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AN APPROACH FOR EFFICIENT PRE-PROCESSING OF MULTI-TEMPORAL HYPERSPECTRAL SATELLITE IMAGERY

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ABSTRACT

The recent advances of technology helps in accessing any data remotely. The observations of earth surface can also be done remotely with the help of high resolution satellite images. These remotely sensed data are used in various applications like urban monitoring, fire detection, flood prediction, oil spills, disaster monitoring, rock type mapping, road networks, change detection, etc. for continuous monitoring and accurate results, the data which is acquired has to be of high resolution and minimum errors. The multi-temporal satellite data gives the data in periodic basis which helps for continuous monitoring, but due to the earth's rotation, climatic changes, sensor characteristics, etc. there are too many distortions and noises which has to be removed before further processing for getting better results. Many researchers have put forth different methodologies for removing the different kinds of noises from the satellite data. Each and every methodology helps in removing a specific kind of noise. This paper proposes a method named Cellular Automata based Gaussian Filter for pre-processing of Multi-temporal Hyperspectral Satellite Images which could be used for removing the noises, filtering it and giving an enhanced image which forms as input for image registration. The performance is analyzed using the Peak Signal to Noise Ratio. The results specify that the proposed methodology is better than the traditional Gaussian Filter.

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KEY WORDS

Cellular Automata, Pre-processing, Noise Removal, Gaussian Filter, Hyperspectral Images and Multi-temporal Images.

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INTRODUCTION

The satellite images acquired can vary in resolutions. Based on the resolution in which the data is acquired, they are broadly classified as Spatial Resolution, Spectral Resolution, Radiometric Resolution and Temporal Resolution. The Temporal Resolution satellite data is highly useful in detecting the changes in earth surface, for periodic monitoring of climatic changes, updating the map and predicting the natural disasters.

For these applications to yield best results, the remotely sensed data has to be accurate enough for further processing. But in reality, the data which is sensed remotely suffers from various distortions due to climatic conditions, earth rotation, reflection and refraction. These real time factors which cause the distortions cannot be avoided but the distortions can be removed at the initial stage before further processing. For removing these distortions, there are various traditional methodologies like low pass filter, median filter, high pass filter, etc. The filtering is the basic step which is done in any image processing application for removal of the base noise. Among the various filters available, the Gaussian Filter is commonly used in satellite images for noise removal.

This paper focuses on a pre-processing methodology where cellular automata is used along with the traditional Gaussian Filter and hence the basic white noise, speckle noise and all other reflection and refraction based noises are removed from the multi-temporal hyperspectral satellite images. The paper has been organized into five sections. The Section II presents a description about the earlier research works relevant to the image pre-processing methods. Section III involves the detailed description about the proposed pre-processing methodology for multi-temporal hyperspectral satellite imagery. Section IV presents the performance analysis of the proposed method. The conclusion and future work are discussed in Section V.

RELATED WORK

There are different uses of Cellular Automata (CA), for example, in complex frameworks' demonstrating, dissecting and controlling are: The Games of Life [1], Cell Automata in natural framework and environmental framework [2, 3], organic frameworks [4], cell automata in the activity framework [5], cell automata in machine learning and control [6] what's more, CA in cryptography [7].

Advanced Digital Image Processing assumes an essential part in actuality applications, for example, satellite TV, PC tomography and attractive reverberation imaging. It is additionally utilized in zones of examination and innovation, for example, natural data frameworks and astronomy [8].

CA is utilized as a part of different image processing assignments such as Image Filtering in preferred path over some current channels in denoising process [9, 10, 11], Border Detection in Computerized Images that give limits of pictures [12], CA in edge derivation [13, 14, 15], connected set morphology, thinning and thickening of images [11], Image segmentation which is a necessary pieces of image processing applications like restorative picture examination and photograph editing [16, 12] and in image enhancement on account of its element behavior [17].

Popovici and Popovici [9] proposed cellular automata based channel in which the Von Neumann neighborhood norm is used. On correlation with the Gaussian channel, this strategy performs better image upgrade utilizing CA. Selvapeter and Hordijk proposed uniform cellular automata rules for improving the performance of the filtering process [18]. Rosin used a three state automata for removing the noise [19].

The existing approaches are suitable for a basic 2D image where the noise is only a single type, the noise reduction level varies drastically when the level of distortion increases and also the computational time is higher.

PROPOSED METHODOLOGY

Cellular automaton

The cellular automaton is a model which is related to the computational theory. This is otherwise called as cellular spaces. The automaton is made up of a grid of cells which are finite in number and is usually called as states. Out of the available states, one state is considered to be initial state and the nearby cells are considered to be neighborhood and using some mathematical function the new state or next state is determined. The cellular automaton can be one dimensional, two dimensional or n dimensional.

Generally a two dimensional automaton which is deterministic in nature can be well suited for image processing applications. The CA is represented as a triplet as follows.

$$A = (S, N, \delta) \qquad (1)$$

Here 'S' represents a non-empty set which is called as the state set i.e. it is the set of the initial states and next states.

'N' represents the neighborhood cells or states and

δ is the mathematical function or rule which is the condition for moving from initial state to the next state.

This transition is represented by

$$\delta : S^{\wedge}N \rightarrow S \qquad (2)$$

The neighborhoods are found by using basic available norms. There are two commonly used norms namely Von Neumann neighborhood and Moore Neighborhood. The Von Neumann neighborhood is given by,

$$R^2 \ni x \rightarrow h(x) := |x|_1 = |x_1| + |x_2| \,\varepsilon\, R_+ \qquad (3)$$

Moore Neighborhood is using the norm,

$$R^2 \ni x \rightarrow h(x) := |x| = \max\{|x_1|,|x_2|\} \mathcal{E} R_+ \qquad (4)$$

The cellular automata A can be either symmetric or asymmetric. The symmetricity is known by following the local rule where the final value is a constant using the following equation,

$$\delta(s1, s2, \ldots, sn) = \delta(S\sigma(1), S\sigma(2), \ldots\ldots) \qquad (5)$$

where $s_1, s_2, \ldots., s_n \mathcal{E} S$
$\sigma \mathcal{E} S_N$

where N is the permutation group.

Gaussian filter

Gaussian Filtering is widely used in spatial domain for suppressing the noise but the signal is distorted as well at the same time. Gaussian Filters are widely used in computer vision applications too. There are various forms of Gaussian Filter which are as given below.
The initial variety of filter which was designed for noise suppression was 1D Gaussian filter which is given by,

$$G(x) = \frac{1}{\sqrt{2\Pi\sigma}} \exp\left(-\frac{x^2}{2\sigma^2}\right) \qquad (6)$$

where σ is the standard deviation.

The standard deviation is usually calculated for the normal distribution which is always assumed to have the mean as 0.

The later filter which was used is a two dimensional filter which is given by,

$$G(x) = \frac{1}{\sqrt{2\Pi\sigma}} \exp(-(x^2 + y^2)/2\sigma^2) \qquad (7)$$

Where σ^2 represents the variance
x and y are the co-ordinates.

The 2D Gaussian functions are to be used for working with images. This is just the product of the basic 1D Gaussian function. Here the mean is considered to be (0, 0) and the standard deviation is calculated based on the normal distribution similar to the 1D filter.

Cellular automata based Gaussian filtering

The digital image is taken as the input and it can be assumed as a two dimensional array with m*n pixels. Since the image is a satellite image, the pixel can vary in the color. Hence the satellite image input can be considered as another triplet similar to that of the cellular automaton as,

$$(x, y, I) \qquad (8)$$

where x and y are the pixel co-ordinates of the digital image.
I forms the color intensity of the corresponding pixel.

Now, since the image is represented as a triplet, it can be considered as a state in the cellular space of the array m*n. The non-empty set S is modeled as {#, 0, 1, …., I-1}
and the color of the pixel is represented by the states

{0,1,…,I-1}

where I=2 for a monochromatic image
I=16 for an image with 16 colors.
I= 256 for an image with 256 colors.

The Von Neumann norm is used as the neighborhood function in the method. Now, let (x_1, y_1, I_1) be considered as the pixel value and hence the nearby pixels will be (x_2, y_2, I_2), (x_3, y_3, I_3), …, (x_n, y_n, I_n). The transition function δ is given by,

$$P^N \rightarrow P \qquad (9)$$

where P is the set of pixels.

THE IIOAB JOURNAL ISSN: 0976-3104

After the noise is reduced using the cellular automata, Gaussian filter is performed using the weighted probability density function using,

$$W_{i,j} = \frac{1}{2\pi\sigma^2} exp\left\{\frac{-(i^2+j^2)}{2\sigma^2}\right\} \qquad (10)$$

where σ^2 is the variance and is considered to be greater than or equal to 1.
i and j are the pixels of the image.

The algorithm for the pre-processing of the multi-temporal hyperspectral satellite image set is given in the algorithm below.

Algorithm Cellular Automata Based Gaussian Filter

Procedure CANoiseGaussianFilter
    For a set of N multi-temporal images of B bands each
        For each image I in the set
            For each band B_0 to B_B
                Take the pixels at I(x,y) co-ordinate with I intensity.
                Identify the neighborhood of I(x,y) with I intensity using Von-Neumann Neighborhood Norm.
                Calculate the mean and use the transition function to create a new state N(x,y)
            end for
        Update the image band as per the new N(x,y)
        end for
        Update the image in the set.
    end for
    For set of updated N multi-temporal images of B bands each
        For each image I in the set
            For each band B0 to BB
                Smoothen using the weighted Gaussian filter as per the equation 10
            end for
        end for
    end for
end procedure

RESULTS

The algorithm is implemented and tested with a multi-temporal hyperspectral satellite image set having nine images of a same place taken on different dates which are of 27 bands. The original nine satellite images are given in the **Figure– 1**.

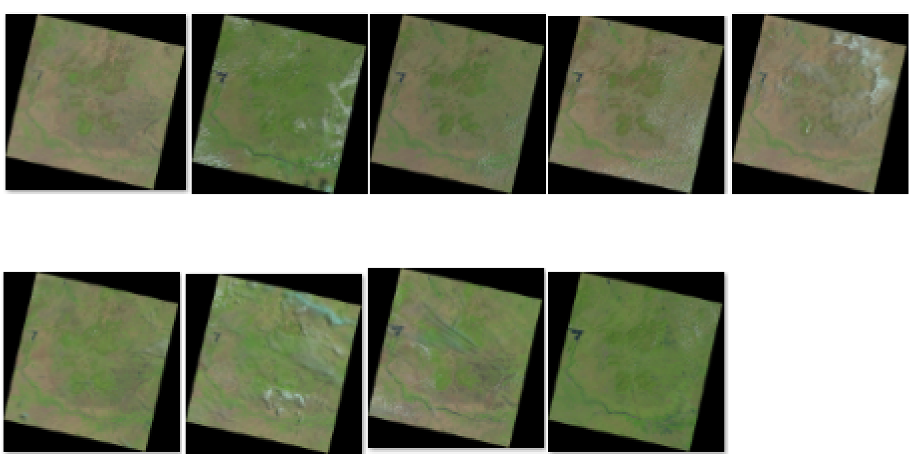

Fig: 1. Multi-temporal hyper-spectral satellite images

These input images are pre-processed with the algorithm and the resulting images with respect to each band of a single image is shown in the **Figure– 2**.

THE IIOAB JOURNAL
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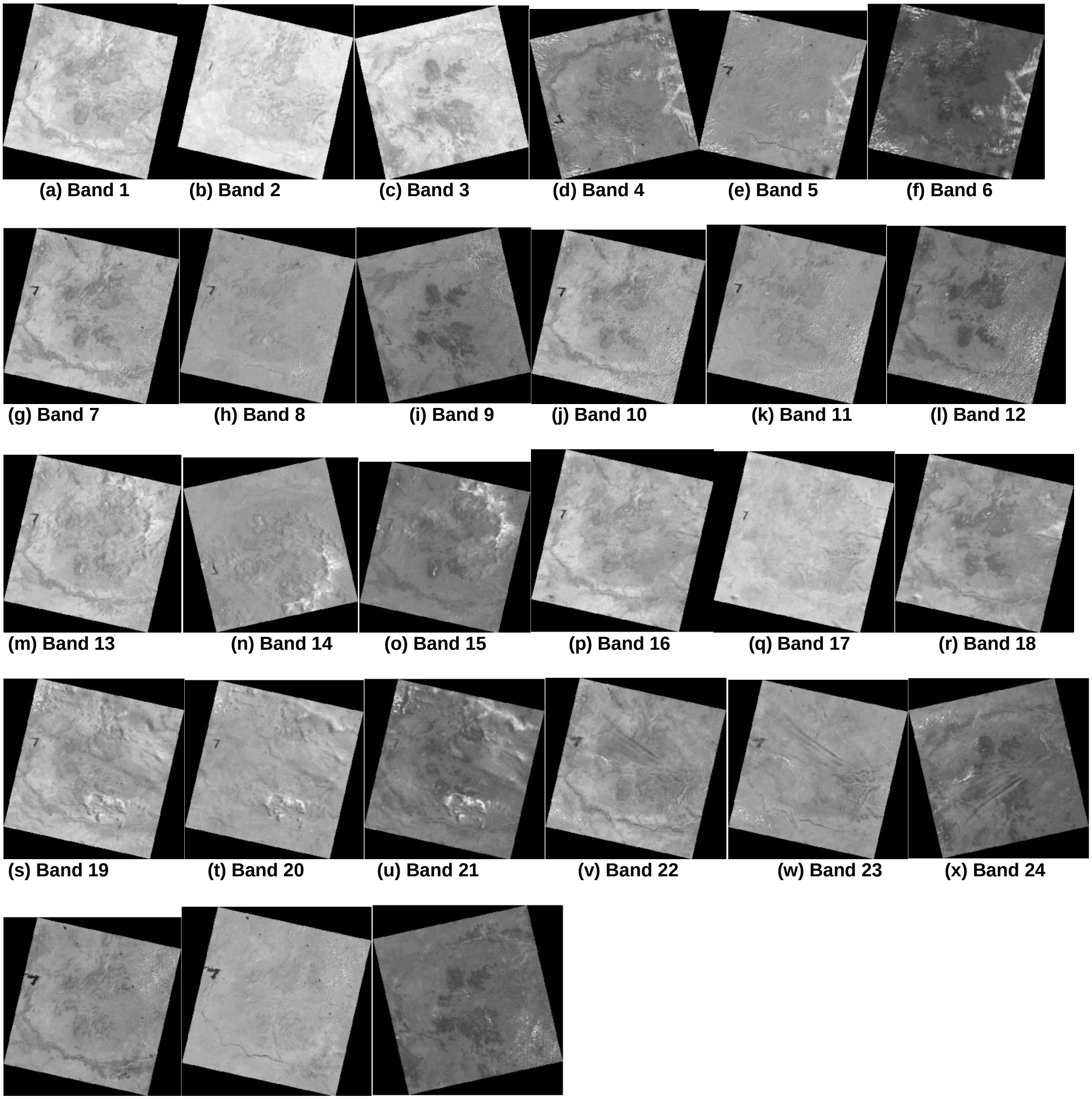

(a) Band 1 (b) Band 2 (c) Band 3 (d) Band 4 (e) Band 5 (f) Band 6
(g) Band 7 (h) Band 8 (i) Band 9 (j) Band 10 (k) Band 11 (l) Band 12
(m) Band 13 (n) Band 14 (o) Band 15 (p) Band 16 (q) Band 17 (r) Band 18
(s) Band 19 (t) Band 20 (u) Band 21 (v) Band 22 (w) Band 23 (x) Band 24
(y) Band 25 (z) Band 26 (a1) Band 27

Fig: 2. Filtered images

Similarly all the other images in the set are also pre-processed. The Peak Signal to Noise Ratio (PSNR) values and Mean Square Error (MSE) obtained for each band of the hyperspectral satellite image is tabulated in the Table–1 and 2 respectively and the results are compared with the existing Gaussian Filter Method.

THE IIOAB JOURNAL
ISSN: 0976-3104

Table:1 PSNR values Vs band number of the image

Band No.	PSNR (%)	
	Proposed CA Based Gaussian Filter	Existing Gaussian Filter
1	38.8034	34.0132
2	39.1606	34.0132
3	38.9423	34.0132
4	30.7844	27.2317
5	30.8598	27.3217
6	30.7343	27.0132
7	33.0398	31.73
8	33.2244	31.82
9	33.1554	31.79
10	27.9696	21.8723
11	28.0001	21.9231
12	27.9378	21.8723
13	35.076	34.0132
14	35.2707	34.0132
15	35.2117	34.0132
16	37.6825	34.0132
17	37.9293	34.0132
18	37.7219	34.0132
19	36.0227	34.0132
20	36.0969	34.0132
21	35.7978	34.0132
22	33.7271	33.5211
23	33.8309	33.5217
24	33.661	33.4217
25	33.3715	32.0122
26	33.4710	32.1576
27	33.5596	32.9717

Table: 2. Band Number of the Image Vs Mean Square Error (MSE) for the Proposed Method

Band No.	Mean Square Error (MSE)	
	Proposed CA Based Gaussian Filter	Existing Gaussian Filter
1	28.6496	32.5432
2	7.8278	10.1234
3	8.2957	9.1234
4	54.2802	56.2309
5	53.3454	57.3456
6	54.9098	58.9876
7	32.2927	37.8767
8	30.9485	32.1234
9	31.4439	35.4312
10	103.7807	107.1234
11	103.0563	106.0123
12	104.5438	108.1234
13	20.206	22.2134
14	19.3204	22.7654
15	19.5844	19.9678

THE IIOAB JOURNAL
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16	11.0874	13.4234
17	10.4748	12.234
18	10.9873	12.12
19	16.2483	17.154
20	15.9731	16.102
21	17.1118	17.789
22	27.566	28.987
23	26.9149	32.345
24	27.9886	34.1534
25	29.9178	36.6545
26	28.1126	38.7912
27	28.6496	41.3456

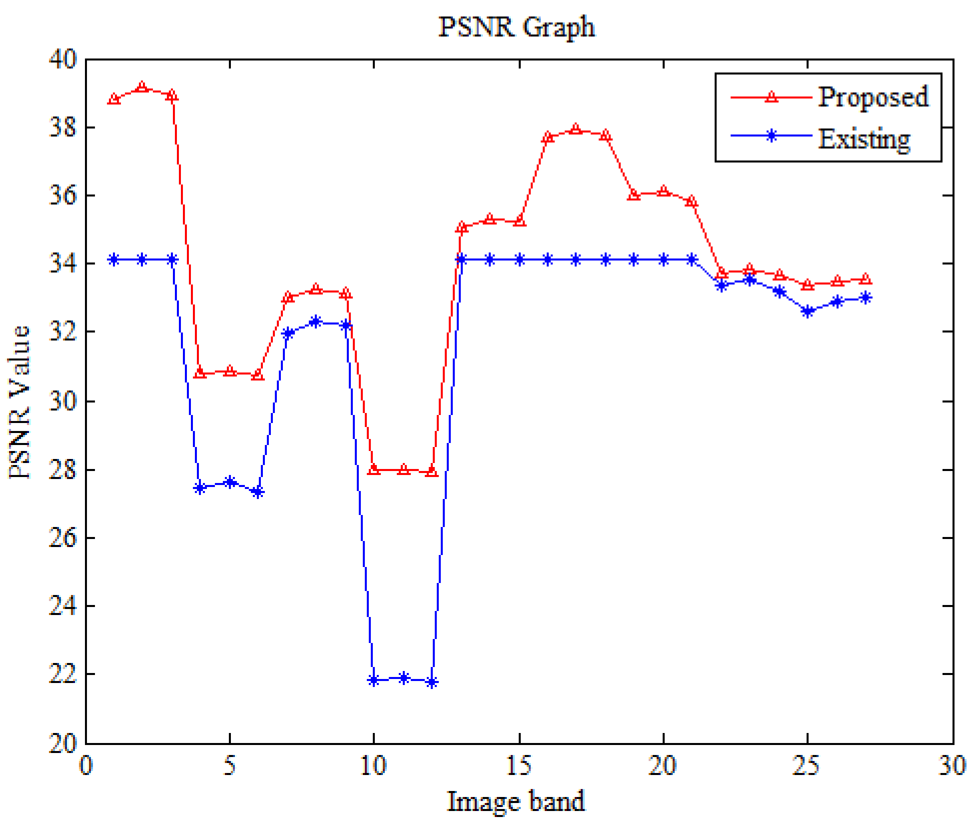

Fig: 3. Image band vs. PSNR value (%)

The performance analysis graph for the proposed cellular automata based Gaussian filter and the existing Gaussian filter is shown in the **Figure– 3**. The performance graph clearly shows that the proposed method gives a better PSNR value compared to the existing method.

The performance analysis graph comparing the MSE values for the proposed cellular automata based Gaussian filter and the existing Gaussian filter is shown in the **Figure–4**. The graph shows that the error rate is reduced than the existing method and the error rate is reduced further when the number of bands increases in the hyperspectral images.

ISSN: 0976-3104

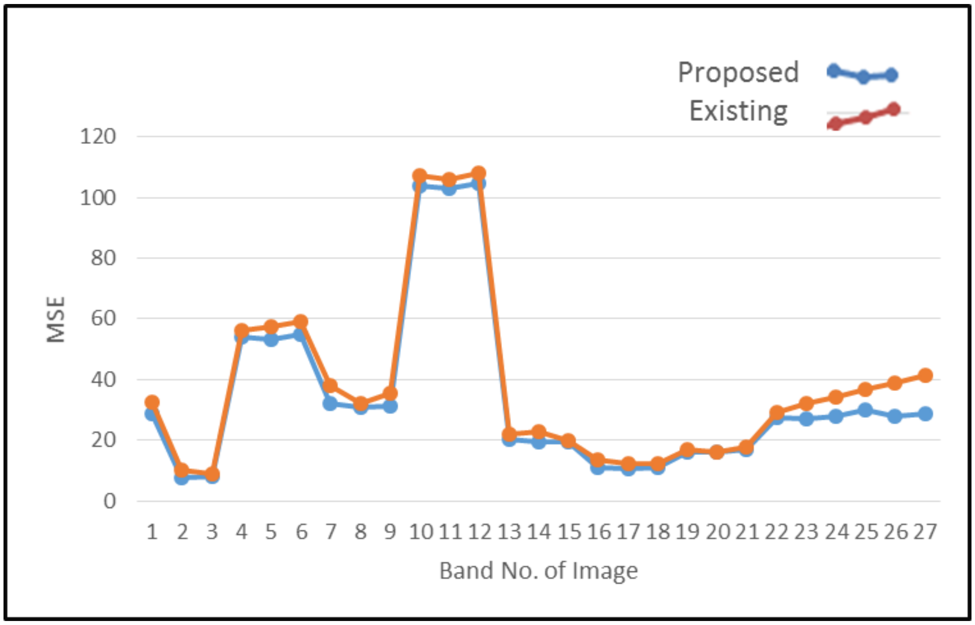

Fig: 4. Image band vs. MSE value

CONCLUSION AND FUTURE WORK

This paper proposes a cellular automation based Gaussian filter for pre-processing of multi-temporal hyperspectral satellite images. This algorithm initially removes the salt and pepper noise, noise caused due to the reflection and refraction, white noise and the speckle noise at the cellular automaton level. Further the Gaussian Filter function smoothens by the linear kernel using the normal distribution where the other random noises are suppressed still further. The performance analysis also clearly shows that the proposed methodology removes the noise at a better level which is proved by the increased PSNR value at each band. The future work is to remove the noises caused due to cloud cover and mask, generally any distortions due to haze which is not focused in this work.

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CONFLICT OF INTEREST
No conflict of interest

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THE IIOAB JOURNAL
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