

INVESTIGATION OF RESAMPLING EFFECTS ON IRS-1D PAN DATA

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ABSTRACT:

Image resampling is frequently employed in geometric correction as a part of preprocessing of a remotely sensed image. The resampled images will have a noticeable change in image quality, which may have an adverse impact on the accuracy of subsequent image analysis for information extraction. Information of edges is very important, especially in high spatial resolution imagery. The present study has investigated the effects of resampling on edge information for Indian remote sensing (IRS)-1D panchromatic (PAN) imagery with 5.8 m spatial resolution. Raw PAN images have been resampled during shift resampling and geometric rectification processes by using bilinear, cubic B-Spline and cubic convolution resampling methods. The cubic convolution was implemented with three different parameter values of a as -1.0, -0.75 and -0.5. The resampled images were then used to identify edges. It has been observed from the statistical properties and by using edge detected images that the cubic convolution method of resampling with a as -0.75 value is the most suitable resampling approach for IRS-1D PAN imagery, especially for detecting edges.

1. INTRODUCTION

Resampling also known as intensity interpolation applied for a digital image in various geometric transformation processes such as scaling, rotation, shearing, warping etc. Conceptually, image resampling comprises of two stages: image reconstruction followed by sampling. Although resampling takes its name from the sampling stage, image reconstruction is the implicit component in this procedure (Wolberg, 1990). For remotely sensed (RS) satellite data, resampling is necessary, when images are to be geometrically corrected or registered into a different coordinate system defined by a map, another image or spatially referenced data set (Roy and Dikshit, 1994). When an image is subjected to resampling, there is often a noticeable change in image quality. This in turn may have an adverse impact on the accuracy of subsequent human and machine assisted image analysis for information extraction such as classification (Devereux *et al.*, 1989), texture (Roy and Dikshit, 1994) and sharp image details or edges. In relation to resampling studies, considerable work has been done by the earlier researchers. But, limited number of studies was concentrated about the effects on RS imagery. The effects of resampling have to be studied during various image-processing operations such as classification, principal component analysis, edge detection etc.

Same resampling method may give dissimilar results for separate sensor data. This is due to the fact that performance of resampling function depends on the spatial structure of pixels and the viewing geometry. But, nothing has been reported on the effects of resampling for Indian remote sensing (IRS) satellite data. One of the best spatial data available to user community from IRS satellites is PAN data with 5.8 m spatial resolution and 6-bit quantization (NRSA, 1997). From PAN data, we can extract majority of edge features such as road network, fly-overs etc, which make up to 70% features that are available in 1:25,000 maps (Katiyar S. K., 2001). Hence, this study presents the investigated effects of resampling for IRS sensors, especially the high spatial resolution PAN sensor.

2. DATA AND TOOLS USED

The study has been conducted for three study sites consisting of rapidly changing Indian urban environments, which were located in Kanpur, Lucknow and Bhopal. The Level 1 data was acquired from National remote sensing agency (NRSA), Hyderabad, which is corrected only for radiometric errors. It is not corrected geometrically, which means it has not undergone resampling. For this reason, Level 1 data of IRS-1D, PAN sensor being used to achieve the objectives of present study. From every image a test site of size 512x512 pixels have been extracted. These test sites have been selected so that they contain major land cover features such as water bodies, urban, rural regions, vegetation, farm lands etc., and prominent edge features like roads, canals, streams etc. These test sites are shown in Figure 1 and details are given in table 1.

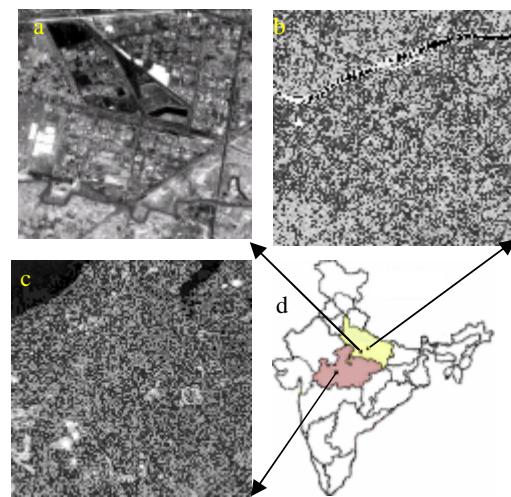


Figure 1: Test images showing (a) Kanpur, (b) Lucknow, (c) Bhopal, and (d) their location in Indian map.

| City | Date | Row | Path | Sub scene |
|---------|------------|-----|------|-----------|
| Bhopal | 24-03-2001 | 55 | 97 | D8 |
| Kanpur | 22-04-2002 | 53 | 99 | B5 |
| Lucknow | 15-03-2001 | 53 | 100 | A3 |

Table 1: Details of IRS-1D, PAN data

Resampling for two study cases were implemented in Matlab 6.5 commercial software. The process of Geometric correction was validated with the corresponding module present in ILWIS 3.0 software. GPS survey was carried out using hand held GPS (GS5) and differential GPS (SR530) from Leica Geosystems.

3. METHODOLOGY

Resampling process deals with image pixel values only. That means only radiometric modifications are expected due to resampling. Geometric rectification process modifies an image both geometrically and radiometrically. Therefore, investigation for resampling effects cannot be justified by only analyzing the geometrically rectified images. For this reason, resampling of images is also performed by shifting an image in both directional axes. The same has been called as the Shift resampling and used in present study. Hence, two experiment cases are shift-resampling (SR) and geometric rectification (GR). The methodology implemented is represented in the following flowchart.

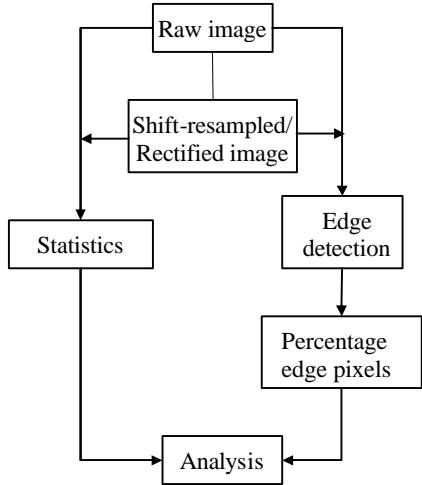


Figure 2: Methodology flowchart

In shift-resampling case, shifting value is referred in terms of pixel units. A shift of 0.5 pixel values on both the directions (x and y) was used, since this value gives the maximum reconstruction error (Shlien, 1979). This shift has been adapted for analyzing the change of pixel values due to resampling alone. While geometric rectification was done using precise Ground Control Point (GCP) coordinates. These GCPs were collected during an extensive Global Positioning System (GPS) survey work conducted in all the three cities and were used for geometric rectification of images using affine transformation (Wolberg, 1990).

$$\begin{aligned} u &= a_{11}x + a_{21}y + a_{31} \\ v &= a_{21}x + a_{22}y + a_{32} \end{aligned} \quad (1)$$

Where, u, v refers to output coordinates corresponding to input pixel coordinates x, y . The coefficients of transformation

matrix $a_{11}, a_{12}, a_{21}, a_{22}$ specify a linear transformation for scaling, shearing, and rotation, while a_{31}, a_{32} produces translation.

Interpolation or resampling is a common process of filling in unknown values (output) in a sequence by examining the known values (input). One-dimensional interpolation is illustrated in Figure 3(Wolberg, 1990), where the interpolating function $h(x)$ is centered at x , which is the location of point to be interpolated. The value at that point x is equal to the sum of the values of the discrete input scaled by the corresponding values of the interpolating function.

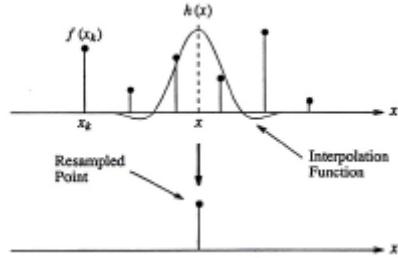


Figure 3. Interpolation of single point

In both the cases, three resampling methods were used viz, Bilinear (BL), B-Spline (BS) and Cubic Convolution (CC). Implementation of CC was done along with three different values of parameter a as -1.0, -0.75 and -0.5. The algorithms given by Wolberg (Wolberg, 1990) are being adopted in the study. They are:

$$h(x) = \begin{cases} 1-|x| & 0 \leq |x| < 1 \\ 0 & 1 \leq |x| \end{cases} \quad (2)$$

$$h(x) = \begin{cases} (a+2)|x|^3 - (a+3)|x|^2 + 1 & 0 \leq |x| < 1 \\ a|x|^3 - 5a|x|^2 + 8a|x| - 4a & 1 \leq |x| < 2 \\ 0 & 2 \leq |x| \end{cases} \quad (3)$$

$$h(x) = \begin{cases} \frac{1}{2}|x|^3 - |x|^2 + \frac{2}{3} & 0 \leq |x| < 1 \\ -\frac{1}{6}|x|^3 + |x|^2 - 2|x| + \frac{4}{3} & 1 \leq |x| < 2 \\ 0 & 2 \leq |x| \end{cases} \quad (4)$$

The shift-resampled or geometrically rectified images are used extraction of edges using Canny edge algorithm (Canny, 1986). Detection of edges was done for each raw and resampled image using canny edge detector. Canny assumed that a step edge subject to Gaussian noise and also assumed that, the edge detector as a convolution filter that smoothens the noise and locates the edge using the Gaussian function. The form of Gaussian function is given below

$$G(x) = \frac{1}{s\sqrt{2\pi}} e^{(-\frac{x^2}{2s^2})} \quad (5)$$

Where, s is the (one dimensional) space constant of the Gaussian function, and x is the distance between the point of interest to the middle of the Gaussian function.

The Canny edge detector works in a multi-stage process as given below:

- i) Image is smoothed by Gaussian convolution filter.
- ii) Directional gradients are computed by numerically differentiating the smoothened image to compute the x and y gradients, and compute the resultant gradient or magnitude.
- iii) Non-maximum suppression finds peaks in magnitude-image.
- iv) Thresholding locates prominent edges.

The size of Gaussian smoothing filter is taken as $3w$, where $w = 2\sqrt{2}s$ is the width of the central excitatory region of the filter (Huertas, 1986), hence the size of filter will be proportional to the s value. Gaussian filter was used for smoothening images with a parameter (s) as 2.0. After many trials, it was found that this value was suited best for finding the prominent edges. The same value was used for all experiments of study. Threshold values were obtained by computing auto thresholding value using Trussel method (Trussel, 1979). In Trussel method of thresholding, optimum threshold value is obtained by iteration process. The equation used for iteration process is given in (Eq - 6).

$$T_{k+1} = \frac{\sum_{i=0}^{T_k} i n(i)}{2 \sum_{i=0}^{T_k} n(i)} + \frac{\sum_{i=T_k+1}^N i n(i)}{2 \sum_{i=T_k+1}^N n(i)} \quad (6)$$

Where T_k Threshold at k^{th} iteration
 i Pixel value in magnitude image
 $n(i)$ Frequency of grey level i , $0 \leq i \leq N$
 N Number of pixel values

Further, statistical parameters for all the raw and resampled images were computed for further analysis. While, edge detection extracted the boundaries of prominent features such as roads, water bodies, stadiums, canals etc, were identified as edges in raw images. Then experiment results were analyzed with respect to the raw images. The same results and conclusions are presented in the following sections. In present study. The edge pixel identified by the Canny edge detector was assumed as a true edge pixel. Based on this assumption, the percentage of edge pixels corresponding to raw and resampled images were calculated. This percentage is the ratio of number of edge pixels to number of data pixels in corresponding input image.

Change in edge information was also obtained by preparing classified edge images from both raw and processed (shift-resampled). These classified images contain 4 classes of pixels, whose description is given below.

- Class 1 – Unchanged edge pixels
- Class 2 – Changed from edge to non-edge
- Class 3 – Changed from non-edge to edge
- Class 4 – Unchanged non-edge pixels

Resampled images in both cases were analyzed based on visual and statistical parameters. The corresponding results are presented with observations and interpretations in the following section.

4. RESULTS AND DISCUSSION

4.1 Shift resampling (SR)

Images subjected to shift resampling are visually interpreted and few statistical parameters were computed. The visual interpretation was difficult find any anomalies as the changes were very minute, i.e about 0.2 pixel variation in mean (Figure 4.a) only. The statistical parameters include mean, standard deviation for individual images and coefficient of correlation of resampled images with respect to corresponding raw image. These values depicted in Figure 4. In these plots few terms Raw, BL, CC-1.0, CC-0.75, CC-0.5 and BS are used, which represents raw image and SR images obtained using Bilinear, Cubic Convolution with parameter values -1.0, -0.75, -0.5 and cubic B-spline respectively. Then there are three axes in each plot, each of them represent one city data, colours are mentioned as a legend. All the axes represent same i.e. either mean, standard deviation etc.

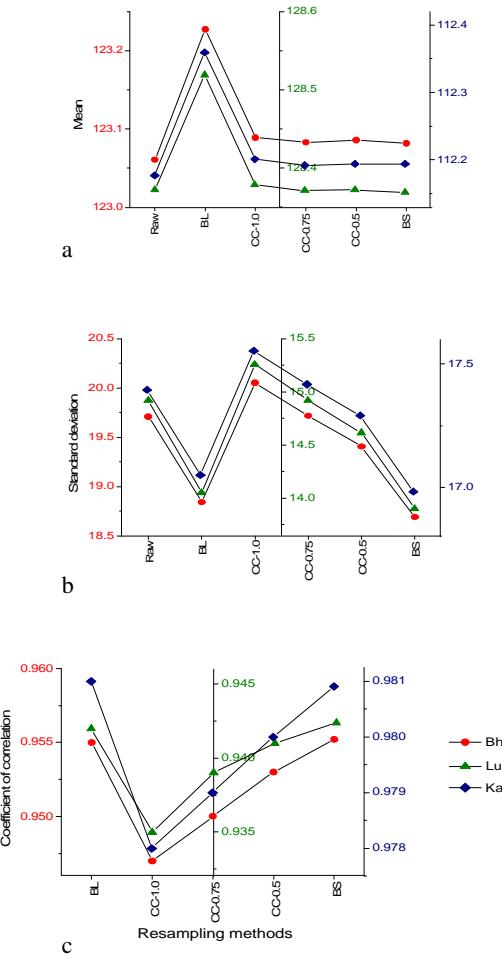


Figure 4: Statistical parameters (a) Mean, (b) Standard deviation and (c) Coefficient of correlation for raw and SR images.

From the statistical properties it was observed that, the standard deviation of image pixel values was reduced due for BL and BS resamplers. For resampled images with CC, the change in standard deviation is relatively less. For a as -0.75, the standard deviation was nearest to that of the raw image. While, the coefficient of correlation of raw image with other resampled

images was highest in case of BL resampled images and the least for CC resampled image with a as -1.0. The maximum difference between raw and resampled images for the minimum pixel value is '2'. The minimum pixel value did not change for Bhopal and Lucknow for CC resample with a as -0.75 and -0.5. For Kanpur, however, it remained unchanged with a as -1.0.

The used high resolution data, gave very large number of edges when Canny method was applied after Gaussian smoothing. The percentage of edge pixels in the edge images listed in Table 4.2 and corresponding graph is provided in Figure 4.2.

| | Bhopal | Lucknow | Kanpur |
|---------|--------|---------|--------|
| Raw | 15.67 | 16.45 | 14.01 |
| BL | 15.30 | 16.08 | 13.53 |
| CC-1.0 | 15.88 | 16.70 | 14.11 |
| CC-0.75 | 15.84 | 16.63 | 14.19 |
| CC-0.5 | 15.60 | 16.38 | 13.99 |
| BS | 15.16 | 15.92 | 13.37 |

Table 2. Percentage edge pixels for SR images

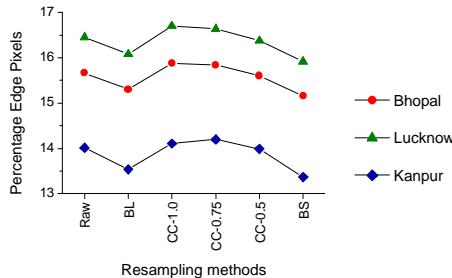


Figure 5. Percentage edge pixels (Table 2)

From these values, it can be observed that percentage edge pixels increased due to CC resampler with a as -1.0 and -0.75. The number of pixels did not change much in SR image obtained by a as -0.5. However, the percentage of edge pixels decreased in case of BL and BS methods. Further the retention ratio of same pixels, i.e. number of class-1 pixels were computed from the classification images and are present in the Table. An example of resampled image and its corresponding edge classified image are presented in the figure.

| | Bhopal | Lucknow | Kanpur |
|---------|--------|---------|--------|
| BL | 54.91 | 54.96 | 54.91 |
| CC-1.0 | 56.03 | 56.39 | 55.63 |
| CC-0.75 | 56.09 | 56.2 | 57.21 |
| CC-0.5 | 55.68 | 55.76 | 56.89 |
| BS | 54.49 | 54.47 | 55.05 |

Table 3. Percentage of unchanged edge pixels (class1)

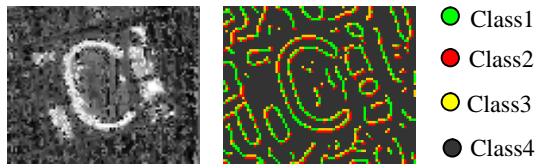


Figure 6. Part of Resampled and its edge classified images

From these classified images it was observed that More than 54 percent of edge pixels are common in both raw and SR edge images. Maximum percentage of Class1 pixels were observed

in case of CC with $a = -0.75$ for Bhopal and Kanpur study sites and with -1.0 value for Lucknow area. Most of the new edge pixels (Class3) were visually seen to be located across the direction of shift i.e. top-left and bottom-right diagonal direction. It was also observed that there was minimum loss in continuity of edge features, where as for some features continuity was established after SR.

4.2 Geometric Rectification (GR)

The co-ordinates of ground control points (GCPs) are very important in terms of spatial interpolation, which governs the position of new pixel where the resampled values will be placed. The images in present study were geo-referenced with GPS survey carried in three cities, about fifty well distributed control points were collected. These were identified from the images and survey of India topo-sheets as well. Due to the good accuracy of collected GCPs, geometric rectification was able to achieve less than 0.5 pixel error. In this case statistical parameters mean and standard deviations were computed. The coefficient of correlation was not computed due to difference in size of raw and resampled images. The plots of these values are given in Figure 7.

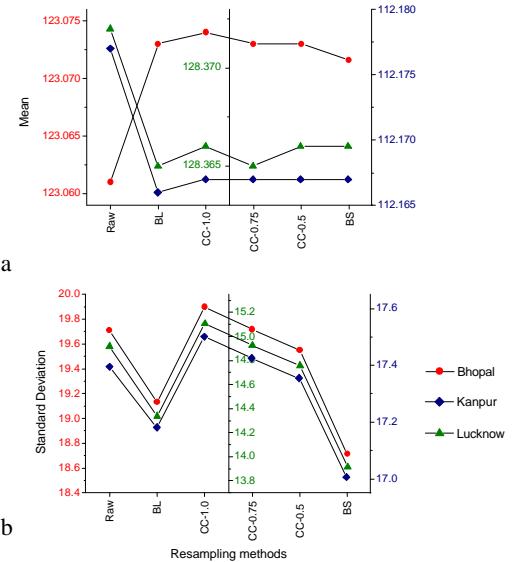


Figure 7. (a) Mean and (b) Standard deviation plots for raw, GR images

The observations made from the values and graphs include that, the Mean values for all GR images are similar to raw image value. For all study sites, the difference in standard deviation is minimum in case of CC with a as -0.75 and the maximum in case of BS method. The change of minimum pixel values was least in CC resampling method.

| | Bhopal | Kanpur | Lucknow |
|---------|--------|--------|---------|
| Raw | 15.67 | 14.01 | 16.45 |
| BL | 16.15 | 14.73 | 17.07 |
| CC-1.0 | 16.56 | 15.18 | 17.43 |
| CC-0.75 | 16.43 | 15.09 | 17.32 |
| CC-0.5 | 16.32 | 14.97 | 17.18 |
| BS | 15.83 | 14.47 | 16.71 |

Table 4. Percentage edge pixels for raw and GR images

In GR images, there were many blank pixels due to rotation of image. So, number of data pixels was only calculated and used for obtaining the percentage of edge pixels, but classified images were not computed due to size mismatch. The percentage values are tabulated in Table 4 and the corresponding graphs are shown in Figure 8.

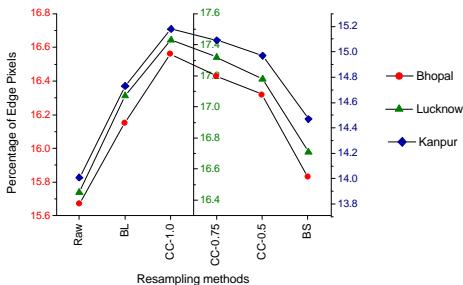


Figure 8. Percentage edge pixels (Table 4)

From the table and graph, it was observed that in all GR images the number of edge pixels was more than that was identified in raw image. The maximum percentage was observed using CC with $a = -1.0$.

Based on the results obtained in geometric rectification, following interpretations can be made:

- (i) Change in mean value is significantly less. This could be due to good accuracy of geometric rectification as indicated by smaller values of sigma.
- (ii) The change in standard deviations has shown the same trend as SR. This means that the information content was unaffected due to the transformation processes.
- (iii) Percentage of edge pixels was significantly increased in all GR images. This could be due to warping of image involved in affine transformation. However, the trend in variation of percentages was similar to edge images obtained by SR (Figure 5).

5. CONCLUSIONS

The present study has investigated the performance of resampling methods by analyzing the statistical parameters of images obtained by various resampling algorithms. The investigations have demonstrated that resampling techniques have profound effect on detection of edge features. Although Bilinear (BL) and cubic B-spline (BS) methods maintain high correlation between raw and resampled images due to their positive interpolation values, these algorithms smoothen the image causing disappearance of edge features. Cubic convolution (CC) method with three different parameter values has shown similar performance. However, resultant images are very different from the raw images (indicated by low correlation values). The CC method with $a = -0.75$ value has shown similar values of statistical properties and number of edges in most of resampled images to that of raw image values. Although the trends of standard deviation and percentage of edges were similar for SR and GR images, the number of edge pixels significantly increased in GR images, which could be due to warping of images in transformation process. Hence, based on various results, CC method with a as -0.75 is

recommended for performing the resampling process on IRS-1D, PAN imagery, especially if the aim is to detect edges. Because, it gives good number of edge pixels with minimum correlation deviation from raw data.

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