CONTRACT ENHANCEMENT

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CONTRAST ENHANCEMENT

1. Introduction

Image enhancement is used to enhance the information available from an image for any specific purpose. The enhancement may be done either in the spatial domain or in the frequency domain. The frequency domain enhancement is based on the modification of the Fourier transformation of the original image. On the other hand, spatial domain enhancement involves manipulation of the pixels in an image from the image plane itself.

This module we will learn the basics of image enhancement in the spatial domain.

2. Contrast stretching

Contrast stretching is used to increase the dynamic range of the gray levels in the image. For example, in an 8-bit system the image display can show a maximum of 256 gray levels. If the number of gray levels in the recorded image spread over a lesser range, the images can be enhanced by expanding the number of gray levels to a wider range. This process is called contrast stretching. The resulting image displays enhanced contrast between the features of interests. For example, Fig. 1(a) shows the unstretched Landsat TM Band-5 image. The original image is vague. Fig. 1 (b) shows the contrast-stretched image.

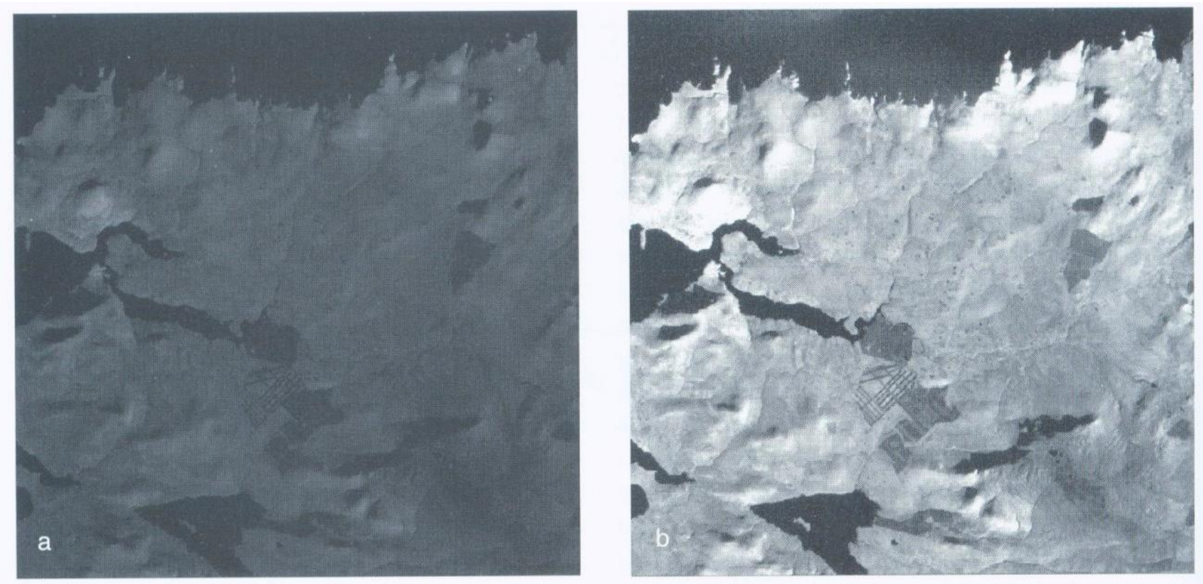


Fig. 1 Landsat TM Band-5 image before and after the contrast stretching

The transformation functions used to convert the values of the original image into corresponding values in the output image may be linear or non-linear functions.

3. Linear Contrast Stretching

When the values in the original image are expanded uniformly to fill the total range of the output device, the transformation is called linear contrast stretching. If DN is the Digital Number of the pixel, DN_{st} is the corresponding DN in the enhanced output image, DN_{max} and DN_{min} are the maximum and minimum DN values in the original image, the linear contrast stretching can be graphically represented as shown below.

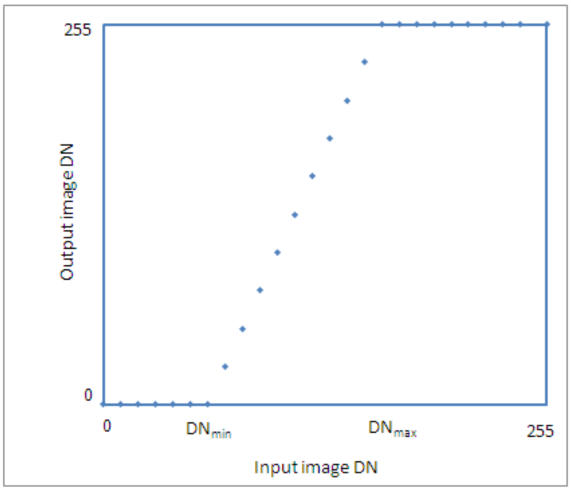


Fig. 2. Graphical representation of the linear contrast stretching function

For example, for an 8-bit display system, linear contrast stretching transformation can be achieved as given below.

$$DN_{st} = 255 \times \frac{(DN - DN_{min})}{(DN_{max} - DN_{min})} \quad (1)$$

where DN values in the range DN_{min}-DN_{max} are rescaled to the range 0-255 in the output image. Fig. 3(a) shows histogram of the Landsat TM band-5 image, wherein the DN values range from 60 to 158. Therefore in the display of the original image, display in the ranges 0-59 and 159-255 are not utilized, giving a low contrast image as shown in Fig. 1(a). Histogram of the enhanced image is shown in Fig. 3(b), wherein the values are expanded to fill the entire range -255, giving better contrast. The enhanced output image is shown in Fig. 1(b).

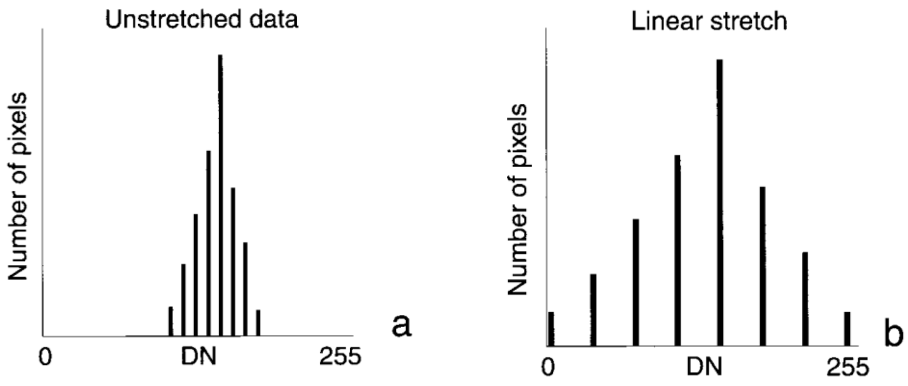


Fig. 3 Histograms of the Landsat TM Band-5 image before and after contrast stretching

In the contrast stretched image the light tone areas appear lighter and the dark tone areas appear darker. The variation in the input data, now being displayed in a wider range, thus becomes easily differentiable.

From the histogram of the original image it can be observed that though the DN values ranges from 60 to 158, number of pixels having DN values in the range 60-90 are very less. Nevertheless, in linear stretching equal number of display levels are assigned to these ranges. Consequently, for the higher values not many display levels are available. In other words, the number of display levels available for different DN ranges are not in proportion to the number of pixels having DN values in the range. To solve this problem, non-linear contrast stretching has been used.

4. Non-linear Contrast Stretching

In non-linear stretching, the DN values are not stretched linearly to uniformly occupy the entire display range. Different non-linear contrast stretching methods are available. Some of them are the following.

- ✓ Histogram-equalized stretch
- ✓ Piece-wise linear stretch
- ✓ Logarithmic, power law or Gaussian stretch

Histogram–equalized stretch:

In histogram-equalized stretch the DN values are enhanced based on their frequency in the original image. Thus, DN values corresponding to the peaks of the histogram are assigned to a wider range. Fig.4 compares the histogram of a raw image with that of the images enhanced using linear stretching and histogram-equalized stretching

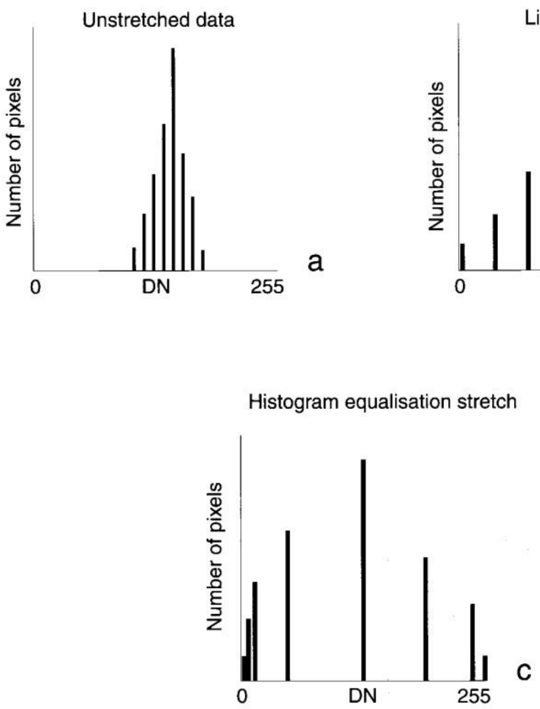


Fig. 4. Histograms of (a) Unstretched image (b) Linear contrast stretched image(c) Histogram equalised image Fig.5 (a) shows a sample histogram of an image and Fig.5 (b) shows the corresponding histogram-equalization stretch function. Input DN values corresponding to the peak of the histogram are stretched to a wider range as shown in the figure.

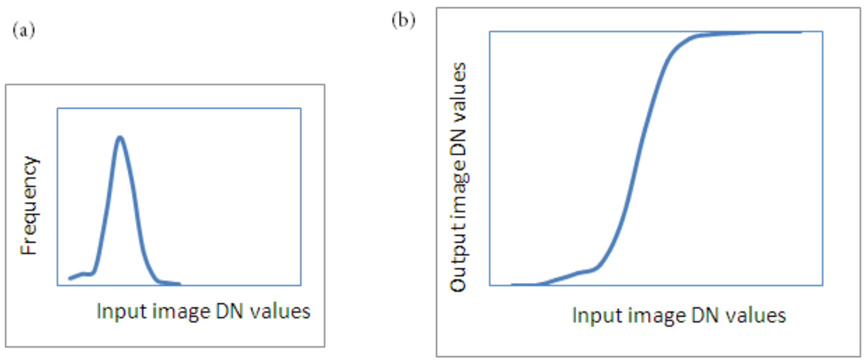


Fig.5 (a) Sample histogram of an image and (b) Function used for histogram equalized stretch

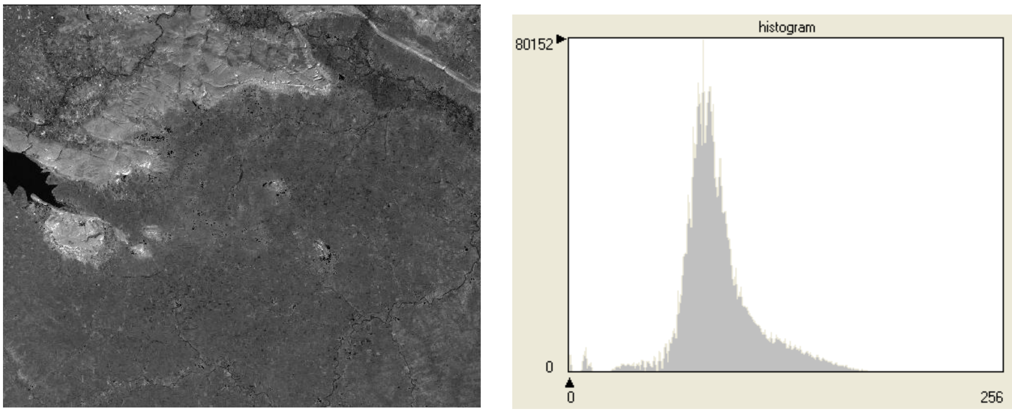
For example, for an 8-bit display system, the histogram equalization function used for stretching the input image can be represented as follows.

$$DN_{st} = 255 \sum_{j=0}^{k} \frac{n_j}{N}$$

where n_j is the number of pixels having DN values in the j^{th} range, k is the number of DN value ranges, and N is the total number of pixels in the input image.

By assigning more display levels to the higher frequency region that contains majority of the information, better information enhancement is possible using histogram-equalized stretch.

(a)



(b)

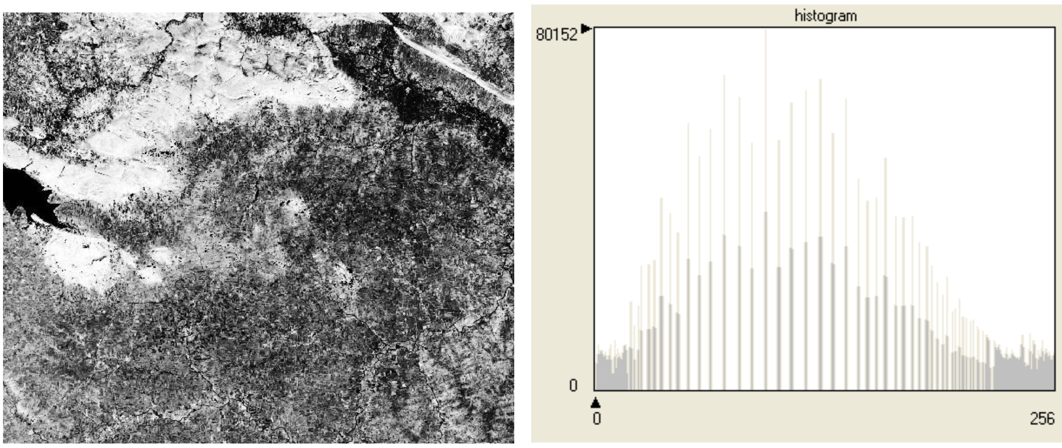


Fig. 6 Landsat ETM+ Band 5 images and the corresponding histograms (a) before contrast stretch and (b) after histogram equalization stretch

Piece-wise Linear Stretch

In piece-wise linear stretch, different linear functions are used for enhancing the DN values in different ranges within the same image. In other words, different parts of the histogram are stretched by different amounts. It is generally useful in cases where the original image has bi-modal histogram.

Fig.7 shows a sample bimodal function for piece-wise linear stretching.

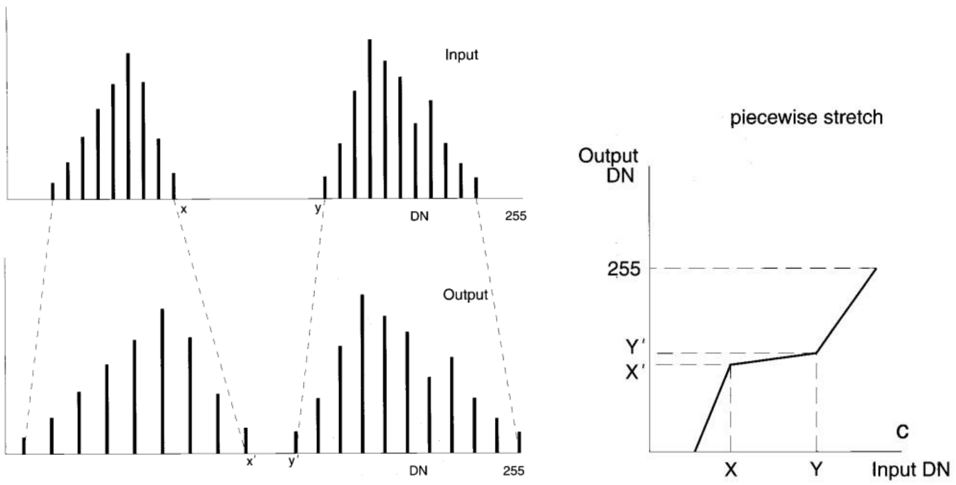


Fig. 7. A sample bi-modal histogram, piece wise linear function used for the contrast stretching and the histogram after piece wise contrast stretch

Using the piece-wise linear stretch function, region between the two modes of the histogram may be compressed, whereas the regions corresponding to the histogram peaks may be enhanced as shown in Fig.7. It is also used to enhance any special features in the image.

Logarithmic, power law or Gaussian stretch

In logarithmic stretching, curves having the shape of the logarithmic function are used for rescaling the original DN levels into the wider output range, as shown in Fig. 8.

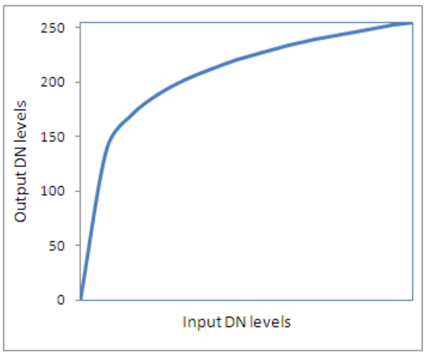


Fig. 8. A sample logarithmic stretch function

General form of logarithmic stretching uses the following form.

DNst = c log (1+DN)

where c is a constant.

As shown in Fig. 8, in logarithmic stretching, smaller values are stretched to a wider range, whereas narrower output range is used for higher values. This type of stretching is generally used to enhance the information contained in the dark pixels, during which process the information contained in the lighter pixels are compressed.

Application of power law executes the stretching in an opposite way. Power-law contrast stretching generally uses the following form.

$$DN_{st} = c\ DN^{n}$$

where c and n are positive constants. Fig. 9 shows the sample power function for contrast stretching. While using the power functions, higher values are expanded to a wider range. This enhances information contained in the higher DN values, whereas the lower DN values are compressed.

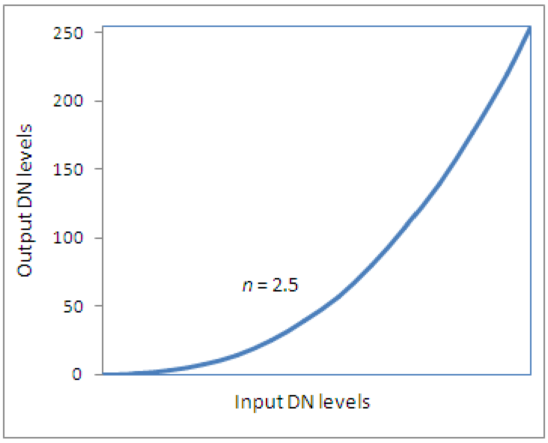


Fig. 9. A sample function used for power law contrast stretching

In Gaussian contrast stretch, the DN values are modified in such a way that the stretched brightness value distribution resembles a normal distribution. Fig. 10 shows the Landsat ETM+ Band 5 image after applying the Gaussian contrast stretching. Original image is shown in Fig. 6(a).

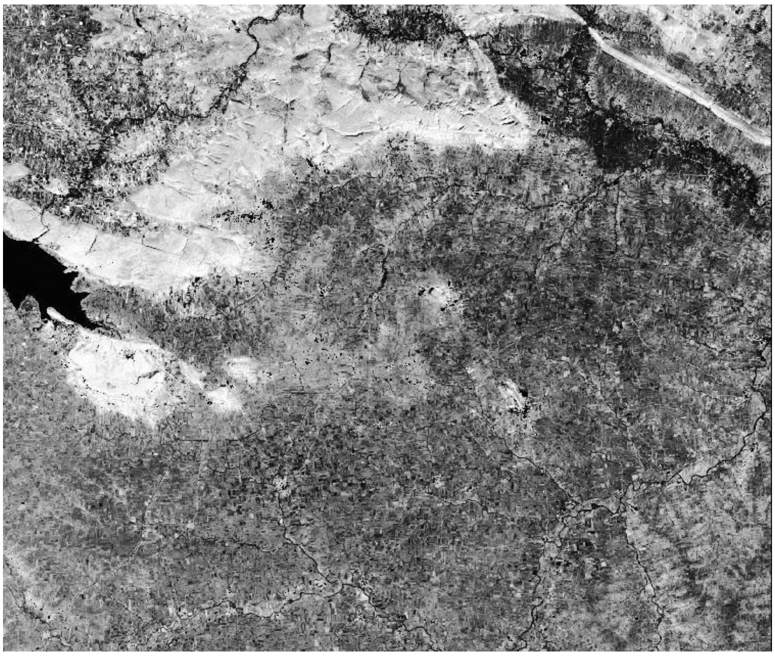


Fig.10. Landsat ETM+ Band 5 image after applying the Gaussian contrast stretching

Fig. 11 gives the schematic representation of all the above contrast stretching methods. Histogram of the original image is shown in Fig. 11(a). The values are only in the range 60-158. Therefore in an 8-bit display system, only the range 60-158 is used for the image display resulting in poor contrast. Fig.11 (b) shows the linear stretching, wherein the range 60-158 is equally transformed into the full range 0-255 using linear function. Fig.11 (c) shows the schematic of the histogram equalization stretch. The range 60-108, having low frequency, is transformed into a relatively narrower range 0-38, whereas the high frequency range 108-158 is transferred to a wider range 38-255. Fig.11 (d) shows special stretch wherein only the range 60-92 is stretched to occupy the full display range. The remaining ranges are compressed.

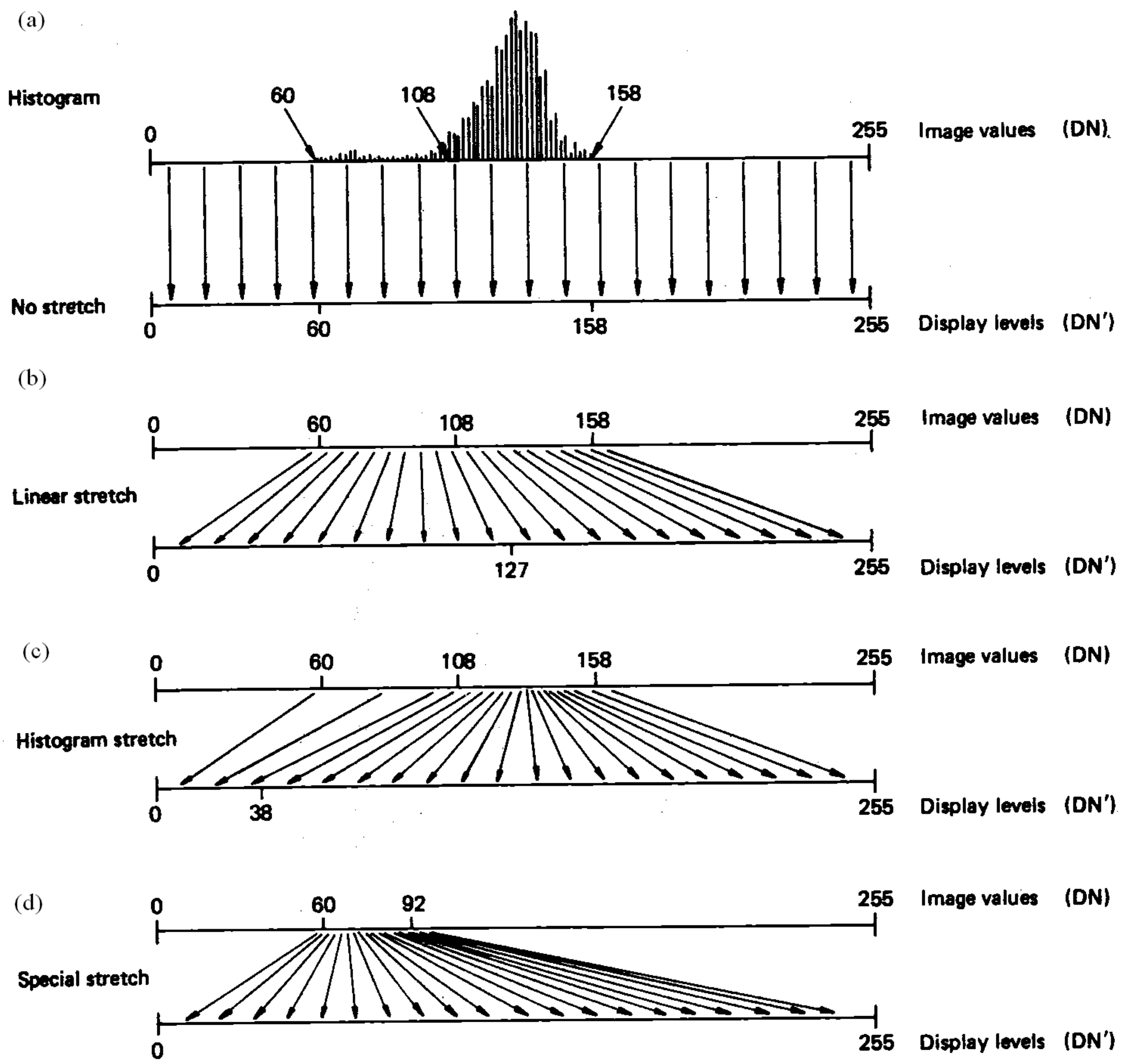


Fig. 11. Schematic representation showing various contrast stretching algorithms (Courtesy: Lillesand et al., 2004)

5. Look-up Table

In contrast stretching, DN values in the original image are transformed into another range and the resulting new DN values (DNst) represent the enhanced image. If the transformation has to be estimated for every pixel of an image using the transformation functions, the procedure would involve significantly large amount of computation. For example, a 60 x 60 km multispectral SPOT image would require new DNs to be calculated for 27 million pixels. Assuming 500,000 arithmetic operations a second, this procedure would take nearly four minutes.

On the other hand, since the transformation functions are well defined, it is possible to calculate DN_{st} for all possible DN values in a single stretch, and can be presented in a tabular form, as shown in Fig. 12. Such a table is called look-up table (LUT). Fig. 12 (a) shows a sample linear transformation function used for contrast stretching. Fig. 12 (b) shows the LUT for this function.

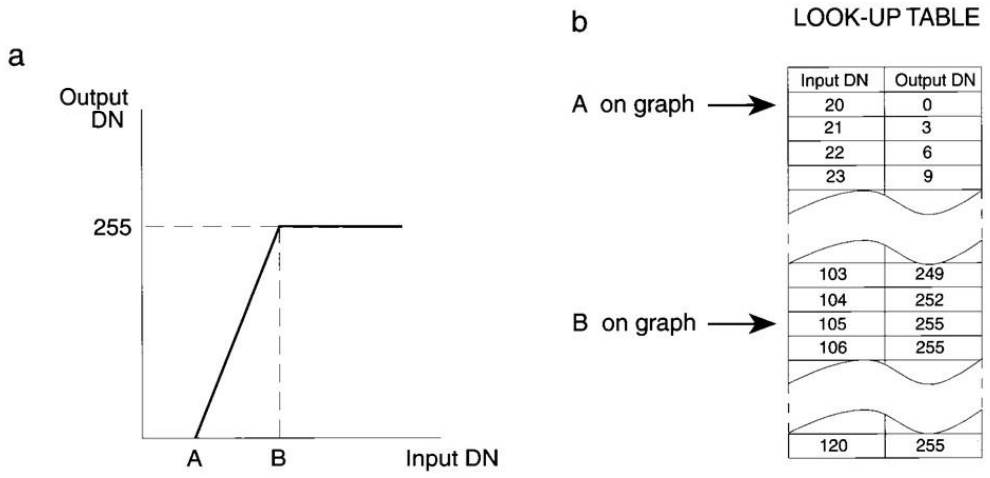


Fig. 12 (a) A sample linear transformation function used for contrast stretching (b) LUT for this function

LUT can be used to simplify the contrast stretching process. For any pixel in the original image, the corresponding DNst may be obtained from the LUT, and thus the contrast stretching procedure can be speeded up.