Detection of Flooded Areas from Multi-Temporal SAR Images using Different Image Enhancementtechniques–A Comparison

Preethi Sharma K*, Anuradha H **, Bindu A***, Bindu S**** and Deepa S*****
*-*****Global Academy of Technology, Bengaluru
*ksharma.preethi@gmail.com,**anu.hariprakash51@gmail.com, ***bindunaidu63@gmail.com,
****bindus.siddu@gmail.com, *****deepasvhally@gmail.com

Abstract: SAR images are generally available as multi-temporal images. To recognize the changes between these images precise calibration and perfect spatial registration are required.Due to high asymmetry in the image histograms and minor unavoidable calibration errors, conventional image pre-processing techniques cannot be adopted in case of SAR images. A chain of pre-processing techniques with cross normalization is suggested. The pre-processing chains involving different histogram equalization techniques like Histogram Equalization, Adaptive Histogram Equalization, Local Histogram Equalization and Contrast Limited AHE are used in the image pre-processing chain and results are compared to identify best suited image pre-processing chain cross-normalization process.

Keywords: SAR, multi-temporal, Cross-normalization, Histogram Equalization, AHE, LHE, CLAHE.

Introduction

EARTH observation technologies are very important in hazard monitoring. Synthetic aperture radar (SAR) acquisitions play a decisive role in this context due to their all-weather capability. The revisit time and the wide area coverage are playing an increasingly important role in flood detection [1].
Synthetic aperture radar (SAR) images are ideal information source for performing change detections, since they are independent of atmospheric and sunlight conditions [2]. With the development of earth observation programs, more and more SAR sensors are capable of collecting hundreds of images for the same area on the earth's surface at shorter intervals [1]. Therefore, SAR images are more frequently used to monitor and evaluate environmental changes. However, SAR images exhibit more difficulties than optical images due to the presence of the speckle noise.
Multitemporal data from the same geographical area taken at different times are particularly useful to those investigating damage. The changes exhibited by an image pair can be identified to generate an overall understanding of the phenomenon in the letter [1], which in turn can help relevant authorities to provide first aid and other assistance to the general population. A very rapid response is mandatory in emergency situations unlike in damage assessments and disaster.
The proposed pre-processing chain, followed by the color image generation process [1], makes it possible to obtain better and more easily understandable visual results than the original images, for a successive photo interpretation analysis aimed at identifying the changes that have occurred in the pair of images. The method has also been successfully used to manage responses to other disasters such as earthquakes and tsunamis, or to carry out sea monitoring through polarimetricSAR images acquired indifferent acquisition modes from Cosmo/Skymed satellites have been used for the experiments [4].Section IIbriefly describes previous studies. Section III analyses and discusses the problem domain and challenges.Section IV reviews the statistical models of SAR imaging and provides a description of histograms and their modifications that are usually employed in image processing.
The results and conclusion are presented in Section V, together with a discussion of the experimental procedure that made it possible to validate the image properties discussed in this paper. The process of setting the appropriate processing parameters is also discussed.

Previous Work

Variety of methods has been used to delineate changed areas via SAR imagery [1]. Usually, to support the mapping of changed areas, some related preprocessing operations must be performed. These include the co-registration, geolocation and orthorectification of SAR data ([5], [6]) .These operations must be completed for change information to be determined and then displayed by a Geographic Information System (GIS). Different filters have been proposed in the literature, including the Lee, Frost, Enhanced Lee and Frost filters [8], and more recently, the speckle reducing anisotropic diffusion filter in which water can be easily identified via a data fusion process that involves multitemporal backscatter intensity .The

additional information provided by the absence of coherence over water makes it easier to more accurately identify flooded areas than by simply using backscatter intensity. Different techniques are used to obtain change maps. They range from simple visual interpretation to supervised classification and more sophisticated automatic methods.
RGB composition can be used both for a simple display able to enhance regions of interest and as a preprocessing step intended to aid in identification, in which the combination is based on textural features of images[1]. Calibration or histogram matching is performed before the multitemporal data fusion process.

Problem domain and challenges

In this paper we use chain process of image preprocessing techniques. In the recent past, a variety of methods have been used to delineate changed areas via SAR imagery [1]. To support the mapping of changed areas, some relevant preprocessing operations must be performed. These operations must be completed for change information to be determined and then displayed by a Geographic Information System (GIS). Problems are Radiometric calibration chain is affected by measurement errors, flooded areas are not segmented properly, image quality is poor and computational complexity is high.

Statistical models of SAR imaging

Histogram Equalization

Histogram equalization is a method in image processing which is used for adjusting the contrast of an image using image's histogram. This method usually increases the overall contrast of many images, especially when the usable data of the image is represented by close contrast values. This adjustment allows the intensities to bedistributed better on the histogram. This allows areas of lower contrast to gain a higher contrast. Histogram equalization accomplishes this by spreading out the most frequent intensity values effectively.
Modifications of this method use multiple histograms, called sub histograms, to emphasize local contrast, rather thanthe overall contrast. Examples of such methods include adaptive histogram equalization or AHE, contrast limited adaptive histogram equalization or CLAHE.

Implementation Of HE

- Consider a M x N q-bit image.
- Compute the histogram for the image.
- Compute the probability density function which is given by

$$P_x(i) = \frac{n_k}{n}$$

- Where n_k is the number of occurrences of gray level i, *n* is the totalnumber of pixels in an image.
- Calculate the cumulative distribution function (CDF) $cdf(i) = P_x(i) + P_x(i-1)$
- Calculate the new values through the general histogram equalization formula.

$$h_v - round\left(\frac{cdf_v - cdf_{min}}{(M \ x \ N) \quad 1} \ X \ (L-1)\right)$$

Where l is the total number of gray levels (typically 256), cdf_{min} is the minimum non-zero value of the CDF and M x N gives the image's number of pixels.

- Assign new values for each gray value in the image.

Local Histogram Equalization

Local histogram equalization can enhance minute details of the image .Different transformations of the same gray level at different places in the original image is taken. Local Histogram Equalization takes out block-overlapped Histogram. LHE implements the sub-block and improves the image. Histogram equalization is useful for the center pixel used in CDF of the sub-block [3]. Then, the sub-block is moved by one pixel and the sub-block histogram is repeated again and again until the image achieved.

Implementation Of LHE

- Based on the neighborhood value the histogram equalization is done for each pixel. Histogram equalization can be enhanced by changing the matrix size.
- Consider a matrix A of an image
- Copy the matrix A into matrix into another matrix B and pad it with zero all the sides
- Consider a window size m*n and start tracing from the first position (1,1)
- Find the probability function and cumulative distribution function of each pixel value inside the matrix.

- Find the middle element in the window.
- Replace the value of middle element by the value obtained by its CDF. Similarly, the computation is done for the whole matrix.
- Transform the input image with the output value obtained.

Adaptive Histogram Equalization

Adaptive histogram equalization isa technique used in image processing which is used to improvethe contrast of an image. AHE is a computer based image processing technique. Itvaries from ordinary histogram equalization in the respect that the adaptive method computes several histograms, each corresponding to a distinct section of the image which is used to redistribute the lightness value of the image. Therefore, it is suitable for improving the local contrast and enhancing the definitions of edges in each region of an image. However, AHE has a tendency to over amplify the noise in relatively homogeneous regions of an image.

The ordinary histogram equalization also known as HE technique uses the same transformation derived from the image histogram to transform all the pixels of the image. This works well when the pixel values are distributed similarly throughout the image. When the image contains parts that are lighter or darker than most of the image, the contrast in those regions will not be sufficiently enhanced.

Adaptive histogram equalization (AHE) improves the histogram equalization by transforming each pixel which is derived from a neighbourhood region using a transformation function. It was developed for use in aircraft cockpit displays. Each pixel is transformed based on the histogram of a square surrounding the pixel in its simplest form. The derivation of the transformation functions from the histograms is exactly the same as that of ordinary histogram equalization. The transformation function is proportional to the cumulative distribution function (CDF) of pixel values present in the neighbourhood.

Pixels which are present near the image boundary have to be treated specially, because their neighbourhood pixels will not lie completely within the image. This problem can be solved by extending the image by mirroring the pixel lines and columns with respect to the image boundary. Copying the pixel lines on the border is inappropriate, as it would lead to a highly peaked neighbourhood histogram.

If the image region contains a pixel's neighborhoodthat is fairly homogeneous, its histogram will be strongly peaked, and the transformation function will map a narrow range of pixel values to the complete range of the result image. This causes Adaptive Histogram Equalization to over amplify small amount of noise in large homogeneous regions of the image.

Implementation Of AHE

- Consider an M x N q-bit image.
- Find the histogram of an image.
- Consider the sub-block of the image.
- Calculate the PDF.
- Calculate the CDF.
- Calculate the new values using general histogram equalization formula.
- Assign new values for each gray value in the image.

Contrast Limited Adaptive Histogram Equalization

Contrast Limited AHE (CLAHE) differs from the adaptive histogram equalization by the contrast limit. This feature can also be applied to global histogram equalization which gives rise to contrast limited histogram equalization (CLAHE), which is rarely used in practice. In CLAHE, the contrast limiting procedure has to be applied for each neighbourhood pixel from which a transformation function is derived. CLAHE was developed to prevent the over amplification of noise that adaptive histogram equalization produced. This can beobtained by limiting the contrast enhancement of AHE. The contrast amplification in the vicinity of a given pixel value is given by the slope of the transformation function. It is directly proportional to the slope of the neighbourhood cumulative distribution function also known as CDF and therefore to the value of the histogram at that particular pixel value. CLAHE limits the amplification by clipping the histogram at a predefined threshold before computing the CDF. This limits the slope of the CDF and therefore the transformation function is limited. The value at which the histogram is clipped, called the clip limit, depends on the normalization of the histogram and thereby on the size of the neighbourhood region.

Implementation Of CLAHE

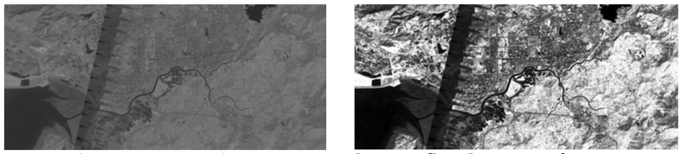
- Finding the inputs: Image, the number of regions in row and column directions, number of bins for the histograms used in building ,the image transform function or the dynamic range and clip limit for contrast limiting normalized from 0 to 1 is obtained.

- Pre-processing the inputs: Determine the real clip limit from the normalized value if it is necessary, pad the image before splitting the image into regions.
- Process each contextual region thus producing gray level mappings: Extract a single region of the image, plot the histogram for this region using the specified number of bins, clip the histogram using clip limit or threshold limit and create a mapping or transformation function for this region.
- Interpolating the gray level mappings in order to assemble final CLAHE image: Extract cluster of four neighboring mapping functions, process image region partly overlapping each of the mapping tiles, from this extract a single pixel value and apply four mappings to that pixel and interpolate between the results to obtain the output pixel; repeat over the entire image.

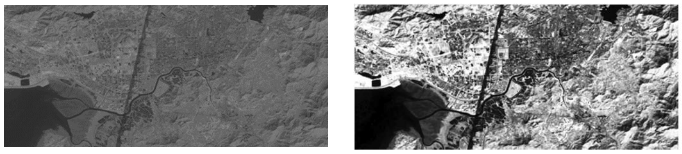
Simulation Results and conclusion

In this section, we consider four histogram based techniques for image enhancement. These techniques are HE, LHE, AHE, CLAHE as shown in Figures (1), (2), (3) and (4) respectively. Multitemporal SAR pre-flood and post-floodimages are considered. These techniques are applied and are compared based on the contrast enhancement.

The results of these techniques are presented here. Fig(1) shows that HE enhances the contrast of the entire image and it also amplifies the noise level of images along with some undesirable side effects such as washed-out appearance.



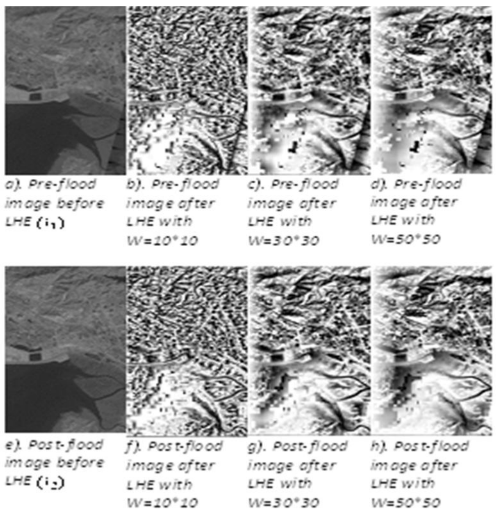
a) Pre-flood image before HE(i_1) *b) Pre-flood image after HE*



c) Post-flood image before HE(i_2) *d) Post-flood image after HE*

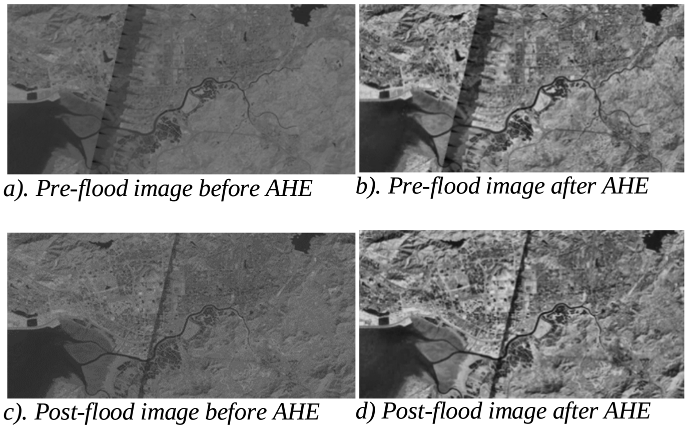
Fig(1): Simulation of Histogram equalization

Fig(2) shows that LHE improves the contrast of an image based on different window size MxN. Fig(2b), Fig(2c) and Fig(2d) shows the pre-flood image after applying LHE with window sizes 10*10, 30*30 and 50*50 respectively. Similarly, it is done for post-flood image as shown in Fig(2f), Fig(2g) and Fig(2h). Smaller the window size more is the enhancement and vice-versa.



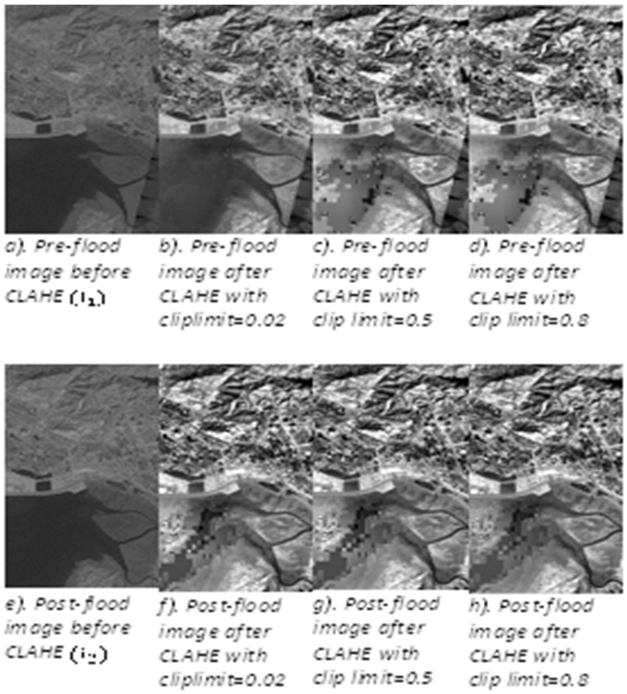
Fig(2): Simulation of Local Histogram equalization

Fig(3) shows that AHE enhances the image region which are significantly lighter or darker rather than enhancing the entire image



Fig(3): Simulation of Adaptive Histogram equalization

Fig(4) shows that CLAHE enhances the image by considering the sub block of an image called tiles. Depending on the clip limit factor, CLAHE enhances the images.



Fig(4): Simulation of Contrast limited Adaptive Histogram equalization

On comparing these techniques, Histogram equalization is a simple and straightforward image processing technique often used to achieve better quality images. LHE cannot provide partial brightness andenhancement of the image depends on the size of the window. The local histogram equalization processoften results in unacceptable modification of the original image appearance. In AHE, when the image region containing a pixel's neighborhood is fairly homogeneous, its histogram will be strongly peaked, and the transformation function will map a narrow range of pixel values to the entire range of the result image. This causes AHE to over amplify small amounts of noise largely in homogeneous regions of the image. CLAHE introduces changes in the pixel intensity. This leads to some processing artifacts which affects the decision making process and has a tendency to produce noise. HE is a simple and effective technique but accurately changes the brightness of image. LHE, AHE and CLAHE are useful to enhance the brightness of image. CLAHE is better than LHE because LHE is a time consuming technique. CLAHE is used to enhance the contrast of image and also to remove the noise but still it has some tendency to produce noise. It is found that, Histogram equalization technique is the best enhancing technique which can be considered in cross- normalization pre-processing chain.

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