AN ANALYSIS ON SYNTHETIC APERTURE RADAR DATA AND ENHANCEMENT OF RECONSTRUCTED IMAGES

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ABSTRACT

In this paper, properties of raw and processed synthetic aperture radar (SAR) data are discussed. Statistical analyses are carried out on ERS-2 data to understand the nature of the data of interest. Best approach to achieve this goal is to analyze the related histograms Histograms of various sample data are plotted and checked whether they are similar to some known distributions, parameters needed to define these distributions are determined. To improve visual quality of the reconstructed images histogram expansion, which is a global enhancement method, is used.

I. INTRODUCTION

Synthetic aperture radar techniques and its applications were much emphasized in the field of remote sensing in recent years. SAR sensors are being developed as a key mapping source day by day as their high quality imaging capability is realized and improved. While technological progresses are rapidly extended, both airborne and spaceborne SAR systems demonstrate their feasibility and more engineering projects in this area is developed. A SAR imaging sensor synthesizes a long antenna by transmitting pulsed signals and coherently adding the reflected signals successively to obtain high resolution in azimuth direction. The resolution in range direction is achieved by transmitting very short pulses or wide bandwidth pulses (chirp). Thus, it provides information about the surface by measuring and mapping the reflected energy in the microwave region. The wide varieties of potential applications of SAR imaging caused the development of the SEASAT satellite. The launch of the SEASAT satellite into the Earth orbit by NASA in June 1978, provided an opportunity to investigate the utility of SAR for environmental monitoring and ocean observation from space which was impossible before. During its mission period of three months, a large amount of imagery was obtained and it was shown that spaceborne SAR was an advantageous choice for global monitoring of the Earth. To obtain a better understanding of the spaceborne SAR remote sensing, a series of Shuttle Imaging Radar (SIR) flights, which include the 1981 SIR-A, 1984 SIR-B etc., was performed. Recognizing the utilities of SAR, different countries developed their own spaceborne SAR sensors to obtain high – resolution images of the Earth for civilian applications. Russia launched in 1991 ALMAZ-1, Japan in 1992 JERS-1 and Canada in 1995 RADARSAT. European Union started ERS-1 and ERS-2 in 1991 and 1995, respectively.

In this study, ERS-2 raw and processed data for a chosen part of Istanbul are analyxed by histogram analysis. Various histograms are plotted for the mentioned data and parameters are defined. In image enhancement steps, histogram expansion and contrast modification are used. As a result, visual appearance of the images are considerably improved.

II. STATISTICAL ANALYSIS

Histogram analysis is a remarkable way to analyze images statistically. A histogram is constructed by examining the gray level value of each pixel in the image and counting the number of pixels displaying each of the possible values. On the histogram plot, each gray level value is represented by a histogram bin whose height represents the number of image pixels displaying that value. Therefore the process of constructing the histogram corresponds to the filling of histogram bins.

Histogram of an image gives an estimate of the probability of occurrence of gray levels. A plot of this function for all gray levels provides a global description of the appearance of the image. For example, a histogram on which the gray levels are concentrated toward the dark end of the gray scale range means an image with overall dark characteristics. Opposite is true as well. A histogram which has a narrow shape indicates little dynamic range and thus corresponds to an image having low contrast. As all gray levels occur toward the middle of the gray scale, the image would appear gray.

Although the properties discussed above are global descriptions that say nothing specific about image content, the shape of the histogram of an image does give us useful information about the possibility for contrast enhancement. As

we have low contrast images, contrast enhancement would be an important improvement factor. To obtain histograms, we first normalize data matrix elements between 0 – 255. Thus we have 256 different gray level values. Then, histograms are constructed by the properties discussed above.
Let us consider a 1024x1024 ERS-2 raw data and the image that is produced via narrow focusing given in Figure 1.

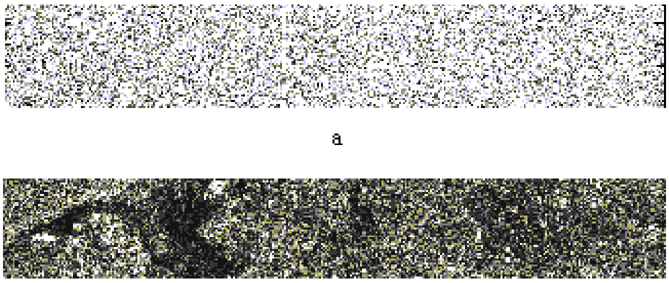


Figure 1. Raw data (a) and image reconstructed via narrow focusing (b)

Histograms of the given raw and processed images can be seen in Figure 2 and Figure 3, respectively. It is realized that processed image is a dark and a low contrast image since its histogram is mounted around dark gray levels and has a narrow peak. This histogram has a mean of 18.

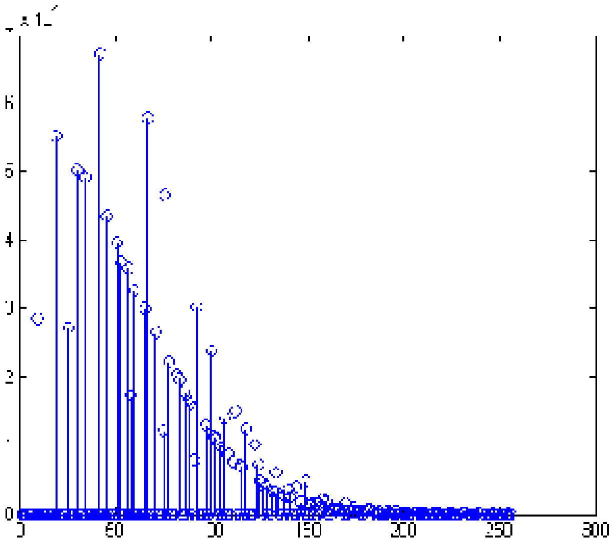


Figure 2.. Histogram of the processed image

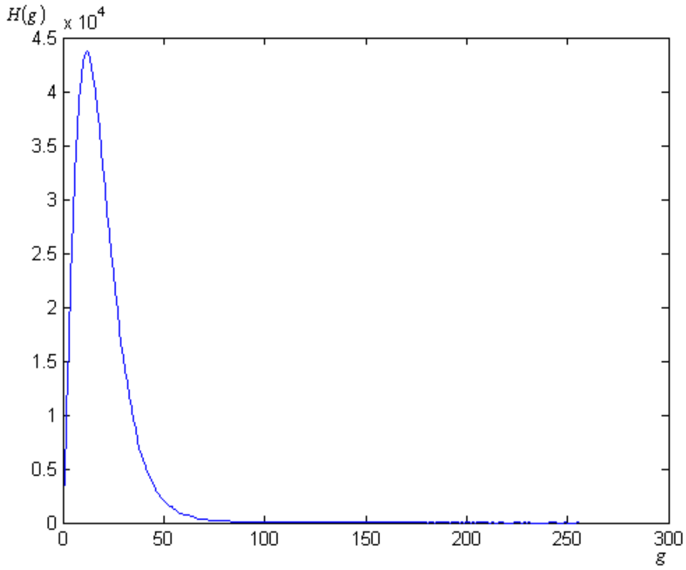


Figure 3. Histogram of the processed image

Distribution observed in Figure 3 is quite similar to Rayleigh distribution which is defined as

(1)

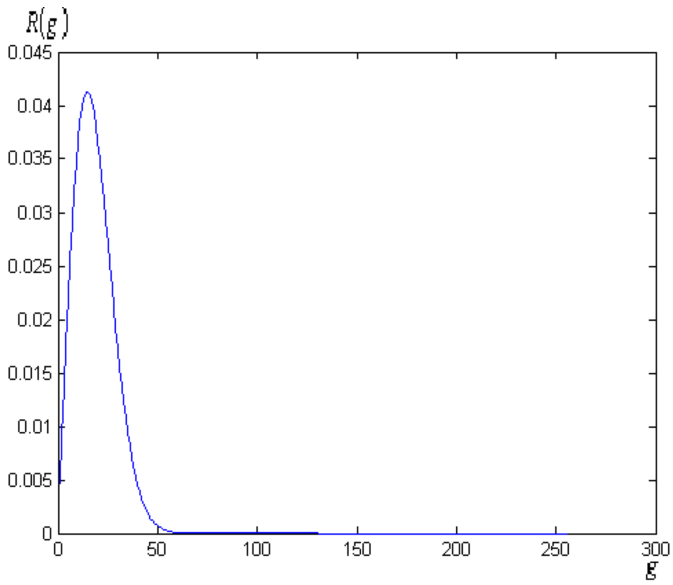


Figure 4. Rayleigh distribution

Normalized histogram according to Rayleigh distribution can be seen in Figure 5. Histogram of the raw data has also a Rayleigh distribution which is the case in Figure 2. Same procedure can be followed for raw data as well.

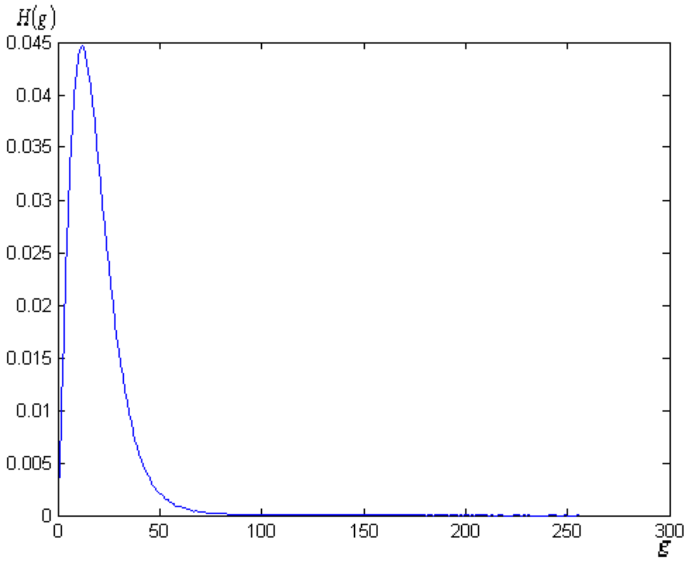


Figure 5. Histogram normalized by Rayleigh distribution

III. IMAGE ENHANCEMENT

The principle objective of enhancement techniques is to process an image so that the result is more suitable than the original image for a specific application. Image enhancement is treated here as a processing technique to increase the visual contrast of an image in a designated gray level range. Although the degree of enhancement may be subjective, procedures to perform a given type of enhancement can be directly related to the desired purpose. The method described here is a histogram transformation, hence a global enhancement is presented. It generates a new output histogram by modifying the shape of the input histogram according to a specific mapping function that is chosen to enhance contrast in the range of interest. The result of this is that the gray level values of the original image are modified to improve its appearance or effectiveness for visual analysis.

The method applied here is histogram expansion. It is the most straightforward transformation for enhancement. This is a linear transformation that entails an input intensity range to an output intensity range, which typically uses the full dynamic range.

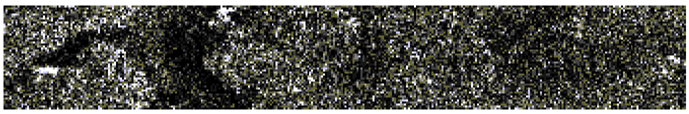
Remember the image in Figure 1.b and its histogram. The histogram has a narrow peak, which means the image is a low contrast image. Hence, histogram expansion can be applied on this histogram to use the full dynamic range (that is gray levels are between 0 – 255).

Linear mapping function which is used to expand the example histogram is;

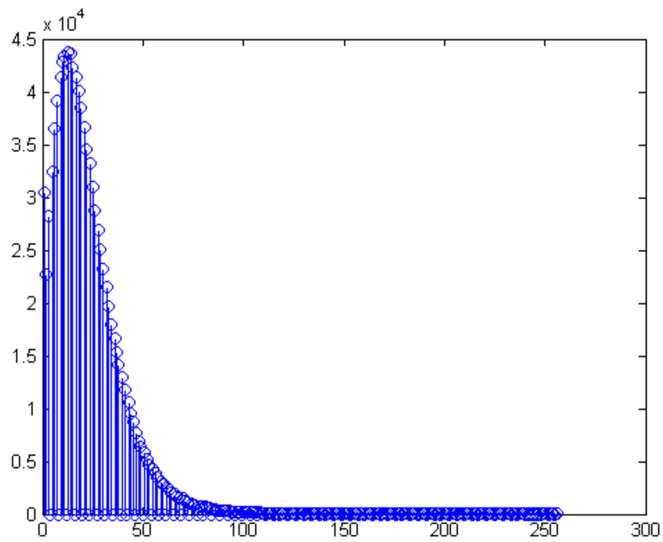
$$y = \frac{x - x_{\min}}{x_{\max} - x_{\min}} . y_{\max} \qquad (2)$$

where x_{min} and x_{max} are the minimum and maximum values of the input histogram, respectively while y_{max} is the upper boundary for the output histogram interval [0, 255]. However, this mapping function is not efficient for narrow-peak and long- tail histograms since their gray level values reach to the minimum and maximum of the full range. Thus, we can define intervals for the input gray levels to eliminate the ones on histogram tails.

Firstly, we choose input histogram interval as [0, 150] by mapping the gray level values which are greater than 150 to 150. As a result, all the values in data matrix are between 0 and 150. Then we apply the expansion formula and obtain the output histogram given in Figure 6.b where the defined upper bound of the input histogram is denoted by ‘ parameter ’. Contrast improvement of the resulting image is clear.



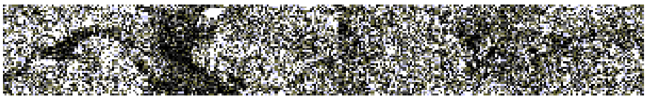
a



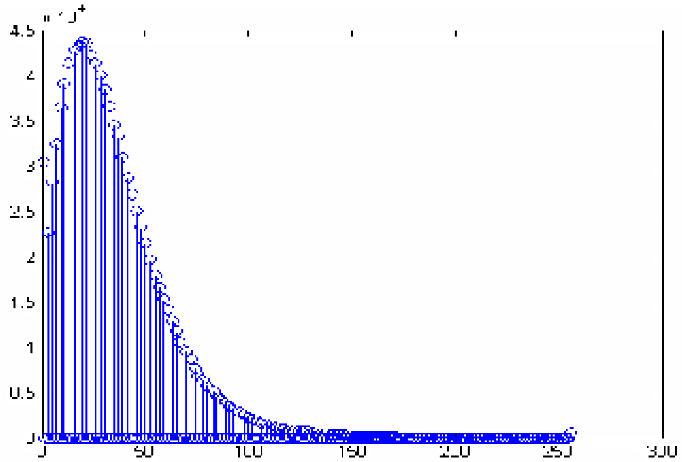
b

Figure 6. Improved image (a) and its histogram via histogram expansion (b) with parameter = 150

As a second choice, interval for the input histogram is determined as [0, 120]. Gray levels greater than 120 are mapped to 120 in the data matrix. Application of the formula results in Figure 7.



a



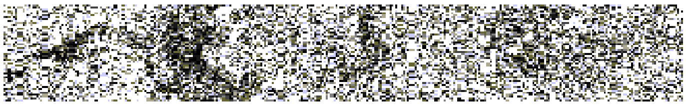
b

Figure 7. Improved image (a) and its histogram via histogram expansion (b) with parameter = 120

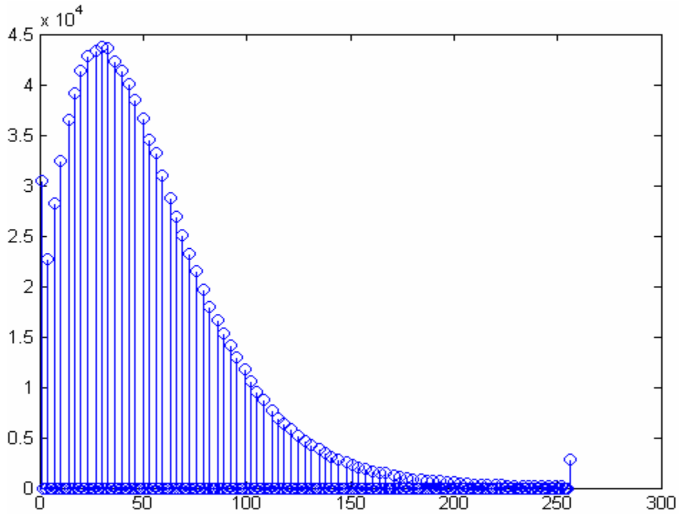
Same procedure is repeated for a parameter value of 80. Obtained results are shown in Figure 8. Note the peak on the gray level 256, this effect occurs because all the values of 80 in the matrix are mapped to 256. Also, as the chosen upper bound is lower, a more significant effect on the image is observed.
Another enhancement approach is to apply contrast correction to the image before application of histogram expansion. Contrast correction is a histogram operation which is used to enhance the visual appearance of an image. Contrast modification of an image is defined as

$$s_i = m.(g_i - avg) + avg \qquad (3)$$

where s_i is the ith graylevel value of the contrast enhanced image. g_i is the ith graylevel value of the original image, *m* is a contrast factor and *avg* is the mean value of the original image. Resulting image and histogram for *m*=2.5 and parameter=150 is shown in Figure 9. Graylevel values less than *avg* are mapped to zero since negative values are experienced in this range.

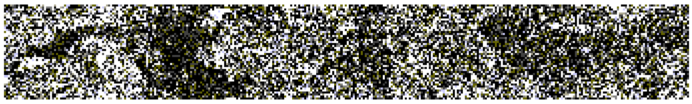


a

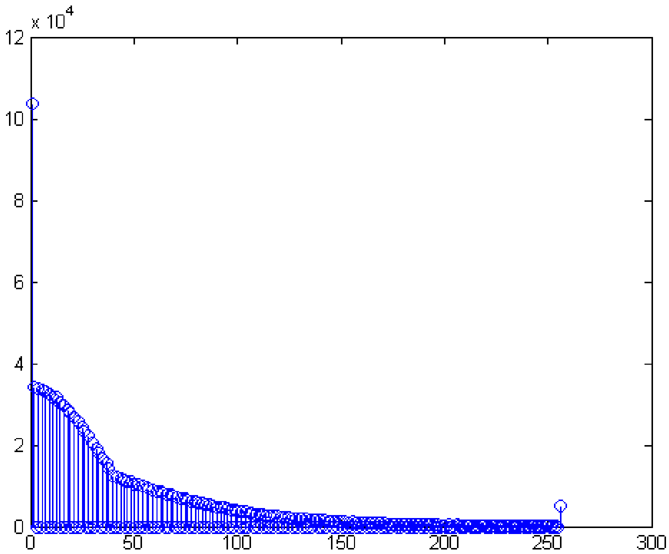


b

Figure 8. Improved image (a) and its histogram via histogram expansion (b) with parameter = 80



a



b

Figure 9. Improved image (a) and its histogram via histogram expansion (b) with m=2.5 and parameter = 150

IV. CONCLUSION

A discussion on synthetic aperture radar data is presented. Different aspects of given ERS-2 data are explained by histogram based methods. Proposed approaches are used for the analysis of mentioned data and visual improvement of reconstructed images. It is realized that plotted histograms are similar to some known distributions which have specific parameters. Once the images are formed, a number of post-processing steps are used to maximize the usefulness of the information in the radar imagery. Visual enhancement on generated images is achieved.

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