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Image enhancement and performance evaluation using various filters for IRS-P6 Satellite Liss IV remotely sensed data

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This paper presents fast and effective filtering techniques for image enhancement from remote sensing Indian remote sensing satellite P6 Liss IV remotely sensed data like Near-Infrared band. There are four filtering techniques used for image enhancement based on spatial domain filters and frequency domain filters such as median filter, wiener filter, bilateral filter and Gaussian homomorphic filter and selected noises salt and pepper and Gaussian noise used with filter. Selected images tested with each filter and based on *PSNR* performance metric value and best filtering technique identified from these filters. Finally, Gaussian homomorphic filtering technique is suitable for image enhancement of the Liss IV remotely sensed Near-Infrared band. Image enhancement technique is pre-processing for future work such as edge detection and image segmentation.

Keywords: enhancement, median filter, wiener filter, bilateral filter, gaussian homomorphic filter, Liss IV data

1. Introduction

Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object and thus in contrast to on site observation (Campbell, 2002). Remote sensing is a tool or technique similar to mathematics using sensors to measure the amount of electromagnetic radiation exiting an object or geographic area from a distance and the extracting valuable information from the data using mathematically and statistically based algorithms is a scientific activity (Jensen, 1996). Remote sensing scenes are based on digital image. That a remote sensing scene is not an image it is a spatial distribution of spectral reflectance. Earth surface information is hiding within remote sensing digital images and it may be varying from different types of

satellite sensors. These images utilized for different purposes and noise is an unwanted component of the image. Noise occurs in images for many reasons. Gaussian noise is a part of almost any signal. For example, the familiar white noise on a weak television station is well modelled as Gaussian (Bovik, 2009).

2. Materials and methods

2.1. Data selection

Data or satellite image selection is very important role in remote sensing system. This system consists of different types of spectral bands and resolution. First, which features we should extract from remote sensing images. In this paper, we used the Liss IV data for feature extraction and this data like Linear Imaging and Self Scanning Sensor from Indian Remote Sensing Satellite P6 version. The LISS IV bands are (Fig. 1a) Green band with spectral resolution 0.52–0.59 μm , (Fig. 1b) Red band with spectral resolution 0.62–0.68 μm and (Fig. 1c) Near Infrared band with spectral resolution 0.76–0.86 μm and image scale is 1:50 000 approximately 5.8m spatial resolution per digital number.

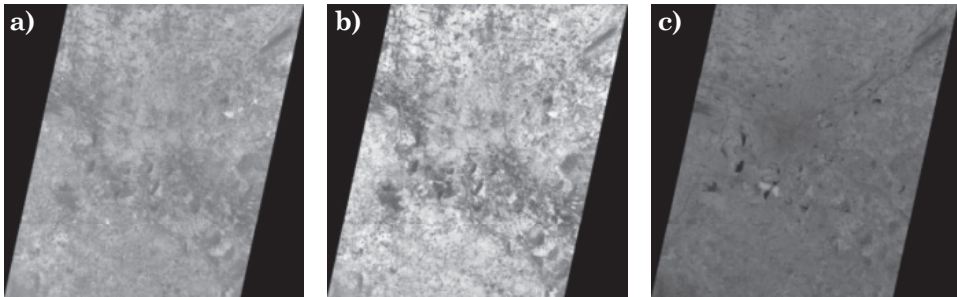


Figure 1. Original IRS P6 Satellite Liss IV Data.

2.2. Study area

In this paper proposed study areas is geographically located at the Madurai district, Tamilnadu, India. This Liss IV data coverage area is 23.5 km \times 23.5 km with 5.8 m spatial resolution. In this paper related with road extraction from remotely sensed data in future work. Road feature spectral information is highly reflected in Near Infrared band. Therefore, this single band only used for research purpose likes image enhancement and road shape segmentation. Some of the selected areas cropped from near infrared band and every cropped image having 256 \times 256 pixels and it may be total coverage on earth surface 1 280 square kilometres. These are the input images (Figs. 2a, b) for image

enhancement. Already these Liss IV Near-Infrared band geometrically corrected, but applies necessary enhancement technique for noise removal. It will improve the image contrast and appearance of an image.

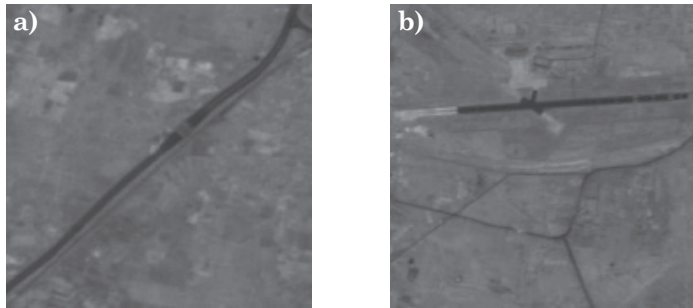


Figure 2. Input images cropped from original data.

In this paper some of the enhancement techniques were considered: median filter, wiener filter, bilateral filter and Gaussian homomorphic filter. An Input images applied in each filter and best performance and suitable filters identified by *PSNR (Peak Signal Noise Ratio)* value.

2.3. Median filter

Median filter in an image processing is often desirable to perform some kind of noise reduction on a digital image. This filter is a nonlinear digital technique and it is used to remove the noise from digital image (Huang et al., 1979; Kumar et al., 2014). The median filter is to run through the image entry by entry and replacing each entry with the median of neighbouring entries. The pattern of the neighbouring pixels like matrix is called the window, which slide entry by entry and move along the entire image (Arce, 2005; Arias-Castro and Donoho, 2009). Median filter is a nonlinear operation such used in a digital image processing to reduce the salt and pepper noise. Median Filter is termed as a nonlinear digital filtering technique and it is used to remove salt and pepper noise. It is often used in image processing because it preserves edges under some conditions while removing the noise. In median filtering, the neighbouring pixels are ranked according to intensity (brightness) and the median value becomes the new value for the central pixel. Median filters don't provide reduction in contrast across steps. It does not shift boundaries but it can happen with conventional smoothing filters. Since the median in median filters is less sensitive than the mean to extreme values, those extreme values are more effectively removed and the median is a more robust as it is not affected by extreme values. Since the output pixel value

is one of the neighbouring values, new unrealistic values are not created near edges.

Median filters smooth the images and it can preserve discontinuities in a step function. It can smooth a few pixels whose values differ significantly from their surroundings without affecting the other pixels. Median filtering performs on the matrix in two dimensions. Every result pixel contains the median value in the neighbourhood pixels around the corresponding pixel in the input image (Lim, 1990). The median filter is much better of preserving sharp edges than the mean filter (Davies, 2004; Marion & Polley, 1991). Where median filtering really comes into its own is when the noise produces extreme outlier pixel values, as for instance in which has been corrupted with salt and pepper noise (Vernon, 1992). The median filter image enhancement result shown in (Figs. 3a, b).

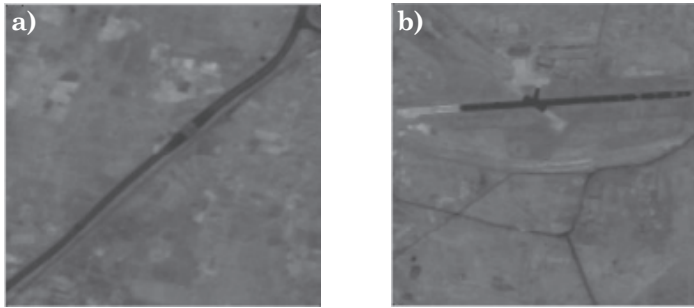


Figure 3. Median filter based image enhancement.

2.4. Wiener filter

The wiener filter is a filter used to produce an estimate of desired or target random process by linear time-variant filtering an observed noisy process, assuming known stationary image and noise spectra and additive noise (Grover and Hwang, 1992). The inverse filtering is a restoration technique for deconvolution, when a known low pass filter blurs the image; it is possible to recover the image by inverse filtering or generalized inverse filtering. However, an inverse filtering is very sensitive to additive noise. This filter is optimal in terms of the mean square error. It reduces the overall mean square error in the process at inverse filtering and noise smoothing. This filters the input image using pixel wise adaptive wiener filtering, using neighbourhoods of size of matrix to estimate the local image mean and standard deviation. The size of matrix is default to three. Assumed additive noise is the Gaussian white noise power. Wiener filter require more computation time then linear filtering (Tomasi and Manduchi, 1998). This filter works best when the noise is constant power additive noise. It has called as Gaussian noise. This wiener filter estimates the local mean and variance around each pixel.

$$\mu = \frac{1}{NM} \sum_{n_1, n_2 \in \eta} a(n_1, n_2) \quad (1)$$

$$\sigma^2 = \frac{1}{NM} \sum_{n_1, n_2 \in \eta} a^2(n_1, n_2) - \mu^2 \quad (2)$$

where η is N-by-M local neighborhood pixel. Wiener 2 dimensional filter creates a pixel wise wiener filter using these estimates

$$b(n_1, n_2) = \mu + \frac{\sigma^2 - \nu^2}{\sigma^2} (a(n_1, n_2) - \mu) \quad (3)$$

where ν^2 is the noise variance. If the noise variance is not given, two-dimensional uses the average of all local estimates (Tomasi and Manduchi, 1998). The wiener filter image enhancement result shown in (Figs. 4a, b).

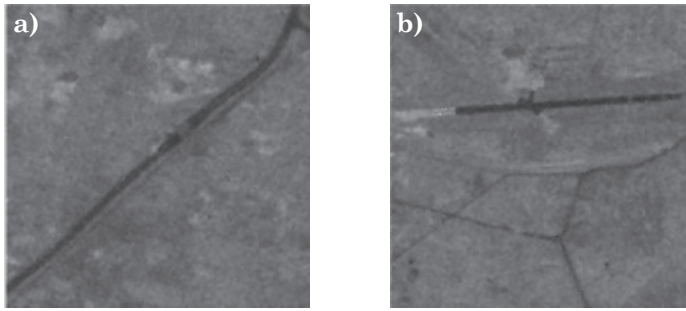


Figure 4. Wiener filter based image enhancement.

2.5. Bilateral filter

Bilateral filtering technique is smoothing an image while preserving edges, by means of a nonlinear arrangement of nearby image value. The method is non-iterative, local and simple. However, a gray scale image only used for bilateral filter. A bilateral filter can enforce the perceptual metric underlying the space, and preserve edges in a way that is human perception (Williams and Madisetti, 1997). The bilateral defined as

$$I^{filtered}(x) = \frac{1}{W_p} \sum_{x_i \in \Omega} I(x_i) f_r(\|I(x_i) - I(x)\|) g_s(\|x_i - x\|), \quad (4)$$

where the normalization term

$$W_p = \sum_{x_i \in \Omega} f_r(\|I(x_i) - I(x)\|) g_s(\|x_i - x\|). \quad (5)$$

The filter preserves images energy and, $I^{filtered}$ is the filtered image, I is the original input image to be filtered, x are the coordinates of the current pixel to be filtered, Ω is the window centred in x , f_r is the range kernel for smoothing differences in intensities. This function can be Gaussian function, g_s is the spatial kernel for smoothing differences in coordinates. Both can be Gaussian function. W_p is assigned using the spatial closeness and the intensity difference. Consider a pixel located at (i, j) which needs to be denoised in image using its neighbouring pixels is located at (k, l) , the weight assigned for pixel (k, l) to denoise the pixel (i, j) is given by (Tomasi and Manduchi, 1998):

$$w(i, j, k, l) = e^{\left(\frac{(i-k)^2 + (j-l)^2}{2\sigma_d^2} - \frac{\|I(i, j) - I(k, l)\|}{2\sigma_r^2} \right)} \quad (6)$$

Where σ_d and σ_r are smoothing parameters and $I(i, j)$ and (k, l) are the intensity of pixels (i, j) and (k, l) respectively. Then calculate the weights and normalize them

$$I_D(i, j) = \frac{\sum_{k, l} I(k, l) w(i, j, k, l)}{\sum_{k, l} w(i, j, k, l)} \quad (7)$$

Where I_D is the denoised intensity of pixel (i, j) . As parameter, σ_r increases the bilateral filter approaches Gaussian convolution more closely because the range Gaussian widens and flattens, which means that it becomes almost constant over the intensity period of the image. On increasing the spatial parameter σ_d , the generously proportioned features get smoothed in (Tomasi and Manduchi, 1998). The bilateral filter image enhancement result shown in (Fig. 5a, b).

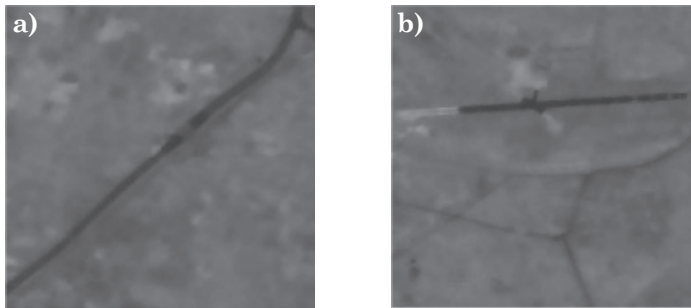


Figure 5. Bilateral filter based image enhancement.

2.6. Gaussian homomorphic filter

Homomorphic filtering is one of the image enhancement techniques based on frequency domain. This is a generalized technique for image processing and signed processing, involving a nonlinear mapping to a various domain in which linear filter techniques are applied, followed by mapping return to the original domain. Homomorphic filter is simultaneously normalizing the brightness an image and increase contrast. Here homomorphic filter is used to remove the Gaussian noise.

Gaussian noise

Gaussian noise is statistical noise having a probability density function equal to that of the normal distribution, which is also known as the Gaussian distribution (Barbu, 2013), (Arias-Castro and Donoho, 2009). Principal sources of Gaussian noise in digital images arise during acquisition. For example, these sensor noises are caused by poor illumination. In digital image processing system, the Gaussian noise can be reduced using a spatial filter and frequency filter (Barbu, 2013). The noise can take Gaussian distributed values. The probability density function name p of a Gaussian random variable z is given by

$$p_G(Z) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(z-\mu)^2}{2\sigma^2}} \tag{8}$$

Where z in a gray level, α the mean value and σ is the standard deviation. This Gaussian noise applied in homomorphic filtering technique. In homomorphic filtering illumination and reflectance are made additive by taking the logarithm of the image intensity. Therefore, these components of the image can be separated linearly in the frequency domain. The high frequency components are increased and low frequency components assumed to represent mostly the reflectance in image, the low frequency components assumed to represent mostly the illumination in an image (Williams and Madisetti, 1997). In frequency domain, the homomorphic filtering process looks like in Figure 6.

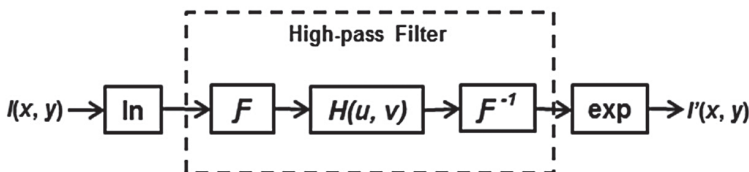


Figure 6. Homomorphic filter process.

First, we have to construct a frequency-domain high-pass filter. A simple Gaussian high-pass filter directly given into the frequency domain. In frequency domain filtering, we have to be careful about the wrap-around error, which comes from the fact that Discrete Fourier Transform, treats a finite-length signal as an infinite-length periodic signal where the original finite-length signal represents one period of the signal. Therefore, there is interference from the non-zero parts of the adjacent copies of the signal. To avoid this, we will pad the image with zeros. The size of the filter (M, N) even numbers to speed-up the FFT computation. A standard deviation for the Gaussian, which determines the bandwidth of low-frequency band that will be filtered out. Then, high-pass filters the log-transformed image in the frequency domain. First, compute the FFT of the log-transformed image with zero-padding using the `fft2` syntax that allows us to simply pass in size of the padded image. Then we apply the high-pass filter and compute the inverse-FFT. Finally, we can crop the image back to the original unpadded size. The final step is to apply the exponential function to invert the log-transform and get the Gaussian based Homomorphic filtered image and enhancement result shown in Figure 7(a-b).

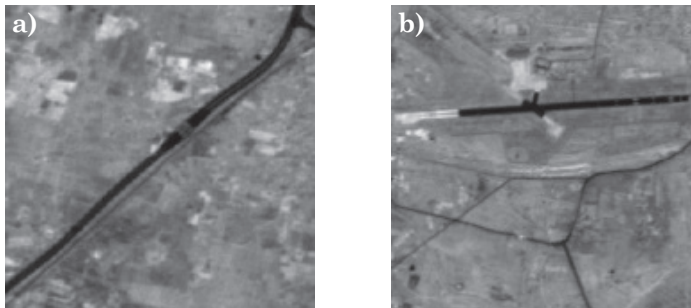


Figure 7. Gaussian homomorphic filter based image enhancement.

2.7. Peak signal to noise ratio

The *PSNR* block computes the peak signal-to-noise ratio, in noise, between two images between original image and enhancement image (Kaur & Singh, 2014). The higher *PSNR* gives the better the quality of an enhanced image. The Mean Square Error (*PSNR*) and the Peak Signal to Noise Ratio (*PSNR*) are the two error metrics used to compare image-enhancement quality. The *PSNR* represents the cumulative squared error between an enhancement image (I_2) and the original image (I_1), whereas *PSNR* represents a measure of the peak error. To compute the *PSNR*, the block first calculates the mean-squared error using the following equation:

$$MSE = \frac{\sum_{M,N} [I_1(m,n) - I_2(m,n)]^2}{MN} \quad (9)$$

In the previous equation, M and N are the number of rows and columns in the input images, respectively. Then the block computes the $PSNR$ using the following equation:

$$PSNR = 10 \log_{10} \left(\frac{R^2}{MSE} \right) \quad (10)$$

In the previous equation, R is the maximum fluctuation in the input image data type. For example, if the input image has a double-precision floating-point data type, then R is 1. If it has an 8-bit unsigned integer data type, R is 255. It means maximum possible gray level values in the image.

Table 1. Performance evaluation results for various filters.

Input image	Median filter		Wiener filter		Bilateral filter		Gaussian homomorphic filter	
	<i>MSE</i>	<i>PSNR</i>	<i>MSE</i>	<i>PSNR</i>	<i>MSE</i>	<i>PSNR</i>	<i>MSE</i>	<i>PSNR</i>
Figure 2a	1.0838	47.7812	12.5061	37.1596	8.4541	30.7293	0.1242	57.1912
Figure 2b	3.5279	42.6556	14.1878	36.6117	9.0868	30.4159	0.1244	57.1811
Average	2.3058	45.2184	13.3469	36.8856	8.7704	30.5726	0.1243	57.1861

3. Results

In this paper, Performance evaluation of different filters is done by two parameters. They are $PSNR$ and $PSNR$. Higher in $PSNR$ Values show that the particular filter is performing well. From the results shown in Table 1, it is observed that $PSNR$ values for Gaussian Homomorphic Filter is high when compare to other filters. On an average, it produces a $PSNR$ value of 57.1861 db. Similarly, the same filter produces low $PSNR$ values when compare to other filters. On an average, it produces a $PSNR$ value of 0.1243. On the other hand, Median filter also produces high $PSNR$ values next to Gaussian Homomorphic Filter. On an average, it produces a $PSNR$ value of 45.2184db and it produces a $PSNR$ value of 2.3058. So overall, Gaussian Homomorphic Filter is superior to other filters.

4. Conclusion

This work presents an investigation on the analysis of remote sensing Liss IV near-infrared band. We studied how the use of Liss IV data may improve the quality of image. We have shown results using actual as well as cropped remote sensing Liss IV near-infrared band. We found that a filtering strategy based on spatial domain tool and frequency domain tool allows the enhancement of near-infrared band. Based on input images and filtering technique best performance result given by the Gaussian Homomorphic filter. A very important task for the future is the development of smarter and more detailed enhancement schemes for remote sensing IRS P6 Liss IV near-infrared band list.

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SAŽETAK

**Poboljšanje slike i vrednovanje radnih značajki
korištenjem raznih filtera na daljinski mjerene podatke
IRS-P6 satelita Liss IV**

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U radu su prikazane brze i učinkovite tehnike filtriranja za poboljšanje slike iz podataka u bliskom infracrvenom području dobivenih indijskim satelitom za daljinska istraživanja P6 Liss IV. Korištene su četiri tehnike filtriranja temeljene na filtrima u prostornoj i frekvencijskoj domeni kao što su: medijan filter, Wiener filter, bilateralni filter i gaussovski homomorfni filter uz odabrane šumove “*salt and pepper*” i gaussovski šum s filtrom. Odabrane slike testirane su sa svakim od filtera te je na temelju metričke vrijednosti *PSNR (Peak Signal Noise Ratio)* radne značajke prepoznata najbolja tehnika filtriranja. Konačno se pokazalo da je gaussovska homomorfna tehnika filtriranja prikladna za poboljšanje slika dobivenih pomoću satelita Liss IV u bliskom infracrvenom području. Tehnika poboljšanja slike je predobrada za budući rad, kao što je detekcija ruba i segmentacija slike.

Ključne riječi: poboljšanje, medijan filter, Wienerov filter, bilateralni filter, gaussovski homomorfni filter, podaci Liss IV satelita

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