in our work for vegetation enhancement.[17]It is one the most commonly used vegetation indices, which is the composite of the daily observations of the high resolution radiometer. It is ultimately used for getting cloud-free remote sensed image and shows the absorptive and reflective characteristics of the green areas (https://lta.cr.usgs.gov/NDVI). Vegetation Index (VI) for given by the Equation (10).

$$VI = \frac{PAN - I}{PAN + I}; \qquad NDVI = \frac{NIR - R'}{NIR + R'} \quad (10)$$

Vegetation index calculated from Equation (7) results an image from which the vegetation and shadows cannot be distinguished. Hence, we used high resolution NDVI with threshold 0.15[18], where the low resolution R band from the fused image and NIR band is used to highlight the vegetation areas. It is calculated using Equation (11).

$$HRNDVI = \frac{Fused\ NIR - Fused\ R'}{Fused\ NIR + Fused\ R'} + \alpha \quad (11)$$

where α= 0.75 x G + 0.25x B. The vegetation areas in the fused image is enhanced and it is now became a suitable input for segmentation. The output images are given in Fig.2.

Fig. 2(a) – Multispectral image

Fig. 2(b) – Panchromatic image

Fig. 2(c) – Proposed fusion method output

Fig. 2(d) – Vegetation Enhanced Image

Fig.2 – Fusion and vegetation enhancement

The proposed IIHS Fusion incorporates the new transformation scheme enhances the quality of the fusion, reduce the processing time and improves the precision. Because on space transformation, the intensities are processed with wider angle (60°). Also, the additional NIR band is appended to spotlight the vegetation areas and NDVI is used to distinguish the shadows and vegetation areas.

Segmentation

After fusion coarse to fine level set segmentation method is used to segment the vegetation area from the fused images. On segmentation, the enhanced vegetation region can be visualized with more clarity. In literature, fused image is segmented using methodologies like hierarchical method of segmentation[20], region based segmentation[21]or with the Euler Lagrange equations[22].In this work, coarse to fine level set scheme is used for segmenting the vegetated areas. It has three subsets:

Coarse scalar extraction

The energy function can be reduced by this technique. The summation of weighed homogeneity of four components gives energy function given in Equation (12).

$$F_N(c) = \mu \int |\nabla H_\emptyset| dx\, dy + \sum \varepsilon_{,c}) \int (d^i - d_1^{-j})^2 H_\emptyset dx\, dy \sum_{j=1}^{4} \varepsilon i_{,c} \int \Omega_0 (d^i - d_1^{\bar{i}})^2 (1 - H_\emptyset) dx\, dy \quad (12)$$

Fine scalar extraction

The contour evolution space can be reduced with the Equation (13).

$$R_\alpha(x.y) = \exp((-d(x, y, \gamma_\alpha) - \tfrac{1}{2}) \quad (13)$$

Euler Lagrange solution

Euler Lagrange is used to implement the fine level scalar as it helps to solve the problem of contour extraction and to reduce the uniform level set functions[21 - 24] Equation (14) is the Euler Lagrange equation:

$$\frac{\partial \emptyset}{\partial} = \delta(\emptyset) R_\alpha [\mu div \left(\frac{\nabla \emptyset}{|\nabla \emptyset|}\right) - \sum_{j=1}^{4} (\varepsilon i_{,c} \left(d^i - d_1^{\bar{i}}\right)^2 - \varepsilon i_{,c} \left(d^i - d_2^{\bar{i}}\right)^2)] \quad (14)$$

where the variable t is set to Φ. The segmented fused image is given in Fig.3.

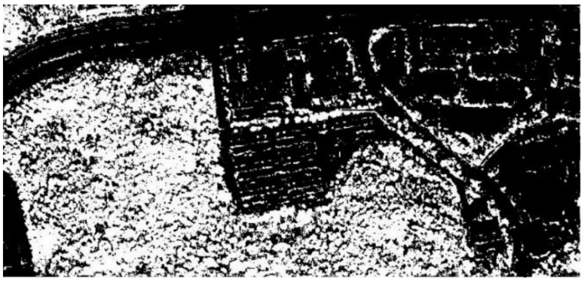

Fig.3 – Segmentation using LSM

Results and Discussion

An improved IHS fusion algorithm is implemented in the multispectral and panchromatic images of the IKONOS satellite sensor. The spatial details of the panchromatic image are injected into the multispectral image and it yields the resultant image in Fig.2(c) with high spatial and spectral resolution. Vegetation characteristics of the fused image are enhanced using NDVI. Application of NDVI in fused image gave better result (Fig.2 (d)) than its application in raw multispectral or panchromatic data. Then, the Level set method is applied on the fused, vegetation enhanced image. Fig.3 shows the segmented image. The segmentation is validated by superimposing the segmented image on the vegetation enhanced-fused image. Exactly, the enhanced vegetation area is segmented by the LSM and it is shown in Fig.4.

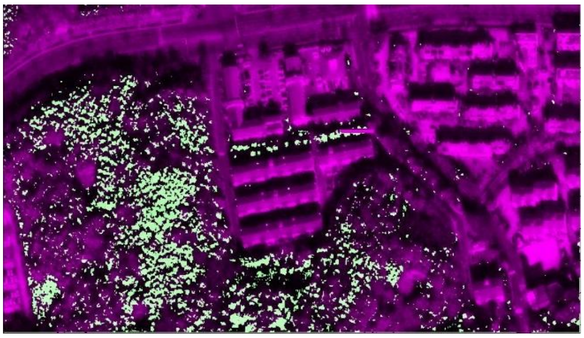

Fig.4 – Superimposition of vegetation segmented image (Fig.3) on fused-vegetation enhanced image (Fig. 2(d))

The segmentation of vegetation enhanced chlorophylls pigments are shown in Fig.5.

Hence from the Fig.5, it is proved that the combination of fusion and vegetation enhanced image results in better segmentation of the vegetation area.

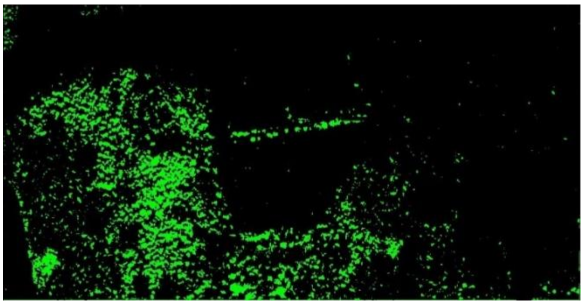

Fig.5 – Segmentation of vegetation enhanced Chlorophyll pigments

In addition, the obtained results of the fusion and segmentation are evaluated using the Digital Number (DN). "Intensity of the pixels are digitised and recorded as a Digital Number" [24]. Here, the average DN of the input and output images are given in Table 1. The multispectral image is injected with the panchromatic intensity by the proposed fusion method and the data is highly preserved. It is interpreted from the mean DN values of the input multispectral image and fused vegetation enhanced image. The average DN of the segmented image is also given in the Table 1.

Table 1: Mean values of Digital number of input and output images

S.No.	Image	Mean of the DN
1	Fig. 2(a) - Multispectral image	81.9621
2	Fig. 2(b) - Panchromatic image	96.7419
3	Fig. 2(d) - Fused & Vegetation indexed image	81.9621
4	Fig. 3 - Segmented Binary image	0.1773
5	Fig. 5 - Segmented image of the vegetation enhanced chlorophyll pigments	73.4779

Accuracy assessment is done using the statistical metrics (mean and variance of individual bands) and image fusion quality metrics (SAM, ERGAS, BIAS and UIQI). Table 2 depicts the mean and variance values of an image which shows how the proposed method gives better results when compared with the state of the art techniques.

Table 2: Comparison of Mean and Variance of each bands

Parameters	Input	*PCA	*BT	Traditional IHS method	Proposed Method
Mean	81.96	83.11	80.03	82.81	**92.86**
Red	88.93	90.92	88.90	92.12	**97.73**
Green	79.82	83.88	81.21	83.88	**91.62**
Blue	77.12	79.41	81.55	80.41	**89.05**
Variance	0.054	0.076	0.071	0.056	**0.033**
Red	0.054	0.079	0.073	0.059	**0.042**
Green	0.055	0.075	0.069	0.065	**0.046**
Blue	0.051	0.071	0.067	0.041	**0.022**

*PCA – Principal Component Analysis; BT – Brovey Transform

Higher the mean value, lower the variance, better the quality of the image. The fusion quality metrics are also evaluated for our IKONOS dataset using existing methods and the proposed method. The measurements are given in Table 3 and the improvement of accuracy is clearly given in Table 4.

Table 3: Accuracy Assessment using Quality Metrics

Parameters	PCA	Brovey Transform	Traditional IHS method	Proposed Method
SAM	5.9723°	5.7114°	4.8031°	**4.1937°**
ERGAS	26.8372	26.8639	25.7166	**21.6270**
UIQI	0.1733	0.1675	0.2319	**0.4725**
Bias	1.1513	-1.9300	0.8500	**10.9000**
Red	1.9976	-0.0310	3.1971	**8.8073**
Green	4.0633	1.3939	4.0628	**11.8162**
Blue	2.2919	4.4391	3.2916	**11.9388**
***RV**	0.0140	-0.0235	0.0103	**0.1329**
Red	0.0223	-0.0003	0.0358	**0.0989**
Green	0.0508	0.01741	0.0508	**0.1478**
Blue	0.0296	0.0574	0.0426	**0.1546**
***SD**	0.6881	0.5146	0.4973	**0.2071**
Red	0.8225	0.7331	0.4025	**0.2354**
Green	0.6733	0.5322	0.4516	**0.2276**
Blue	0.7381	0.6562	0.5361	**0.2188**
***CC**	0.5423	0.5511	0.7018	**0.8131**
Red	0.8238	0.6136	0.7983	**0.9025**
Green	0.2755	0.4914	0.5757	**0.6533**
Blue	0.8332	0.7117	0.7563	**0.9276**

*RV – Relative Variance; SD – Standard Deviation; CC – Correlation Coefficient

Table 4: Accuracy improvement of the Quality metrics

	Improvement in %			
	***PCA**	***BT**	**Traditional IHS method**	**Proposed Method**
Mean	1.40	-2.35	1.03	**13.29**
Red	2.23	-0.03	3.58	**9.89**
Green	5.08	1.74	5.08	**14.78**
Blue	2.96	5.74	4.26	**15.46**
Variance	40.74	31.48	3.70	**-38.88**
Red	46.29	35.18	9.25	**-22.22**
Green	36.36	25.45	18.18	**-16.36**
Blue	39.21	31.37	-19.60	**-56.86**

*PCA – Principal Component Analysis; BT – Brovey Transform

From the results, it seems that the proposed fusion algorithm performs better. A proposed technique described to measure the correctness of contour extraction from the source images[22]. Also the number of pixels in the region both inside and the outside contour region is near to 1 or all segments. This confirms the segmentation efficiency. So such method can be used to count trees in plantation[25, 26].

Conclusion

Thus, the proposed combination of the fusion and segmentation algorithm gives the exact region of vegetation area from the high resolution satellite imagery. The spatial and spectral quality, vegetation region of the image is enhanced by the proposed IIHS fusion methodology and it is fed for segmentation process. Level set Method is applied for the fused and vegetation enhanced image for vegetation segmentation. The performance of the proposed IIHSF – LSM is validated using the statistical measures. Performance analysis shows that the proposed technique is proved to be efficient in terms of computational analysis and it provides the best results in both subjective and objective evaluation. With its considerable functional analysis, this technique will find its usefulness in solving various issues like disaster management, land migration, unauthorized plantation. It can also be extended in identifying the missing and also unauthorized vessels, turbines, tug boats in the marine zones.

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