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SHIFT VARIANT IMAGE ENHANCEMENT TECHNIQUES

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I. ABSTRACT

Many enhancement techniques are available for enhancement of digital imageries. Principal among them are grey scale manipulation techniques and filtering techniques. Most of the available techniques are shift invariant in nature, i.e., transformation functions used for enhancement are shift invariant. However, in practice most of the imageries have different grey value distribution and textural properties at different spatial regions in the imagery. Thus, shift invariant operations may not yield good results for entire imagery. Here, in order to overcome this difficulty, shift variant operators for intensity mapping and filtering have been suggested. The operators are adaptive and have been developed considering local properties of the imagery. In the method developed here, the entire image is first divided into number of segments. For each segment, properties like histogram auto-correlation function are then evaluated. The histograms thus obtained are used to determine transfer functions at centre of each segment for grey scale manipulation and auto-correlation coefficients are used to determine transformation parameters at the centre of each segment for enhancement by filtering. The enhancement parameters at other spatial positions are then determined using bilinear interpolation technique. Thus, shift variant transform functions are evaluated. Using these shift variant transform functions, the enhancement is carried over entire imagery. The algorithms for adaptive intensity mapping and adaptive filtering using above technique have been developed and implemented. As an illustrative, the algorithms have been applied for Landsat data and the results of the same have been shown in the plates.

II. INTRODUCTION

Image enhancement deals with manipulation of imageries to improve its quality for viewing purpose. Many enhancement techniques are available for enhancement of digital imageries. Principal among them are grey scale manipulation techniques like linear, non-linear stretching, histogram equalization. Filtering techniques like homomorphic filtering, high pass enhancement etc.,[1,2,3] are also available. Intensity mapping techniques improve contrast of the imagery while filtering technique enhances fine details and edges in the imagery. Most of the techniques summarized above are shfft invariant. However, in practice most of the imageries have different intensity distribution and texture at different spatial regions in the imagery. Or local properties of various spatial regions in the imagery are different. Thus, shift invariant image operators may not yield good results for the entire imagery. Here, in this paper, in order to overcome this difficulty, shift variant operators for intensity mapping and filtering have been suggested. The operators suggested are adaptive in nature and have been evaluated considering the local properties of the imagery. Thus, transformation coefficients are shift variant. In the method developed here, the imagery is divided into number of segments and for each segment local properties like histogram, auto-correlation coefficients are evaluated. These properties are used for determination of enhancement parameters at the centre of the segment. The enhancement parameters at other spatial locations are obtained by using bilinear interpolation technique [4]. Thus, using these shift variant transformation coefficients, the enhancement for entire imagery has been carried out. Section III describes the methodology and Section IV shows the illustrative examples.

III. METHODOLOGY

In the method developed here, imagery is first divided into small subimages (say of size 64x64) as shown in Figure 1. For each of these subimages, properties like histogram and auto-correlation coefficients are determined. With the help of above local properties, parameters for enhancement at centre of each subimage are determined. Enhancement parameters at other spatial locations are then obtained by using bilinear interpolation technique. Thus, using these enhancement parameters which depend on local properties of the image and which are shift variant, the enhancement for entire imagery is carried out. The methods of shift variant intensity mapping and shift variant filtering techniques are described below in detail:

(a) Method for Adaptive Intensity Mapping

Here, intensity mapping has been carried out using simple transform relationship as shown in Eq.(1).

$$X_{en}(i,j) = \text{Slope} \times X(i,j) + \text{Offset} \quad (1)$$

where X_{en}=enhanced imagery and X=unenhanced imagery.

$$\text{Slope} = (O_{max} - O_{min})/(I_{max}-I_{min})$$
$$\text{Offset} = O_{max} - \text{Slope} \times I_{max} \quad (2)$$

In Eq.(2), I_{min} and I_{max} are chosen to be shift variant in nature and they depend on local intensity distribution or local histogram. O_{max} and O_{min} are maximum and minimum desired output grey values. The procedure can be summarized in steps given below:

Step 1: Divide the imagery into different subimages as shown in Figure 1.

Step 2: Obtain histogram for each of these subimages.

Step 3: Using the histogram obtained in Step 2, obtain slope and offset parameters for enhancement at centres of each subimage.

Step 4: Transformation coefficients at all the spatial position are then obtained by using bilinear interpolation technique.

Step 5: Using the transformation coefficients obtained in Step 4, which are shift variant, intensity mapping for all the pixels is then carried out.

SUB IMAGE 1	SUB IMAGE 2	.	SUB IMAGE n1
.	.	.	.
.	.	.	.
.	.	.	SUB IMAGE n1xn2

FIGURE - 1

(b) Method for Adaptive Filtering

The method for shift variant filtering technique can be described as below:

The enhanced imagery is given by [5,6,7]

$$X_{en}(i,j) = C_1 X_{low}(i,j) + C_2 X_{high}(i,j) \quad (3)$$

In Eq.(3), X_{en} is enhanced imagery. X_{low} and X_{high} are low pass and high pass versions of unenhanced imagery X. X_{low} and X_{high} are defined in Eq.(4) and Eq.(5) respectively. C_1 and C_2 are constants such that $C_1 \leq 1$ and $C_2 > 1$.

$$X_{low}(i,j) = \sum_{p=i-\frac{M-1}{2}}^{i+\frac{M-1}{2}} \sum_{r=j-\frac{N-1}{2}}^{j+\frac{N-1}{2}} X(p,r)h(i-p,j-r) \quad (4)$$

where M=N=7.

$$X_{high}(i,j) = X(i,j) - X_{low}(i,j) \quad (5)$$

In Eq.(4), h(i,j) represents normalized point spread function which is chosen as Gaussian type in this case. Here, h(i,j) is chosen depending on local properties and is shift variant. h(i,j) is calculated at centre of each subimage and inturn it is evaluated at all the other points by bilinear interpolation technique. The method for adaptive filtering can be described in the steps given below:

Step 1: Divide the image into subimages as shown in Figure 1.

Step 2: Obtain the estimate for correlation coefficients for each of the subimage as defined in Eq.(6).

$$\hat{R}(m,n) = \frac{1}{N^2} \sum_{i=1}^{N-m} \sum_{j=1}^{N-n} X(i,j)\, X(i+m,j+n) \quad (6)$$

where N x N is the size of a subimage.

If we consider each of the sub-image to be sample function of a homogenous random field in two dimensional lattice then auto-correlation can be represented as [8]

$$R(m,n) = R(0,0)\, e^{-\alpha_1 |m|} \cdot e^{-\alpha_2 |n|} \qquad (7)$$

where $1 \leq m, n \leq N$

If the sample size is large enough, then we can write [9]

$$R(m,n) \simeq \hat{R}(m,n) \qquad (8)$$

Solving Eq.(6), (7) and (8) values of α_1 and α_2 are obtained for each segment.

Step 3: The point spread function used in Eq.(4) is defined as

$$h(x,y) = \frac{1}{2\pi\, \sigma_1 \sigma_2}\, e^{-(x^2/2\sigma_1^2 + y^2/2\sigma_2^2)} \qquad (9)$$

In Eq.(9), h(x,y) determines point spread function at the centre of each segment. In Eq.(9), values of σ_1 and σ_2 are determined from α_1 and α_2 values, such that,

$$\sigma_1 = \text{Const\_1}/\alpha_1 \qquad (10)$$
$$\sigma_2 = \text{Const\_2}/\alpha_2$$

where Const_1 and Const_2 are constants.

Step 4: Using values of σ_1 and σ_2 that are obtained at the centre of each segment, σ_1 and σ_2 values for all other spatial locations are evaluated by using bilinear interpolation technique, which inturn defines shift variant p.s.f.

Step 5: Thus, the point spread function obtained in above steps is used to carryout filtering for the entire image.

IV. ILLUSTRATION

The above developed algorithms for adaptive grey scale manipulation and adaptive filtering as an illustration have been applied for Landsat and aircraft data. The results of the same are shown in the plates. The algorithms have been developed on EC 2640 computer system.

Example 1: As an illustration, Landsat data from scene 161-043 (Dec. 1979) has been chosen. The image of the size 760 scans x 760 pixels has been chosed. The image has been divided into subimages of size 64 x 64. The adaptive intensity mapping has been carried out using the steps mentioned above. The raw and enhanced imageries are shown in plates 1 and 2 respectively. Computer time taken for the above exchange is about 16 min. CPU.

Example 2: As an illustration, the adaptive filtering has been applied by multispectral scanner. The area is near Cochin, India. The area of size 512 x 512 has been chosen. The area was divided into subimages each of size 64 x 64. For each subimage auto-correlation has been evaluated which inturn has been used for evaluating p.s.f. for filtering. The unenhanced and enhanced imageries have been shown in plates 3 and 4 respectively. Computer time taken for the same is about 28 min. CPU.

V. DISCUSSIONS

The results obtained are presented in examples 1 and 2. It can be seen that computer time taken for shift variant enhancement is quite large compared to similar type shift invariant enhancement. It is obvious that if local properties of the scene do not vary much w.r.t. spatial coordinates, then shift variant image enhancement operators automatically will yield results similar to that of shift invariant type enhancement. Thus, in order to save computer time, enhancement coefficients need not be obtained at each spatial position however, the enhancement transformation parameters can be updated at regular intervals. This technique of updating the transformation coefficients at regular intervals has been used in the illustrative examples. It is also possible to evaluate transformation coefficients at closer intervals when variations in local properties is large.

It can be seen that shift variant image enhancement techniques are more useful where local properties vary considerably. Shift variant grey scale manipulation technique is useful where grey scale variations w.r.t. spatial coordinates, in the imagery are large. Similarly, shift variant filtering is useful for the images where texture in the image varies with spatial coordinates.

In the method described for adaptive filtering, auto-correlation defined by Eq.(6) has been used as a measure for texture to determine the filtering para-

Plate-1

Plate-2

Plate-3

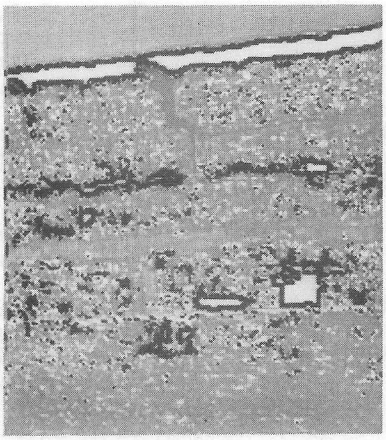

Plate-4

meters. It is also possible to use some other measure of texture for determining the filtering parameters.

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