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A Simplistic and Basic Knowledge Derivative Approach of Intensity Distribution using Histogram Equalization (HE)

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Abstract - Histogram equalization (HE) is employed to enhance an image by re-distributing gray levels or pixel values of an image considering the pixels as continuous random variable using probability distribution function and cumulative density function. Histogram equalization though used as a contrast enhancement technique, it could be utilized as an information extraction technique especially from a remote sensing satellite image. Re-distribution of cumulative frequency of pixel values within a narrow limit may help in bring out subtle user specific information contributing preliminary phase of knowledge domain. In the present paper, the ability of such approach in bringing out interpretative information from diverse image such as satellite based image and conventional image implementing histogram equalization method has been discussed. Besides, sufficient background materials describing various HE methods, the mathematical computation, design and implementation of algorithm and resultant image with lucid interpretation have been also discussed in the present paper.

Keywords: spatial data, satellite image, image processing, histogram equalization, information extraction, knowledge discovery

I. INTRODUCTION

Image processing in its widest spectrum embarces simple to complex data nature invoving from single point straight forward knowledge driven approach to combination of series of techniques. *Knowledge*, depending upon the requirement is either objective or subjective, with the former employing uncomplicated computational techniques where as the latter involving complex procedures. Iages from simple photographic iage throughmedical imaging, video streaming to satellite image carry out different typs of spectral and spatial fusion to bring out "*information*" of objects or features [1] from incliding satellite image data. Among such procedures and techniques, the subjective approach involves simple enhancement techniques so that the brightness values or DN (Digital Number) values of an image may be manipulated to enhance and bringout information from an image. Such modification of intensity or brightness of pixel values or DN values involves low-level image processing [2] used sometimes as pre-processing in the knowledge discovery. Contrast enhancement involving intensity modification or histogram equilization (HE) would operate from local to global region carrying out pixelwise computations in an image ([3]-[5]). It is an important technique finding its aplication in both human [6] and computer arena such as video streaming [7], medical imaging [8], object recognition [9] and so on. Brightness distribution and intensity modification using histogram equilization would assist in understanding subtle pattern in an image and thus gain an insight of the object.

II. CONCEPT OF HISTOGRAM EQUILIZATION

Histogram equalization (HE), a method of image enhancement may involve pixelwise "local" operations like histogram stretching and equalization methods using mathematical functions of square, logarithmic or exponential operators. HE operates on the principle of contrast between objects as it may be generated by the difference in luminance between the surfaces of two objects. It is quantized by their brightness value either in gray scale or RGB in color image. Restriction or concentration of either gray scale values or RGB values within a particular region may sometimes suppress valuable information or leads to the loss of information. To alleviate such a situation, certain basic image processing techniques, such as histogram equalization" is adapted, which enhances the image by computationally re-distributing the brightness values of pixels that has concentrated within a specific range. Methods such as bi-histogram equalization (BHE), multi histogram equalization (MHE) and chipped histogram equalization (CHE) are used to enhance contrast in the image. Some of the common BHE method includes a mean based brightness preserving bi-histogram equalization (BBHE) as explained in [10], median based dualistic sub-image histogram equalization (DSIHE) and its utility in image enhancement [11] and minimum mean brightness error bi-histogram equalization (MMBEBHE) as demonstrated in [12] besides BHE neighborhood metric method [13]. Similarly, MHE shows recursive mean separate histogram equalization (RMSHE) and dynamic histogram equalization (DHE); CHE showing constraints on enhancement control ration using Bin overflow and Bin underflow [14], self-adaptive plateau histogram equalization (SAPHE) and gain controlled (GC) CHE [15] beside quadrants dynamic HE

[16]. Besides these, there are many other HE methods exist that use dynamic histogram specification (DHS), histogram specification with gamma image fusion (HSGI), automatic exact histogram specification (AEHS) and so on ([17], [18]).

III. MATHEMATICAL BACKGROUND OF HE

As discussed in the previous section, various histogram equalization techniques employ transformation of an image with discrete pixel values random variable with probability distribution function (PDF) and related cumulative distributive function (CDF). This may be elaborated by supposing an image *X* showing *m* x *n* dimensional array containing "*mn*" pixels. If the image is an 8-bit integer, then the values of pixel may range from 0 - 255 level. These values represent the intensity of objects in *feature* domain and in turn, any particular range of intensity may help in extracting information on the attributes of an object.

With this background, equation for transformation function for image *X* with *mn* pixels of *L* range values range may be explained by the following equation:

$H_k = p(X) = \sum_{i=0}^{k} n_I / N$, Eq (1)

where $0 \leq H_k \geq 1$and the value of 'k' may have a dynamic range values from 0 to L-1 for a 8-bit integer image, n_i indicates number of pixels having gray values rv_i and '*N*' is the total number of pixels in the image. The probability density function of the image is denoted by *pX*. Depending upon the probability density function, cumulative distribution function may be defined as $cX = (L-1) * pX$. The histogram equalization of global nature as defined through equation1may also be termed as histogram linearization, which may be given as

$U_K = G(K) = \int_0^K p(r_i)\, dr$ Eq (2)

Also, the distribution of sample image is specified, then the pdf and cdf may be written as shown in equation 2 and the new value would be arrived.Because of the discrete nature of new values scaled on an interval 0 to L-1, a Gauss bracket K_{new} + 0.5 is considered. Implementation of such an approach is implemented on image of diverse nature and objects and the results are discussed.

IV. DESIGN AND IMPLEMENTATION OF ALGORITHM

A basic and simplistic approach of HE would concurrently enhance the image and at the same time acts as a simple and powerful information extraction tool in the process of knowledge gathering about objects or object recognition. This becomes especially true while extracting information from satellite image derived from remote sensing satellites for various utility driven thematic applications. An algorithm in Matlab environment is customized to read image, compute and redistribute pixel values based on probability density function and range values.

Step 1: read image
Step 2: conversion of color map to gray scales
Step 3: define gray scale (in this case, it is 256 since the images are of 8 bit integer)
Step 4: assess number of pixels
Step 5: Calculate pdf and normalize it to get n_i / N.
Step 6. Arrive transformed and CDF histogram
Step 7: Apply the derived histogram values of pixels on the image X
Step 8: Resultant enhanced image
Step 9: Display the results
Step 10: write image to file

The algorithm calculates the values of pixels in the sample input and their concentration or density within a region of gray levels and redistributes the density to the entire range of values thus enhancing the image.

To understand the level of information that could be derived from different type of images having simple to complex pattern of objects, a photographic image of a molluscan shell in shallow water, boats in a lake and its shore and lastly, remote sensing satellite image (RSI) have been selected. The algorithm is implemented on these select images and results obtained are discussed in the following section.

V. INTERPRETATIVE RESULTS AND DISCUSSION

A photographic image as shown in Figure 1A depicts a molluscan as observed in shallow water. The photographs shows a relatively white to pinkish colour object surrounded by water reflecting some sunlight as well as its floor covered by fine gray colored silt.

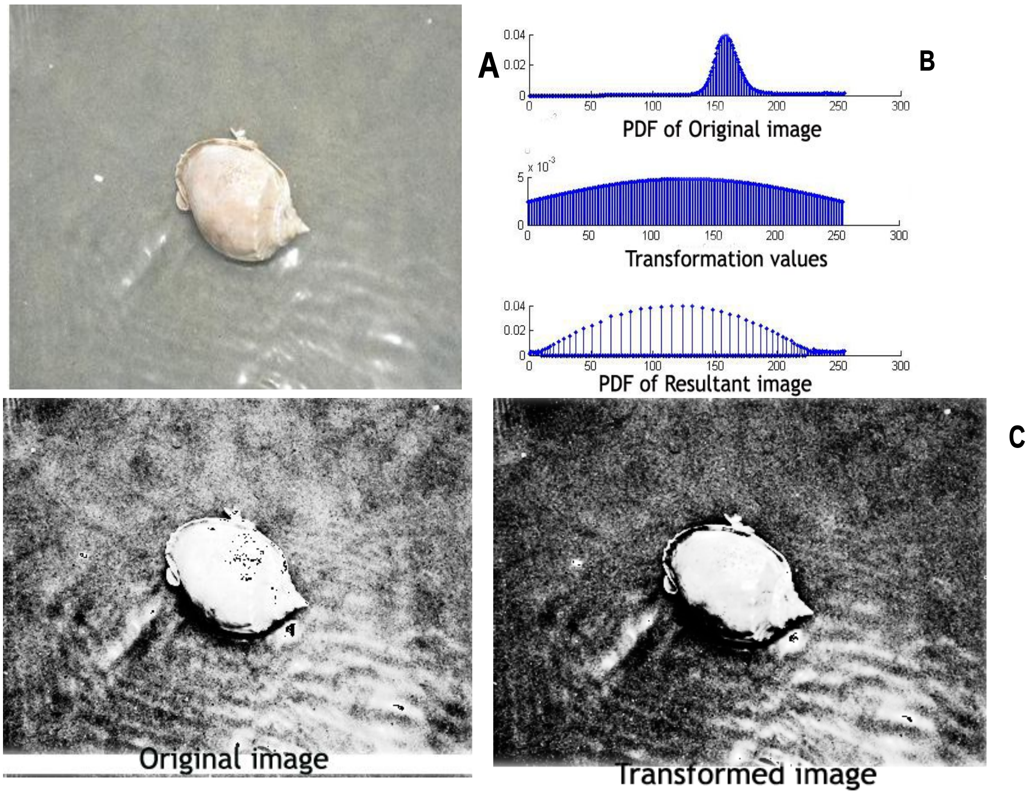

Figure 1. Image showing a molluscan shell, its histogram pattern and resultant images

The image though depicts a single object is not a homogeneous one as it also depicts portion of water, sunlight and silt bottom. But the objects are contrasting with each other with water being an aqueous media does not show character of its own but reflects sunlight and shows its bottom floor. Hence the original histogram as shown in Figure 1B has a *single* peak output at its center reveling concentration of pixels values with a narrow and confined range of 256 gray levels scale. The examination of histogram reveals that majority of the pixels are confined approximately within the range from 140 and 180. Since the major object in the image is the molluscan, the distribution of pixel values reflect that object and the information on the surrounding objects are not prominent. With the implementation of HE, the image could be enhanced as shown in Figure 1C and bring out the details suppressed in the image. For example, the wavy pattern of the water surrounding the molluscan, various shades of bottom sediments leading to the inference on wind direction and composition of sediments of the silted floor. Similar to the above, another image showing two predominant objects water and shore features (Figure 2A) is taken for analysis and the HE algorithm is implemented on it.

The histogram of Figure 2A depicts *two* peaks suggesting two major objects, which may be water and shore features respectively. The *first* peak shows a concentration of pixels approximately in the range from 0 to 160 and the *second* peak though continuous shows an approximate range between 160 and 200. These two major peaks represent two pockets of concentration or density of pixels represents two major objects. But, implementation of histogram equalization technique may bring out more subtle information about the objects by enhancing the image and thus contributing *'information extraction'* from the image. To take it further, the pixels are evenly distributed with gray levels after modifying ad transforming pixels with new values (Figure 2B) so that the information in the image are brought out. In the resultant image (Figure 2C) the shape of boats floating on the lake water are distinctly and sharply enhanced so that their exact dimension

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may be estimated if properly scaled. A dense gray patch adjacent to the boats indicates the shallower part of the lake relative to the other parts. Even the variations in the cloud pattern in the sky have been enhanced besides distinct separation of shoreline and water. Thus, many of the hidden attributes of objects may be extracted by a simple enhancement operator and contribute as baseline details for higher level *'knowledge discovery'*.

Lastly, the same technique is applied on the image obtained from remote sensing satellite data (Figure 3A) and the results are observed for any significant deviation.

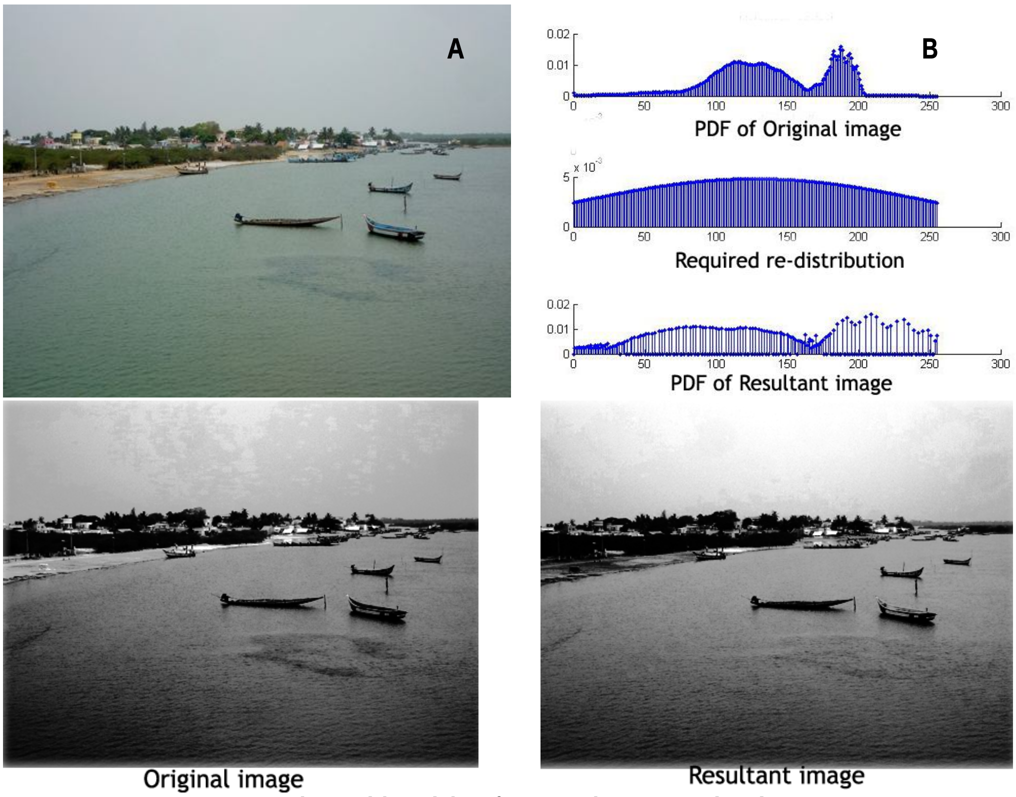
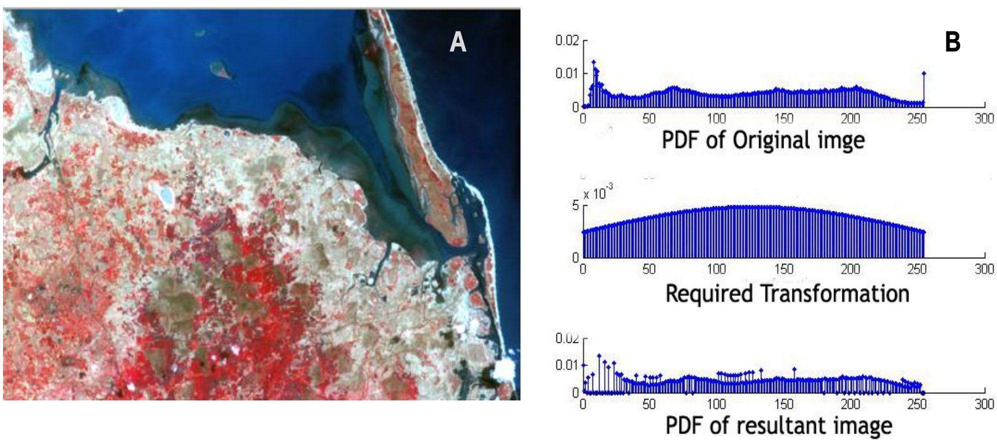


Figure 2. Image showing lake and shore features, its histograms and resultant images



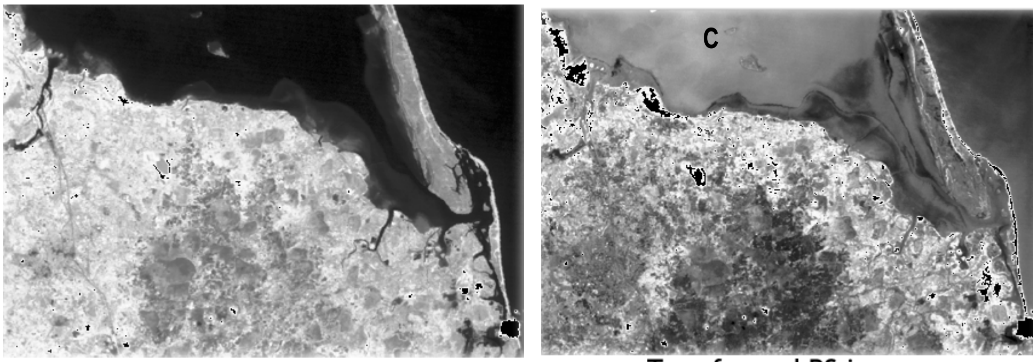


Figure 3. Remote sensing Satellite Image (RSI) of a coastal environment, its histogram and resultant images

The image contains heterogeneous objects that are intrinsically associated aiding to the complexity in *object identification* unlike the other two images as discussed above. The histogram of the image depicts *four* peaks with pixels spreading over the entire scale of gray levels. Because of the varied nature of the objects depicted in the RSI, concentration of pixels below the value 50 is distributed sparsely while transforming. Such re-distribution of pixels at the specified range allowed separation or enhancement of more subtle features that are hidden by their close association with larger object in the image. For example blue color depicted in Figure 3A depicts water body and in this case, it is both sea as well as lagoon when it runs parallel inside the land portion. But within the lagoon, again there may be marshes and tidal flats which are not properly highlighted in the original image. After normalization of pixels, the resultant image showed distinct separation of such objects in the lagoon. This may be clearly observed in the lagoon as darker and lighter clusters of gray colored pixels highlighting presence of marsh and tidal flats after contrast enhancement. Such enhancements of objects reiterate that contrast enhancement using histogram equalization provide meaningful information of the image environment, thus providing necessary domain knowledge.

The implementation of HE on three different images showed their utility value as image processing technique to extract information for generation of a higher level knowledge database in *spatial domain* complementing many integrated datasets.

VI. CONCLUSION

Implementation of histogram equalization (HE) on images having different sources (photographic image and RSI) and types of objects (single predominant object to heterogeneous objects) demonstrated its significance on images for information extraction. The analysis of three different images with perspective predominance of objects revealed the utility of HE as a simple technique in the process of more complex "*knowledge discovery*" in *spatial application domain*. The study revealed that such technique could be used not only to enhance the image but to retrieve information from image having simple objects to more complex heterogeneous objects as seen in RSI. The interpretation as discussed in the paper emphasized the volume of information that could be extracted from images after the implementation of HE technique, which could provide valuable attributive information pertaining to objects leading to constructive knowledge discovery process that could be integrated with other datasets for decision making.

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