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Fuzzy Based Super Resolution Multispectral Image Compression with Improved SPIHT

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Abstract— **Multi spectral images are of high resolution which requires a lot of memory to store and transmit. In order to overcome these limitations compression is applied wherein the fine details of the image will be lost due to the poor quality of image after compression. To reconstruct back the same resolution with same quality involves the super resolution (SR) algorithms. In this paper a fuzzy rule based SR image reconstruction approach is proposed. For the performance evaluation the proposed methodology is been compared against existing algorithms and found that the proposed is yielding better results.**

Index Terms—**Image Compression, Fuzzy, Super resolution.**

I. Introduction

A multispectral imaging system splits the visible spectrum into hundreds of frequency bands and records each of the images as a set of monochrome images. This increases and expands the channel acquisition to the light that is outside of the visible spectrum and offers more advantages over the traditional RGB image. This adds more attraction for research on these images and applications to various human needs from past few years. Normally these images are in uncompressed form requires a huge capacity for storage and consumes much time for transmission, so it is necessary to compress these images with most possible approaches. The very best way is to separate each monochrome image and apply the best suited compression techniques individually. In this paper an improved set partition in hierarchical trees (ISPIHT) is applied for compressing the images. When the compressed image is received it will lack in quality which has to be improvised, for this a single image super resolution technique is applied. There are mainly three types of super resolution techniques given by interpolation based methods, learning based methods and reconstruction based methods. The reconstruction based super resolution methods yields better performance results when compared to the conventional methods. The goal of the super resolution algorithm is to reconstruct a high resolution image from a single or multiple low resolution images. Mainly super resolution (SR) algorithms are classified as (i) single frame SR method (ii) Multi frame SR method.

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The multi frame SR methods are most suited for Video sequences rather than a single frame SR method which can be categorized as (i) Example based and (ii) Hallucination [1] [2] [3]. The main intension of all these algorithms is to represent the given image in a high resolution with finer quality by maintaining the sharpness and texture details of the image. In this paper a fuzzy based super resolution image reconstruction algorithm based on [4] paper is proposed.

This paper is organized as follows, section I explains briefly about the compression and its limitation and also the need for super resolution algorithms. Section II discusses about the Improved SPIHT method and also the fuzzy approach and its rules. Section III discusses about the proposed approach followed in this article ending with its experimental results in Section IV and conclusions in Section V.

II. Related Work

A. *Improved Set Partition in Hierarchical Trees (ISPIHT)*

One of the famous image compression technologies is set partition in Hierarchical trees (SPIHT) which is proposed by A. Said et al in [5] this method depends on wavelet transforms where the image is divided into 'N' sub bands of high and low frequencies. This method has many advantages of lower complexity and faster implementation but it is not a good choice for the images with high texture content since most of the high frequency components are been lost. In order to overcome this limitations an improvisation is been done for the earlier method. Instead of applying discrete wavelet transform a lifting based wavelet transform with CDF9/7 (Cohen-Daubechies-Feauveau) [6] [7] biorthogonal wavelet filters are used. This lifting scheme is very easy to implement and also yields good reconstruction results for high textured images (satellite, Medical Imaging).

Algorithm:

Apply CDF 9/7 lifting wavelet transform at n^{th} level

Calculate $n = \left\lfloor \log_2\left(\max_{(i,j)}\left\{\left|C(i,j)\right|\right\}\right)\right\rfloor$

Set threshold to $T = 2^{N+1-K} + \dfrac{2^{N-K}}{2}$

Set LSP (Least significant pixels) to zeros

Sorting pass;

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Process for LIP (least insignificant pixels)

Output $S_n(i,j)$

If $S_n(i,j)=1$*, move to the LSP and output*
All LIS (least insignificant set)
If it's D type
Output $S_n(i,j)$
If $S_n(i,j)=1$*, then each (k,1)* $\in$ *O(i,j)*
If $S_n(j,k)=1$ *, move (k,l) to LSP and output*
If $S_n(i,j)$ *, move (i,j) to LSP*
If there are L(i,j) then (i,j) the change to join the LIS with L type
If its L type
Output $S_n(i,j)$
If $S_n(i,j)=1$*,(k,1)* $\in$ *(I,j) with D type to join the LIS*
(I,j) LIS removed

Refinement and quantization followed for the obtained coordinates

B. Fuzzy based approach for super resolution image reconstruction

The basic idea of fuzzy approach is referred from [4]. Let us consider a database consisting of LR patches i.e; $X = x_1, x_2, x_3, \ldots\ldots x_N$ and the corresponding HR patches as $Y = y_1, y_2, y_3, \ldots\ldots y_N$ typically X=4*n² and Y=n² where *nxn* is the patch size

Partition the patch database by K-means clustering into C-Cluster centroids

$$V^{\bullet} = \{v_c^{\bullet} = (v_c^x, v_c^y) \in R \; c = 1,2,\ldots c$$

Assume that the input LR feature space and the output HR space lie on the same plane so after clustering if there is a cluster in the input LR patch feature space with centriod v_c^x then the corresponding points in the output HR patch space are likely to forma cluster around $v_c^{\bullet}$. Therefore, for each cluster a rule can be written expressing this concept and combining all those rules we get a locally continuous and smooth predictor that maps input LR patch to approximate HR patch.

C. Fuzzy rules

Let x belongs to LR patches then it can be viewed as

$$\text{If x is CLOSE to } \; v_c^x \approx \begin{pmatrix} \textit{if } x_1 \text{ is close to } v_{c1}^x \\ \textit{And} \text{ if } x_1 \text{ is close to } v_{c1}^x \\ \text{AND } x_p \text{ is CLOSE to } v_{cp}^x \end{pmatrix}$$

More over R_c^{TS} corresponds to HR

R_{cj}^{TS} : If X is CLOSE to v_c^x then

$y_j = u_{cj}(x, v_{cj}^y)$

Using the Non linear Mapping

$u_{cj} = d_{cjo}.v_{cj}^y + d_{cjp}.x_p$ c=1,2…C

Thus the output is linear combinations of centroids v_{cj}^y

The output is computed as

$$y_j = \frac{\sum_{c=1}^{C} \alpha_c u_{cj}(x, v_{cj}^y)}{\sum_{c=1}^{C} \alpha} \quad \text{j=1, 2…q (HR patches)}$$

Where α_c is the firing strength of the rule .For more analyses please refer [4].

III. Proposed Method

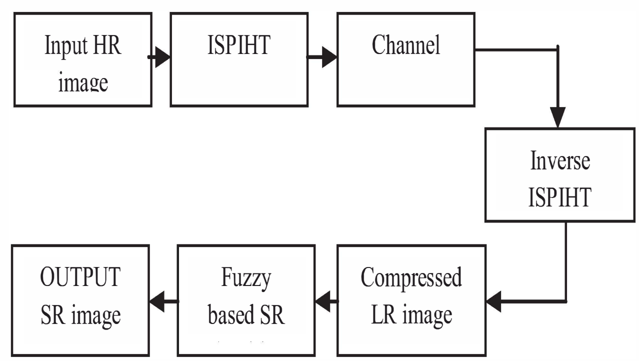


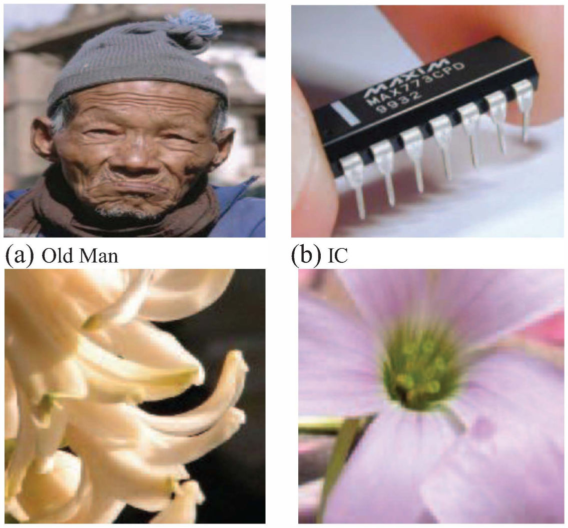
Fig. 1. Proposed Methodology

Multi spectral images are of high dimensions and usually occupy a large space for storage. The transmission rate is very low when compared against to traditional images. So here in this paper an improved SPIHT techniques with lifting wavelet transform is proposed which when reconstructed back can represent the fine texture details [8-14].

Since the multi spectral images do contains a high texture data this compression algorithm is adopted. When it is been transmitted through a channel there is a provision for the insertion of noise here we instead consider the noise to be zero mean white noise.

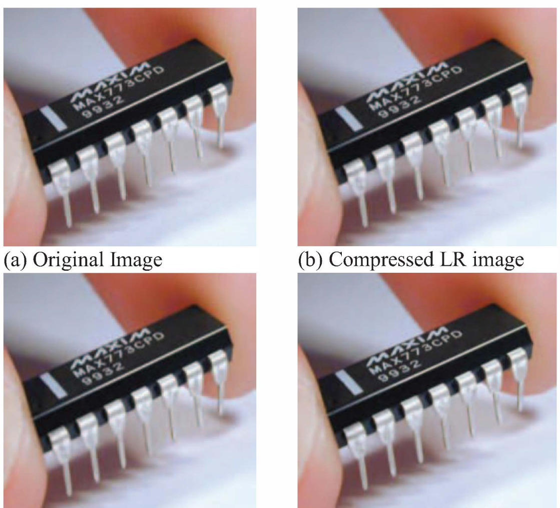
The reconstructed image do suffers from many artifacts which degrade the edges (sharp contents) of the images. This degradation may lead to wrong interpretation or mis-interpretation in multi spectral images [8] [9]. So in order to reconstruct back the original quality we employ the SR image reconstruction algorithm. Here we employ the fuzzy based approach discussed in [4]. The input high resolution multispectral image is encoded by the improved SPIHT and sent through a channel for remote sensing applications. At the output section the output image is decoded by inverse improved SPIHT and the compressed image is enhanced by fuzzy based super resolution algorithm. The experimental results for the traditional and multi spectral images can be seen in Fig. 2 for test samples, Fig. 3 for traditional images and in Fig. 4 for vizag multispectral image. The PSNR and MSE comparisons at 0.05bpp are given in Table II and Table III respectively.

IV. Experimental Results



(a) Old Man (b) IC (c) Lilly (d) Flower

Fig. 2. Test samples Used in this paper

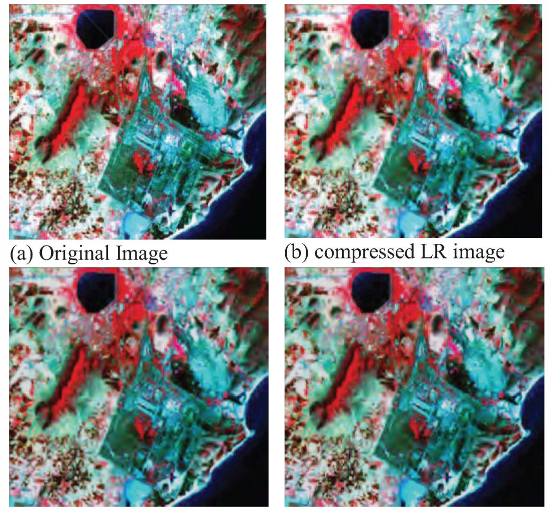


(a) Original Image (b) Compressed LR image (c) Bi-cubic interpolation (d) Fuzzy based approach

Fig. 3. Experimental results obtained with traditional images

TABLE I
COMPRESSION RATIO COMPARISONS at 0.05 bpp

Image	DCT	SPIHT	ISPIHT
Old Man	0.970	0.904	0.911
IC	0.85	0.878	0.901
Lilly	1.05	1.075	1.104
Flower	0.80	0.808	0.808



(a) Original Image (b) compressed LR image (c) Bi cubic interpolation (d) Fuzzy based approach

Fig. 4. Experimental result obtained for Vizag Multi spectral Image

TABLE I
PSNR COMPARISONS at 0.05 bpp

Image	DCT		SPIHT		ISPIHT	
	Bi Cubic	Fuzzy	Bi cubic	Fuzzy	Bi-cubic	Fuzzy
Old Man	24.29	24.25	24.55	24.55	24.59	24.60
IC	22.66	22.61	23.01	22.99	23.02	23.02
Lilly	23.88	23.88	24.13	24.15	24.14	24.18
Flower	22.09	22.09	22.10	22.10	22.10	22.11

TABLE III
MSE COMPARISONS at 0.05bpp

Image	DCT		SPIHT		ISPIHT	
	Bi Cubic	Fuzzy	Bi cubic	Fuzzy	Bi-cubic	Fuzzy
Old Man	238.13	240.36	224.21	224.34	222.38	221.73
IC	319.72	323.09	294.93	296.22	294.21	294.00
Lilly	265.52	265.79	251.02	249.79	250.29	248.37
Flower	401.13	400.84	400.46	400.84	400.77	399.6

From the above experimental results it can be found that the proposed approach performs at lower bpp and also provides and increment in the PSNR with a variation of about 2.5 dB. The proposed approach is evaluated with both natural and standard data base image and few of those results were presented in this paper and with all these images it is found to be satisfactory .

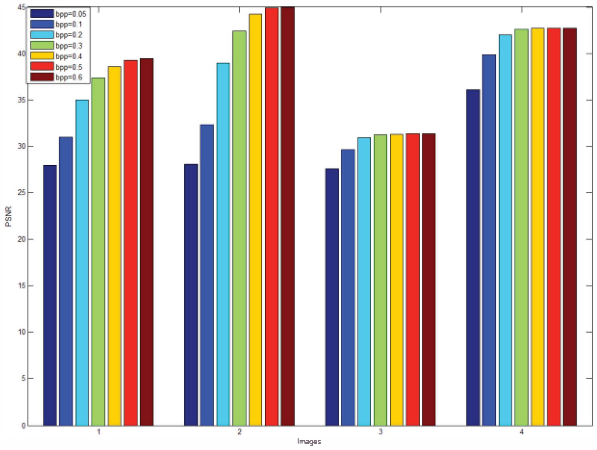


Fig. 5. Performance analysis fuzzy SR reconstruction under varying bpp

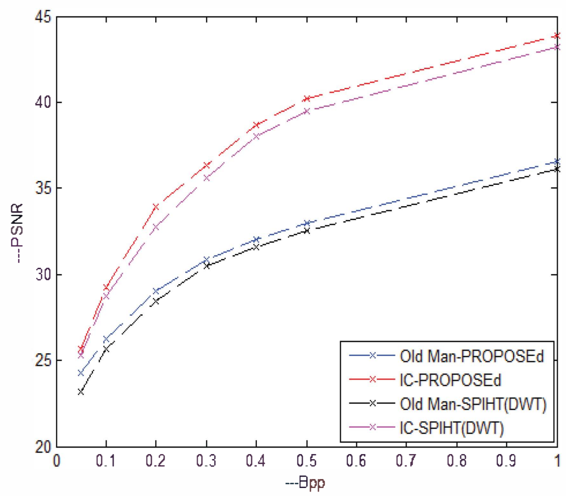


Fig. 6. Evaluation of PSNR w.r.t proposed and conventional SPIHT (DWT) for varying bpp

V. CONCLUSIONS

In this paper an improved SPIHT algorithm and fuzzy based SR image reconstruction is proposed. The method incorporated a new way to overcome the limitation that was prevalent with compression and transmission. The fuzzy based approach is more effective and proves to be likely applicable for multi spectral images. The experiments were conducted both on traditional natural images, synthetic images and also on multi spectral satellite images. In all the cases the method provides compromising results in terms of peak signal to noise ratio and compression ratio even for lower bits per pixel when compared to the conventional methods like DCT KLT and DWT SPIHT. The present method may be improved by using advance transformation approaches like using of contourlets and shearlet transforms.

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